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The Brain of the Smart Transportation System: Exploring the Role of Future Expectations and Sociotechnical Imaginaries in Cutting-edge Science and Technology Policymaking in China

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A thesis submitted in partial fulfilment of the requirement for the degree of Doctor of Philosophy in Sociology

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Table of Contents

List of Abbreviations

AI – Artificial Intelligence

ALI – Autofahrer Leit und Information System

BATD – The four leading Chinese Internet giants: Baidu (百度), Alibaba (阿里巴巴), Tencent (腾讯), Didi (滴滴出行).

BIM – Building Information Modeling

BTH – Beijing–Tianjin–Hebei Region (京津冀经济区)

CBD – Central Business District

CICO – Communications Investment Group CO. LTD. (浙江省交通投资集团)

CNKI – China National Knowledge Infrastructure (中国知网)

CV – Curriculum Vitae

DOT – Department of Transportation of United States

EASTS – East Asia STS

ETC – Electronic Toll Collection

EU – European Union

FA – Fragmented Authoritarianism

GPS – Global Positioning System

IBM – International Business Machines Corporation

ICT – Information and Communications Technology

ICV – Intelligent Connected Vehicles

IDC – International Data Corporation

IEEE – Institute of Electrical Electronics Engineers

IoT – Internet of Things

ITS – Intelligent Transportation System

MIIT – Ministry of Industry and Information Technology of the People's Republic China (中华人民共和国工业与信息化部)

MOR – Ministry of Railways of the People's Republic of China (中华人民共和国铁道部)

MOT – Ministry of Transport of the People's Republic of China (中华人民共和国交通运输部)

MOHURD – Ministry of Housing and Urban-Rural Development of the People's Republic of China (中华人民共和国住房和城乡建设部)

NGO – Nongovernmental Organization

OD – Origin – Destination

POI – Point of Information

PPP – Public-Private Partnership

R&D – Research and Development

SAS – Statistical Analysis System

SASAC – State-owned Assets Supervision and Administration Commission of the State Council (国务院国资委)

SI – Sociotechnical Imaginary

STS – Science, Technology and Society

TCM – Traditional Chinese Medicine (中医)

US – United States

VAT – Value-Added Tax

VR – Virtual Reality

YRD – Yangtze River Delta Economic Zone (长江三角洲经济区)

List of Graphs, Tables and Figures

Table 3. Fields in which the participants work.

Table 4. Expenditure on Transportation from The China Statistical Yearbook.

Table 5. The work plans of Hangzhou Transportation Bureau from 2018 to 2020.

Table 6. The four common goals of Hangzhou Transportation Bureau from 2018 to 2020.

Figure 1. A sketch map of the administrative divisions of China.

Figure 2. A sketch map of the transport sectors in the government.

Figure 3. The papers published in the Intelligent Transportation System.

Figure 4. The papers published in the Smart Transportation System.

Figure 5. The disciplines in the Intelligent Transportation System.

Figure 6. The disciplines in the Smart Transportation System.

Figure 7. The curve of the number of papers published in the top three disciplines

of the Intelligent Transportation System.

Figure 8. The curve of the number of papers published in the top three disciplines of the Smart Transportation System.

Figure 9. The journals of “Road and Waterway Transportation” from CNKI.

Figure 10. The journals of “Computers and Computer Applications” from CNKI.

Figure 11. Prof. Di’s Lab: a model of the traffic system with driverless cars and the related facilities. Photo taken by the author, December 2018.

Figure 12. The screenshot of the APP of Alipay. Screenshot taken by the author, September 2019.

Figure 13, 14, 15, 16, 17. In a Big Data center: data of Buses, Cabs, Public bicycles, Airports and Flights. Photo taken by the author, January 2019.

Figure 18. Prof. Yuan’s office. Photo taken by the author, January 2019.

Figure 19. Prof. Fa’s office. Photo taken by the author, March 2019.

Figure 20. Author’s education background shown on the CV that was handed to the participants.

Figure 21. A two-way, dynamic process between the sociotechnical imaginary of central government and future expectations of local governments.

Table A. List of interviews

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Declaration

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy (PhD). It has been composed by myself and has not been submitted in any previous application for any degree.

Abstract

In recent years, Big Data has developed rapidly, improving the efficiency and safety of the transportation system, but varied understandings of Big Data have shaped contextualised expectations and imaginaries, which has introduced new tension in the policymaking of technology. Additionally the mixed use of concepts such as "future expectation" and "sociotechnical imaginary" in future-oriented STS studies makes the relevant case studies unclear at the theoretical level. Thus, this thesis endeavours to distinguish these concepts within a specific situated context, to shed light on how they work in China's science and technology policymaking process, and to understand the nature of Big Data. To do so it explores a new technology that emerged in China since the 2000s – the Smart Transportation System – a hybrid of the traditional transportation system and Big Data. This thesis draws on a mixed-methods approach, including an analysis of governmental policy documents from 2016 to 2020, 29 semi-structured qualitative interviews with engineers, academics, and local government officials, conducted in seven Chinese cities.

This thesis contributes three advances to knowledge of future-oriented studies, science and technology policymaking studies, and Big Data studies in the Chinese context: 1) by showing that future expectation is related to the paradigms and the interests of two scientific communities of the Smart Transportation System field, while sociotechnical imaginary links to the epistemology and knowledge used in the decision-making process; 2) by outlining a two-way, dynamic circle in which the sociotechnical imaginary of the central government creates an intended institutional void, leaving space for local governments interpretations, and these interpretations in turn drive the birth of a new sociotechnical imaginary of central government; 3) by furthering our understanding of Big Data and Artificial Intelligence via revisiting the nature of Big Data from the perspective of traditional Chinese culture.

Introduction

There is an old Chinese saying: "To get rich, first build roads (要致富，先修路)". Along these lines, China seems to be addicted to developing infrastructure to reach its economic growth. By 2015, the high-speed railway network had been completed: more than 40,000 kilometres of high-speed track (Cao & Zhang, 2017). By 2018, China had 127,000 kilometres of railway in service. According to "The Statistical Bulletin of the Development of the Transportation Industry in 2018 (2018 年交通运输行业发展统计公报)"[1] proposed by the Ministry of Transport (MOT) of the People's Republic of China (中华人民共和国交通运输部), by 2019 the total length of China's highways was 4,846,500 kilometres. In comparison, by 2020 China had more than 5 million kilometres of roads, and 150,000 kilometres of highways (Shao & Wu, 2021).

In recent years, with the rapid development of transportation infrastructures, the Intelligent Transportation System (ITS) has been proposed. Using advanced Information and Information Communication Technologies (ICT) to improve the efficiency and safety. This idea soon became popular throughout China. In 2014, the Minister of the MOT (交通运输部部长), Yang Chuantang (杨传堂), put forward the "Four Traffic" proposal for transportation development:[2] comprehensive,

[1] http://www.chinahighway.com/article/63052.html
[2] http://www.chinahighway.com/news/2015/930125.php

intelligent, green and safe transportation (综合交通、智慧交通、绿色交通、平安交通). The MOT released two documents about ITS in 2017: "The Action Scheme of Using ITS to Make Travel Easier (2017–2020) (推进智慧交通发展行动计划 2017–2020 年)"[3] and "The Action Scheme for Promoting the Development of ITS (2017–2020) (智慧交通让出行更便捷行动方案 2017–2020 年)".[4] Several provinces and cities followed this trend and released their own action schemes for ITS. For example, in 2018 Beijing released "The Action Scheme for promoting the development of the Intelligent Connected Vehicles 2019–2022 (北京市智能网联汽车创新发展行动方案 2019 年–2022 年)".[5] Chinese technology giants also started to invest in the ITS to provide information systems about real-time traffic conditions to guide traffic management. For example, Alibaba (阿里巴巴),[6] co-operating with Hangzhou's local government (杭州), developed a Big Data system called "ET City Brain (阿里云城市大脑)".[7] Additionally, Didi (滴滴出行)[8] released "Didi smart travel (滴滴智慧出行)".[9] In 2018, Tencent (腾讯)[10] and Baidu(百度)[11] released their programs on ITS in Nanjing (南京) and Beijing (北京),[12] respectively.

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[3] http://xxgk.mot.gov.cn/jigou/zhghs/201702/t20170213_2976478.html

[4] http://xxgk.mot.gov.cn/jigou/kjs/201709/t20170926_2975335.html

[5] http://www.beijing.gov.cn/zhengce/zcjd/201905/t20190523_78903.html

[6] **Alibaba Group Holding Limited** is a Chinese technology company in Hangzhou (杭州) focusing on e-commerce, Internet and retail and famous for the electronic payment service Alipay, online shopping search engine Taobao, and cloud computing services Aliyun.

[7] The website of "ET City Brain": https://et.aliyun.com/brain/city

[8] **Didi Chuxing Technology Co.** is a Chinese transportation company in Beijing (北京) providing app-based transportation services. In 2016, Didi acquired Uber China. In 2018, Didi has 550 million users and tens of millions of drivers.

[9] The website of "Didi smart travel": http://sts.didiglobal.com/its/

[10] **Tencent Holdings Limited** is a Chinese company in Shenzhen (深圳) providing several Internet-related services, products, and technologies. It is famous for its social media products such as Wechat (微信) and QQ.

[11] **Baidu, Inc.** is a Chinese technology company in Beijing specializing in Internet-related services and products such as search engine and mapping service.

[12] https://moore.live/news/56094/detail/

Since then, the leading Chinese Internet giants, known as the BATD Group in China, all have entered the ITS field. Another technology giant, Huawei (华为),[13] also provided its plan for the ITS called "Smart Transportation".[14] The above examples begin to demonstrate how the transportation system has become a popular topic, since the Chinese government promoted it.

Research institutions also started to work on this field because ITS needed to be studied in a more careful way to understand its real meaning in a Chinese context. Around 2005, the Chinese introduced a new term the "Smart Transportation System (智慧交通 Zhihuijiaotong)" to replace the sole focus of ITS on the transport system, this new term enabled a broadening of focus relating to the city, citizens' lifestyles, and so on. It has become a development target for the transportation system: a sociotechnical imaginary of China's future transportation system. Thus, the Smart Transportation System is shaped by the political, social and cultural contexts of China. In turn, the Smart Transportation System serves as a window to gain a better understanding of this context.

Research that focuses on the future and studies it through discourse, claims, and practices of cutting-edge technologies are called "Science, Technology and Society [STS] research on future-oriented representations and anticipatory

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[13] **Huawei Technologies Co., Ltd.** is a Chinese technology company based in Shenzhen providing telecommunications equipment as well as smartphones.
[14] The website of "Huawei Smart Transportation": https://e.huawei.com/uk/solutions/industries/transportation

practices" (Konrad *et al.*, 2017), which stresses the importance of "the future" in shaping science and technology policy. STS research has provided us with some valuable keys to study cutting-edge technologies, such as nanotechnology[15] (Selin, 2007), xenotransplantation[16] (Brown & Michael, 2003) and electric vehicles (Lieberman & Kline, 2017). In STS research, the future is not "simply a neutral temporal space into which objective expectations can be projected" (Brown & Michael. 2003, p.2), but an object embedded in present and past activities which can be evaluated. Thus, Brown and Michael suggest that future is a discourse about the history of science and technology "constituted through an unstable field of language, practice, and materiality in which various disciplines, capacities, and actors compete for the right to represent near and far-term developments" (Brown & Rappert, 2017, p.5).

Tracing the history of STS research, on future-oriented and anticipatory practices, involves several different concepts related to this body of work, raising an important issue: "expectations, schemata, images, and visions appear to take a huge variety of forms" (Berkhout, 2006, p.302). A clear distinction of these concepts is required and an increasing number of STS scholars are engaging in distinguishing the concepts of "foresight" and "expectation" (Van Lente, 2012), "expectation" and "promise" (Van Lente, 2012; Brown *et al.*, 2003; Selin, 2007),

[15] the branch of technology that deals with structures that are less than 100 nanometres long. Scientists often build these structures using individual molecules of substances.
[16] the process of taking organs from animals and putting them into humans for medical purposes.

“promise” and “vision” (Berkhout, 2006; Borup *et al.*, 2006; Eames *et al.*, 2006; Konrad *et al.* 2017). Yet little has been done to distinguish “future expectation” and “sociotechnical imaginary”, two influential concepts. Future expectation imagines what the future would be like with science and technology. This concept was first introduced by Nathan Rosenberg (1976) and further developed in “Contested Futures” (2017). While Jasanoff (2015) defines “sociotechnical imaginary” as “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology” (p.5). Both concepts focus on the future, however, Brown, Rip and van Lente (2003) study indicates a distinction between these two concepts, as sociotechnical imaginary focuses more on political factors and power dynamics at the national level. However, it does not clearly distinguish between future expectation and sociotechnical imaginary, because the studies of future expectation also examine the political factors. For example, Brown, Rip and van Lente (2003) argue that expectations are at the heart of transactions, exchanges and politics between the actors, and these activities are called as "the dynamics of a political economy of expectations" (p.6). Therefore, it is hard to demonstrate that concern for political factors is a fundamental difference between the two concepts. Moreover, several studies indicate that the different sociotechnical imaginary might be related to different cultures and political institutions (Berling *et al.,* 2021; Pfotenhauer & Jasanoff, 2017), but these studies have not yet clarified what makes future expectations different. The distinction between future expectation and sociotechnical imaginary might lie here.

Inspired by STS research on future-oriented representations and anticipatory practices, I apply the concepts of "sociotechnical imaginary" and "future expectation" to probe China's policymaking towards technology. Extensive literature has developed around China's policymaking, especially for the post-Mao era. One influential concept that describes China's policymaking in this era is "Fragmented Authoritarianism" (FA) (Han, 2013; Ma & Lin, 2012; Mertha, 2009), first proposed by Lampton (1987) and supported by Lieberthal and Oksenberg (1988). FA argues that bureaucratic units assert their interests in the policymaking process in China as Maoist ideology is replaced with economic development imperatives. Over the last ten to twenty years, there has been a remarkable trend in developing more specific explanations about governmental bureaucracies, instead of employing a general model of FA (Han, 2013; Heilmann and Melton, 2013; Ma & Lin, 2012; Meng, 2010; Zheng, 2008). Instead of analyzing Chinese policymaking at a general level, some Chinese scholars concentrate on more specific themes of policymaking such as housing policy (Jiang, 2013), education policy (Zhao, 2018; Yu, 2020), and healthcare policy (Wang, 2008). However, this body of work loses sight of the policymaking process of science and technology in China, although some researchers try to address this gap (Gohli & Fischer, 2019; Korsnes, 2016; Liang *et al.*, 2020). These researchers point out one perplexing feature of policymaking towards technology in China: “the ambiguity of the government targets on technology projects” (Korsnes (2016), “intentional ambiguity” (Gohli and Fischer (2019), and “the central government orders local government to implement policy without clear direction” (Liang et al. (2020). Yet, these researchers do not elaborate the role that this ambiguity plays in the dynamics between central and local government. In my analysis of the Smart Transportation System I also found this feature, referred to by my participants as “the lack of Designed at The Top Level (缺乏顶层设计)”, indicating the missing role of the central government. “Designed at The Top Level (顶层设计)” is a Chinese phrase that used to be a term in engineering. It means that people should think about every level and every element, and then solve problems from the highest level downwards. It has gradually become a political term, which was first used in the “Twelfth Five-Year Plan”. Inspired by Korsnes (2016) introducing the concepts future expectation and sociotechnical imaginary into the study of science and technology policymaking, I employ these two concepts to explore the dynamic system between different government levels and the role that “the lack of Designed at The Top Level” plays in this context.

As the study progressed, the future expectations of some participants implied that some participants did not trust the results of Big Data, drawing attention to an ongoing discussion about the nature and the credibility of Big Data. According to Favaretto et al. (2020) study of 39 American and Swiss researchers in the field of

Big Data, the first definition of Big Data appeared in the 2000s and remains unclear in 2020. The three V's can be considered the most basic definition of Big Data's technical aspects: Volume, Variety and Velocity (Laney, 2001). However, the technical aspects of Big Data ignore some aspects such as business processes (Ylijoki & Porras, 2016), even while they provide some new features such as value (e.g. IDC[17]) and veracity (Ularu *et al.*, 2012). Yet, Ylijoki and Porras (2016) argue that adding features such as "value" would make the definition vague and lose its "coherency". The definition of Big Data is becoming increasingly broad, adding social and political dimensions. For example, instead of "V features", Lupton (2015) suggests "P features", such as portentous, perverse, personal, political, predictive, etc. On the one hand, continuous additions make the definition lengthier and complex. On the other hand, researchers still try to find its missing perspectives (Ylijoki & Porras, 2016). In order to understand the nature of Big Data in a Chinese context, I examined metaphors emerging in the fieldwork. The metaphor is a suitable way to analyze concepts such as Big Data, because metaphors make abstract concepts easier to understand. For example, Wilken (2013) finds metaphors are useful tools to make sense of "techno-social complexity". Moreover, the use of metaphors also reflects different cultural backgrounds and user contexts. For example, according to Puschmann and Burgess (2014), metaphors in Big Data are a topic worth investigating. As the amount of digital data grows the complexity of Big Data increases its abstraction, so people choose

[17] The definition of big data from International Data Corporation

familiar shapes to communicate with each other. And the choice of the familiar shapes are related to people's cultural, education background.

In this thesis, my goal is to distinguish sociotechnical imaginary from future expectation, and also to demonstrate the role these concepts play in communication and coordination between the central and local government in science and technology policymaking. Additionally, by analyzing metaphors emerging from the fieldwork, this thesis aims to explore the understanding of the nature of Big Data within a specific, situated context. Inspired by studies of future expectations and sociotechnical imaginaries, this thesis draws on a mixed methods, using central and local governments policy documents, 29 semi-structured interviews and supplementary observations conducted in seven Chinese cities: Beijing (北京), Shanghai (上海), Chengdu (成都), Chongqing (重庆), Hangzhou (杭州), Nanjing (南京), and Tianjin (天津) that were carefully chosen from the pilot cities of "smart city" designated by the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD 住房和城乡建设部) in 2012. I attempt to answer the following three research questions.

1. How was the sociotechnical imaginary of the Smart Transportation System constructed in the Chinese context? In particular, what are the key features that distinguish future expectations from sociotechnical imaginaries?

To solve the problem of unclear boundaries between the concepts proposed by Berkhout (2006), I have introduced Kuhn's (1970) concept of paradigm (hereafter: Kuhn's paradigm), Chinese policymaking studies, and Fisher's (2020) algorithmic episteme, to distinguish the two important concepts of future expectation and sociotechnical imaginary. Drawing on interview materials and previous research analysis, I identify two existing scientific communities – "Road and Waterway Transportation" and "Computers and Computer Applications", which illuminates that there is not an academic field called the Smart Transportation System. The existing scientific communities have different paradigms, as Kuhn (1970) suggests, and they also have different future expectations; for instance, the Road and Waterway Transportation community develops infrastructure and hardware facilities and Computers and Computer Applications develops more advanced algorithms to explore data, instead of building roads.

I apply Kuhn's paradigm to understand future expectations as a series real-time shared beliefs about the future in this case, which are derived from the paradigms of different scientific communities. Adopting a Chinese policymaking perspective, future expectations could be construed as "tradable assets" (Brown, Rip and van Lente, 2003) that represent the interests of scientific communities, and could be sold to local governments. Therefore, future expectations derive from the paradigms and the interests of the scientific communities in this case. Conversely, sociotechnical imaginaries link to epistemology and the knowledge used in the decision-making process. Based on the interview materials, besides different future expectations, remains a collective sociotechnical imaginary in academia that regards the Smart Transportation System as a supplementary tool to improve the efficiency of the transportation system. In other words, it cannot work without human intervention, especially in selecting data and verifying results, which indicates an emphasis on expertise.

Inspired by a survey of 344 bureaucrats of the Tianjin Metropolitan Government conducted by Zhu and Tian (2008), I argue that scientists and engineers try to provide their expertise to the decision-making process. Meanwhile, this emphasis on expertise fights against the algorithmic episteme and digital discourse proposed by Fisher (2020), at the epistemological level and at the political level. Fisher (2020) argues that the knowledge generated by Big Data should be considered as a new type of knowledge; that is, the "algorithmic episteme". Thus, this thesis shows that, in the Smart Transportation System, future expectation is related to the paradigms and the interests of scientific communities, while sociotechnical imaginary is linked to epistemology and what knowledge is used in the decision-making process.

2. What is the policymaking process shown by the Smart Transportation System? In particular, what is "the lack of Designed at The Top Level"? And what role does it play in the policymaking process?

I have analyzed the policymaking process of the Smart Transportation System by employing the concepts of future expectations and sociotechnical imaginaries from STS. Inspired by Korsnes (2016), I use the concept of "sociotechnical imaginary" to identify the development targets of the central government and academia as a whole, and I use the concept of "future expectation" to identify the local levels. Drawing on the plans and documents put forward by the central government and the interview materials, this thesis echoes the results of several studies on the policymaking of science and technology in China (Gohli & Fischer, 2019; Korsnes, 2016; Liang *et al.*, 2020), showing that the central government does not provide clear and specific sociotechnical imaginaries (e.g. future targets and directions) on the Smart Transportation System, which is referred to by my participants as "the lack of Designed at The Top Level (缺乏顶层设计)". Contrary to the assumption of central government's missing role, "the lack of Designed at The Top Level" could be divided into two parts. First, the central government's plan offers a broad vision for the Smart Transportation System – the development of infrastructure. Usually in policy documents there no specific meanings of the infrastructure given. In Chinese, the word "infrastructure" is a very broad term, which can refer to bridges, highways, sensors, traffic lights, etc. Thus, almost all hardware facilities that could be built could be seen as an "infrastructure". Second, the other half of the central government's plans suggest directions for management, service, and decision-making in a broad way. In other words, "the lack of Designed at The Top Level" does not mean a missing role, rather that the sociotechnical imaginary of the central government is broad, not absent. Based on local governments' documents and fieldwork materials, this thesis shows that the future expectations of local governments are about infrastructure development that could be understood in different ways, such as the Electronic Toll Collection (ETC) system in Beijing, Smart testing devices in Shanghai, and rural roads in Hangzhou. Instead of different forms of Smart Transportation System projects being raised by local government, the future expectations of the local government fall into the range of the infrastructure, echoing the sociotechnical imaginary of the central government. After four years of development, there is a new sociotechnical imaginary emerging from central government – combination of different local governments' future expectations. For example, in the latest central government's document, it points out that the "infrastructure" refers to country roads, the ETC, Smart Traffic Lights, etc. Thus, by summarizing the future expectations of local government, the sociotechnical imaginary of the central government is narrowed down from the Smart Transportation System to the Smart Transportation Infrastructure.

Heilmann and Melton (2013) argue that the planning process in contemporary China is "an unceasing process of information gathering, consultation, analysis, document drafting, implementation, experimentation, evaluation, and revision that is better thought of as a recurrent cycle of cross-level, multiyear policy coordination, rather than an integrated, unitary plan system" (p.38). This thesis updates the dynamic, cross-level system proposed by Heilmann and Melton (2013). A dynamic system of policymaking for the Smart Transportation System is a two-way process between the sociotechnical imaginary of central government and future expectations of local governments. When starting to develop new technology, such as the Smart Transportation System, the central government gives local governments broad and vague imaginary instead of specific goals. Then local governments take responsibility for implementation by setting their own future expectations.

The future expectations of local government are influenced by economic factors, such as budget, political factors, such as the evaluation system, and epistemological factors, such as the epistemological basis used for making choices. In reporting their performance, local governments inform the central government of their future expectations for the Smart Transportation System (see Figure 23). And the central government analyzes and combines these different future expectations to create a new sociotechnical imaginary. Then this new sociotechnical imaginary is narrowed down to play an important role in guiding development for the next five years. This dynamic process is cyclic. And as technology develops, more than one cycle will arise as each local government repeats this process to the central government's consultation process. This process may repeat multiple times during the development of the Smart

Transportation System towards the “Smart Transportation infrastructure”. The key to the dynamic process is the vague sociotechnical imaginary of central government and the specific future expectations of local governments. Vague sociotechnical imaginary aims to recruit more participants and explore more possibilities for the development of new technology. It is not a purely top-down system, because it leaves room for the specific local conditions. However, local governments are still under supervision by the evaluation system which is set by the central government. Because of the evaluation system's long-standing preference for quantitative standards, local governments have chosen to construct infrastructure as their achievement, rather than “invisible” improvements such as data analysis and algorithm and program updating.

3. What is the nature of Big Data? How does it influence sociotechnical imaginary and future expectation?

I have explored the nature of Big Data through metaphors that emerged from the fieldwork. In the fieldwork, participants draw an analogy between Traditional Chinese Medicine (TCM) and Big Data. I argue that the meaning and use of this analogy are unique in the context, referring to the similarities between ways of thinking of TCM and Big Data. Considering an argument from Puschmann and Burgess (2014), the participants chose TCM as an analogy because it is their “familiar shape”, as TCM is still used in modern Chinese society as a daily medical treatment. In other words, the participants saw several similarities between ways of thinking of Big Data and of thinking of traditional Chinese science and technology, indicating that Big Data has some characteristics that are not found in modern science and technology. The key point is that Big Data is an empirical science from the participants' point of view. Four similarities are proposed by the participants: (1) Big Data, like traditional Chinese technology, is based on a vast amount of experience; (2) Big Data, like traditional Chinese technology, derives a great deal of its experience from observation; (3) Big Data, like traditional Chinese technology, focuses on practice, not theory. Thus, the issue of the "black box" system in Big Data is similar to "Tried and Tested Medical Prescription (验方)" in TCM. People could be unaware of the principles, but the results could be used in practice; and (4) Big Data, like traditional Chinese technology, is worked on a case-by-case basis, so its results are difficult to generalize.

Observation is the main method of accumulating experience for Big Data. The participants used TCM as an analogy because the "observation" of Big Data is similar. TCM accumulates empirical data through people's eyes, hands, etc. The devices used by Big Data to accumulate empirical data (such as sensors, mobile phones, etc.) could be seen as a "medium", as McLuhan suggests. According to McLuhan, "a medium is any extension of ourselves" (Federman, 2004. p2), so sensors and/or devices could be seen as extensions of the human body, such as our eyes and hands. In this sense, the way that Big Data accumulates is through a “medium” that could be viewed as the extension of the human body. Therefore, this data could also be viewed as observation, which is similar to TCM which is through human vision, touch, etc. Moreover, traditional Chinese science observes the real world, Big Data is constructed by real-world data transferred to the digital world. Therefore the operation of Big Data could be divided into four steps: (1) Big Data uses a “medium” to collect a large amount of empirical data from the real world; (2) people use the empirical data, as well as physical, chemical, and biological theories, to simulate the real world and construct a digital world; (3) people make observations and predictions in the digital world that simulate the real world; and (4) people take actions based on the predictions. Thus, Big Data has one more step than TCM: after collecting empirical data from the real world, it uses this data to construct a digital world which simulates the real one, and then people conduct their observations in the digital world. In other words, knowledge of Big Data is generated through a digital world.

Big Data observations can be divided into two types: The first type constructs the digital world (as described above). The second type observes the digital world and gains experience. Instead of classifying the data by its characteristics, I reclassify it based on McLuhan’s theory that “a medium is any extension of ourselves” (Federman, 2004. p2). Thus, I divide the data into two types. First type of data collected by human senses. This type of data is collected by a single sense such as sight, touch, etc. Also, this type of data is collected by the extension of people’s sense. Second, data that is collected by people as a whole. This type of data is not collected by a single sense, but treats people as a whole. It collects the traces left by people in the digital world. In this sense, “people” also become a medium. The first type of data needs to combine physics, chemistry, traffic management, etc., in order to be constructed in a digital world. This data transformation is related to the idea of “data-driven” that means that people will first have a theoretical framework or hypothesis before they analyze the data. While the digital world constructed by the second type of data (e.g. posted on social media posts) does not necessarily need the assistance of theories. It is possible to construct a digital world based on the “performative individual”. It is related to “the end of theory” that argues that an increase in the amount of data will make the results more and more credible. Therefore, I argue that these two epistemologies (“data-driven” and “the end of theory”) are both involved in Big Data, yet rely on different types of data.

Apart from providing an insight into newly emerged technology in China, this thesis makes three important contributions to STS research on future-oriented representations and anticipatory practices, the studies of Chinese science and technology policymaking, and the study of Big Data and Artificial Intelligence (AI). First, this thesis benefits future research into this area and advances future-oriented studies by distinguishing the concepts of future expectation and sociotechnical imaginary from one another. This thesis make this move by explore the formation of different future expectations for which the previous studies hardly provide an explanation. At the same time, I extend the concept of sociotechnical imaginary, which moves beyond the current focus on instrumental, political action (Jasanoff, 2015) to draw attention to the policymaking process in policy documents. Second, this thesis fleshes out the interaction between technology and politics in China, and develops studies of Chinese science and technology policymaking, by outlining a two-way, dynamic circle in which the development goals of technology (based on future expectations and sociotechnical imaginaries) are formulated. In this circle, the sociotechnical imaginary of the central government could be characterized as an intended institutional void, leaving space for regional disparity; while the local governments cleverly drive the birth of a new sociotechnical imaginary through their interpretations, to lead the development of the Smart Transportation System forward. Third, this thesis furthers our understanding of Big Data and AI, by revisiting the nature of Big Data from the perspective of traditional Chinese culture. Thus, two competing epistemologies of Big Data are brought together – "data-driven" and "the end of theory" – arguing that these epistemologies rely on different data types both derived from the "observation" of Big Data in a Chinese understanding, while the knowledge of Big Data is generated by observing the digital world constructed by a large amount of empirical data from the real world through a "medium" such as sensors and mobile phones.

This thesis is organized as follows. Chapter 1 outlines the theoretical framework of this research, located within STS research on future-oriented representations and anticipatory practices, the science and technology policymaking process, and Chinese studies. Chapter 2 outlines the methodological framework, showing how the research theme was shaped and how the methodological strategies were defined. Chapter 3 sheds light on the political, social and cultural context of the Smart Transportation System, highlighting the influence of fiscal decentralization, Big Data, and traditional Chinese culture. Chapter 4 illustrates the factors that contribute to future expectations and sociotechnical imaginary in light of Kuhn's (1970) paradigm, fiscal decentralization in China, and the algorithmic episteme proposed by Fisher (2020). Chapter 5 describes a two-way, dynamic process between the sociotechnical imaginary of central government and future expectations of local governments. Chapter 6 examines the analogy between Big Data and TCM that reflects the participants' perceptions of Big Data. Chapter 7, the conclusion, draws the key findings and arguments of the thesis together.

Chapter 1. Theoretical Framework

This chapter will trace the development of STS research on future-oriented representations and anticipatory practices, focusing on the concepts of “Sociotechnical Imaginary” and “Future Expectation”, calling for a detailed study to distinguish these terms (Section 1.1). Section 1.2 will provide a literature overview on China’s policymaking process, pointing out the key feature of “the lack of Designed at The Top Level (缺乏顶层设计)” which emerged in the science and technology policymaking process, but is, as yet, unexplored in policymaking studies. Section 1.3 will show the varied definitions of Big Data, indicating a general lack of understanding of its nature.

1.1 Development of STS Research on Future-Oriented Representations and Anticipatory Practices

“The future” is becoming an interesting and meaningful STS research subject. In 2001, the Society for the Social Study of Science held a conference in Boston entitled “Fashioning the Future” (Brown & Michael, 2003). Here, STS researchers noticed “the future” in shaping science and technology policy and started to analyze interactions between this discourse of the future, predictive tools and present challenges (Brown & Michael, 2003). In STS, the future is an object which can be studied in many ways, and thus it is not "simply a neutral temporal space into which objective expectations can be projected" (Brown & Michael, 2003, p.2), because the future is not created in a linear or spontaneous way (Brown & Rappert, 2017, p.5) as it involves multiple actors and social powers. The future is therefore embedded in present and past activities which can be evaluated. Thus, Brown and Rappert (2017) suggest that "future" is a discourse about the history of science and technology "constituted through an unstable field of language, practice, and materiality in which various disciplines, capacities, and actors compete for the right to represent near and far-term developments" (p.5). Research that focuses on the future and studies it through discourse, claims, and practices is known as "STS research on future-oriented representations and anticipatory practices" (Konrad *et al.*, 2017).

However, tracing the history of such STS research, there are several different concepts related to this body of work. As Berkhout says, "One of the problems of analysis is that expectations, schemata, images, and visions appear to take a huge variety of forms" (2006, p.302). Specifically, Berkhout notes that unclear definitions of the terms "forecasting", "foresight", "promise", " vision", "expectation", and "sociotechnical imaginary" exist, which has hindered STS studies. So there has been a call for distinguishing these concepts. For example, Brown, Rappert and Webster (2001) propose the concept "foresight", and Van Lente (2012) discusses the differences between "foresight" and "expectation". According to Van Lente, “expectation” should not be too precis in order to recruit as many actors as possible, so expectation can be established in various ways, while “foresight” involves “‘formal’ assessments of the future” and “a systemic instrument” (Van Lente, 2012), which varies according to the methods, the settings, and their objectives, in any given context. Van Lente (2012) also argues that “foresight” belongs to the area of “expectation” because “the formal articulation of futures takes place in situations where expectations abound and informal assessments are continuously made” (p.777).

Also, STS researchers distinguish “promise” from “expectation”, although the former is a concept which often appears with the latter (Van Lente, 2012; Brown *et al.*, 2003; Selin, 2007). According to Konrad *et al.* (2017), “future expectation” focuses on specific technology or future statements. In this sense, future expectation is considered a “promise” or else an “optimistic expectation”. Accordingly, negative situations are often expressed as “problems” or “risks” (Konrad *et al.*, 2017). Most STS studies on the future focus on “promise”, but in recent years some studies have considered risks and problems in the development of technology (Kitzinger & Williams, 2005; McGrail, 2010; Nerlich & Halliday, 2007; Tutton, 2011). Moreover, Borup *et al.* (2006) argue that “promise” and “vision” are an expectation of a desired future, where “vision” can be viewed as a series of future states instead of a specific future state, which is “expectation” (Berkhout, 2006; Eames *et al.,* 2006; Konrad *et al.*, 2017).

Among these concepts, the most influential are “future expectation” and “sociotechnical imaginary”. Future expectation in STS was first introduced by Nathan Rosenberg (1976). The concept was further developed by Brown *et al.* (2017). Brown and Michael (2003) put forward the notion “future expectation” which they think is the leading force of technology and innovation, one being ignored by social studies. While future expectation is about what the future would be like with science and technology, the main concern is whether the future of science and technology would achieve it or not. Social studies on future expectation analyze the social factors that may lead to an achieved or failed future. They also study the possible social and ethical consequences brought about by science and technology. So Brown and Michael (2003) suggest the “co-evolution of the social and the technical” (p.7). In “Contested Futures” (2017), many case studies use the concept of “future expectation”. One example is by Geels and Smit (2017) who study the history of the future expectation of ITS and divide these future expectations into three periods. The first, from the mid-1930s to the mid-1960s, is about automatic cars and road systems. The second, from the mid-1960s to the late-1970s, is about the computer as a “central planning and steering device” (Geels & Smit, 2017, p.133). The third, from the mid-1980s, marks a new field of telematics: “the technological areas of telecommunication, mass-communication, data-communication and data-processing” (Geels & Smit, 2017, p.133). Geels and Smit (2017) conclude that most future expectations of ITS were optimistic at first, and believed they could improve the efficiency of transportation and comfort, and reduce congestion. However, some practical challenges included high costs and technical problems.

Jasanoff suggests that science and technology can shape our future when values, norms and laws also influence the future of science and technology. Jasanoff (2015) calls this situation “co-production”. She puts forward a new notion called “sociotechnical imaginary” to describe the future which would be produced by science and society symmetrically. “Sociotechnical imaginary” includes “sociotechnical” which comes from STS and “imaginary” which comes from political theory, especially issues about national and social identity. Many STS researchers argue that not only science and technology but also “reality” are co-produced by human actors and non-human actors. So the future is a hybrid of social and technical factors. “Imaginary” is a word most used in political theory and refers to collective beliefs in society. Jasanoff (2015) argues that sociotechnical imaginary could fill the gap between STS and political and cultural theory. Sociotechnical imaginary should also not be considered purely positive or negative, but “collective, durable” and “temporally situated and culturally particular” (Jasanoff, 2015). However, what happens in the future might differ from what is expected to happen in the future, and it could also differ from nation to nation. So Jasanoff (2015) suggests that one way to analyze sociotechnical imaginary would be by comparing different social and political structures. This method would help us uncover the content of sociotechnical imaginary, and trace the origin of a particular sociotechnical imaginary (such as TCM in China). Studies using "sociotechnical imaginary" as a theoretical framework often focus on newly emerging technologies. The Smart Transportation System is one such technology having arisen in the past ten years. It is common to see cutting-edge technologies as research objects in studies of "sociotechnical imaginary". For example, Jasanoff and Kim (2009) compare nuclear power projects in different countries and Selin (2007) studies the development of nanotechnology.

Common ground exists between future expectation and sociotechnical imaginary in investigating the future as they are both concerned with the "performativity of future representations" (Konrad *et al.*, 2017). Namely, they are both concerned with future-related discourses and their practices (e.g. social and political factors). None of them guarantees achieving a certain scientific and technological future as the future is a dynamic process, not a unique outcome. For example, in the study of the emergence of nanotechnology, Selin (2007) argues that the future is a "rhetorical and symbolic space" that is constantly changing and being revised according to the agendas, interests and the needs of its actors. Instead of potential, formal and future negotiation processes, future expectation and sociotechnical imaginary are more concerned with discourse, rhetoric, and metaphors related to the future. According to Van Lente (2012), technology forecast and foresight could be seen as "formal" assessments of the future, while the informal ones are also worth studying. In future expectation and sociotechnical imaginary, the future could be seen as a discourse. For example, Selin (2007) argues that future expectation is a rhetoric "translated" between different actors to form a "future expectation". Konrad *et al.* (2017) point out that the study of the future lies in the analysis of rhetoric and metaphors, and that researchers need to show how meaning is constructed through discourse. Jasanoff (2015) also suggests that the appropriate method for studying sociotechnical imaginary is interpretive research and analysis. Concurrently, the analysis of metaphors is one of the key concerns of future expectation and sociotechnical imaginary as social imaginaries are embedded in discourse, norms, metaphors, cultural meanings, the usage of language and metaphors (Graf & Sonnberger, 2020; Jasanoff & Kim, 2009; Martin, 2021). For example, Tutton (2020) focuses on narratives and metaphors to explore how actors shape public imagination.

Both future expectation and sociotechnical imaginary span diverse case studies worldwide, and these topics promote interdisciplinary exchanges, crossing the borders between sociology, anthropology and political science (Borup *et al.*, 2006; McCarthy, 2021). However, according to Konrad *et al.* (2017), most cases studied focus on developed countries, such as the US (Eaton *et al.,* 2014; Lieberman & Kline, 2017; Tidwell & Tidwell, 2018). They also focus on cutting-edge technologies, such as bioenergy (Kuchler, 2014), ecological civilization (Hansen *et al.*, 2018), energy development (Tidwell & Tidwell, 2018), nuclear power

(Jasanoff & Kim, 2009), nanotechnology (Selin, 2007), xenotransplantation (Brown & Michael, 2003), and electric vehicles (Lieberman & Kline, 2017). Future expectation and sociotechnical imaginary concern themselves with the specific social, political and cultural contexts in which science and technology are embedded. For example, Brown, Rip and van Lente (2003) point out that future expectation is related to different knowledge communities; thus, different areas produce different future expectations. For example, Rappert and Brown (2000) compare two health innovations in the UK – genetic diagnostics and telemedicine – and find that future expectations generated by the two areas are quite different. While considering different countries, Pfotenhauer and Jasanoff (2017) argue that the innovation models appear at first to be the same across countries, but they are in fact co-produced with local conditions, developed as "locally specific diagnoses". As Borup *et al.* (2006) suggest, expectations play a central role in science and technology, so understanding expectation is an important aspect to understand technological change. Also, expectations and imaginaries play a coordinating role. For example, Borup *et al.* (2006) argue that expectations coordinate different communities and groups in a horizontal sense between one another, and, also in a vertical sense expectations coordinate different organizations across micro, meso, and macro levels. In a broader sense, the overall expectation is to link technology and society (Borup *et al.*, 2006). Most comparative studies are conducted between developed countries, such as the EU and the US. In recent years, some researchers have focused on developing countries. For example, Delina (2018) explores energy development in Thailand through interviews and policy reports.

Moreover, future expectation and sociotechnical imaginary are often used in combination by researchers in case studies, rather than distinct concepts. Graf and Sonnberger (2020) apply sociotechnical imaginaries to analyze stakeholders' views on the future user of driverless cars. However, they also support the above claims that future expectations are simultaneously related and varied because of different organizational bodies. For example, Korsnes's (2016) study of offshore wind development in China, uses a combination of "expectation" and "sociotechnical imaginary" in his research. Korsnes divides them into two levels: the central government level is called "sociotechnical imaginary" while local levels are defined as "expectations" (Korsnes, 2016). He emphasizes that sociotechnical imaginary from the central government involves ambiguity and ambitiousness, while the local level what he calls "expectations" are more specific aims (Korsnes, 2016). And this strategy is successful in leading Chinese technology development because it gives freedom to the local levels where local government and scientists can set their own targets or expectations. Yet, Korsnes does not put forward his reason for linking sociotechnical imaginary to the central government level and future expectation to the local level. These examples indicate that the two concepts are not clearly distinguished (Berkhout, 2006). Hence, researchers try to figure out the differences between future expectation and sociotechnical imaginary. For example, according to Konrad *et al.* (2017), sociotechnical imaginary focuses more on political factors and power dynamics at the national level. However, this distinction is too simplistic as it does not clearly distinguish between the two terms, because studies of both terms examine political factors. For example, Brown, Rip and van Lente (2003) argue that expectations are central to transactions, exchanges and politics between actors, and such activities are "the dynamics of a political economy of expectations" (p.6). Therefore, it is hard to demonstrate that concern for political factors is a fundamental difference between the two concepts.

Brown, Rip and van Lente (2003) study shows a distinction between the two concepts, yet other perspectives are needed to reveal this difference. Researchers have applied sociotechnical imaginary to show how different political institutions, cultures and traditions are linked to technological development. For example, Pfotenhauer and Jasanoff (2017) study in the UK, Portugal and Singapore introduces sociotechnical imaginary into innovation policy with a innovation model called the "MIT model", which offers new possibilities for theorizing how and where culture matters in innovation policy. Similarly, adopting sociotechnical imaginary, Berling, Surwillo and Sørensen (2021) illuminate how different national identities lead to different energy technology development in Norway and the Ukraine. Future expectation, on the other hand, concentrates on specific technological development processes. At first, researchers focused on a particular change of an expectation of a technology, usually referred to as "dynamic" (Borup *et al.*, 2006; Brown, Rip & van Lente, 2003; Brown & Michael, 2003; Rappert & Brown, 2000;). For example, Brown, Rip and van Lente (2003) illustrate promise-disappointment "cycles", Brown and Michael (2003) compare current expectations with former ones to show how promise-disappointment 'cycles' are constructed and how cycles aid the development of technology, such as life science innovation. According to Van Lente (2012), expectation studies try to elaborate on how the expectations of science and technology are structured and developed, and how these could influence the decisions of governments, enterprises and engineers. Moreover, Van Lente (2012) demonstrates that these studies argue that engineers, governments and businesses share one collective expectation and derive their agendas from it.

Nevertheless, Brown, Rip and van Lente (2003) identify specific dynamics of expectations, varied across different scientific and technological domains. Furthermore, they argue that "Expectations can even be understood as tradable assets whose value lies only in the future, and whose investment burdens are borne in the present." (2003, p.6). Namely, different communities might generate different expectations, and different expectations could be exchanged between different communities. Moreover, according to Brown, Rip and van Lente (2003), expectation is "a nested phenomenon", which means that once an expectation has been accepted, the detailed expectations associated with it should also be accepted. This implies that the variations between different expectations could be significant, because there might be a series of differences. Although Brown, Rip and van Lente (2003) point out that there are different expectations, they do not provide us with the reasons why these differences appear. Thus, the previous studies indicate that different sociotechnical imaginary might be related to different cultures and political institutions, but it has not yet clarified what makes future expectations different. The distinction between future expectation and sociotechnical imaginary might lie here. By analyzing fieldwork material, this thesis will attempt to find out the specific factors that might cause different future expectations and sociotechnical imaginaries to distinguish between the two concepts.

Another empirical gap in studies of future expectation and sociotechnical imaginary is the absence of empirical detail. Although, Brown and Michael (2003) stress "co-evolution of the social and the technical", and Jasanoff (2015) suggests a "co-production" between society and technology, a lack of detail lingers in the interaction between society and technology. More specifically, existing studies ignore the interaction between different social and political communities, so they could not portray "how inter-societal interaction shapes the imaginaries of any given political community" (McCarthy, 2021, p.296). Our ignorance of the interaction of different communities within expectations and imaginaries is partly due to methodology. Research methods often focus on literature at the state level

(Berling *et al.*, 2021; Hodson *et al.*, 2021; Rensfeldt *et al.*, 2020). Tidwell and Tidwell (2018) suggest that sociotechnical imaginary demands a new methodological framework, an approach that focuses on the state level, but also on the local level. Therefore, they examine "real-life language" derived from local communities in order to study "narrative patterns and changes at the local level" (Tidwell *et al.*, 2018, p.103). While Eaton, Gasteyer and Busch (2014) conduct interviews among local residents to study the local sociotechnical imaginary of bioenergy in the US, some researchers study local sociotechnical imaginary in a more detailed way. For example, Graf and Sonnberger (2020) carefully identify different stakeholders in autonomous driving, and examine how different stakeholders construct sociotechnical imaginary. However, this study is still based on the literature, as Graf and Sonnberger (2020) analyze papers on autonomous driving in Germany. In other words, this study lacks an insight about the "real-life language" of different social groups.

Consequently, this thesis tries to add diversity to STS research on future-oriented representations and anticipatory practices by turning our attention to a newly emerged technology in China – the Smart Transportation System. Also, this thesis seeks to advance studies on the interaction between society and technology by adding empirical detail from fieldwork. Finally, this thesis attempts to distinguish the two concepts – future expectation and sociotechnical imaginary – through the fieldwork material by bringing the "paradigm" proposed by Kuhn (1970) into the analysis to show the factors related to future expectation. I additionally introduce studies of Chinese policymaking, especially studies that demonstrate the linkages between knowledge and decision-making in China. For example, Zhu and Tian (2008) survey of 344 bureaucrats of the Tianjin Metropolitan Government. The study puts forward four types of knowledge used in the decision-making process: internal knowledge that comes from within the government, expert knowledge that comes from experts outside of government, popular knowledge that comes from citizens, and media knowledge. The above study also shows that decision makers use knowledge selectively. Therefore, as the sociotechnical imaginary could be exemplified as the government development targets, the formation of sociotechnical imaginary is worth exploring within the perspective of policymaking. Is there some connection between the use of policymaking knowledge and the formation of sociotechnical imaginary? Moreover, considering the centre of the Smart Transportation System – Big Data – Fisher (2020) argues that the knowledge generated by Big Data should be considered as a new type of knowledge defined as "the algorithmic episteme". According to Fisher (2020), algorithms of Big Data would see "reality" in a different way, e.g. an epistemic object. This perspective is called "the data gaze" by David Beer (2018). Moreover, Fisher argues that algorithms would "re-conceptualize and redefine that which they see" (2020, p.5). For example, Fisher studies the use of Waze (satellite navigation software) in Israeli cities and concludes that the algorithm provides "new knowledge about space" (p.4). In another example, using Big Data in risk assessment, Mehozay and Fisher

(2019) argue that algorithms should be considered as “a new conception of human nature” (p.523) in risk assessment.

1.2 Advance Studies of Chinese Science and Technology Policymaking

Extensive literature has developed around China’s policymaking, especially for the post-Mao era, e.g. “Fragmented Authoritarianism” (FA) (Han, 2013; Ma & Lin, 2012; Mertha, 2009). FA was first proposed by Lampton (1987, pp. 3–24) and supported by Lieberthal and Oksenberg (1988). Lampton (1987) argues that bureaucratic units would assert their interests in a FA policymaking process because of the replacement of Maoist ideology with economic development imperatives. Studies using the concept of FA show that several interest groups exist within the policymaking process in China, which challenges the idea that the policymaking process is monolithic (Gilli & Qian, 2018; Han, 2013). As studies applying the concept developed, several other actors became involved such as peripheral officials, non-governmental organizations (NGOs) and the media (Mertha, 2009). FA was initially used to study hydropower development in China (Heggelund, 2002; Lampton, 1987; Lieberthal & Oksenberg, 1988). Then it was employed with other case studies, for example, in international trade (Mertha, 2009), and in Chinese grid-connected wind energy (Lema and Ruby (2007).

Although FA-based studies reveal the diverse actors in the Chinese policymaking process, these studies only show the top-down process, ignoring how consensus is formed in such a fragmented process (Ma & Lin, 2012). Another concept that works closely with FA is "fiscal decentralization", which means that local governments are permitted to retain most of the revenues (see Chapter 3).

This body of work lacked the voice of Chinese scholarship until the 2000s, which limited studies on Chinese policymaking, such as grasping its complexity and dynamics from a Chinese perspective (Ma & Lin, 2012). In the 2000s, Chinese scholarship starts to emerge (Ma & Lin, 2012). After critically reflecting on research by Western scholars, they develop more specific explanations about governmental bureaucracies instead of employing the general model of FA (Ma & Lin, 2012). For example, Zheng (2008) is inspired by the Polsbian's classification of the internal and external groups of agenda proposers, arguing that there is a new model unaddressed by existing Western theory. The new model brings the internal and external group together in the case of Nu River. Similarly, Han (2013) explores the case of Nu River, highlighting the important role played by nonstate actors such as NGOs and international entities. Some Chinese researchers focus on the policymaking framework shift in the mid-2000s, arguing that the emphasis of Chinese policymaking is gradually shifting from economic to social policies (Meng, 2010). Some Western scholars also notice the importance of examining the details in Chinese policymaking. For example, Heilmann and Melton (2013) note that the applications and influences of planning processes have been largely neglected in Western studies of China's political system. After analyzing the planning system at provincial- and central-levels, Heilmann and Melton (2013) conclude:

> Development planning in contemporary China is driven by an unceasing process of information gathering, consultation, analysis, document drafting, implementation, experimentation, evaluation, and revision that is better thought of as a recurrent cycle of cross-level, multiyear policy coordination, rather than an integrated, unitary plan system. Considering the mix of coordination mechanisms as well as the variation in the effectiveness and credibility of planning efforts across policy sectors, it is clear that China's planning system is not capable of dealing with everything it claims to address at once. (p.38)

Heilmann and Melton (2013) describe Chinese planning practices as a dynamic system rather than as a static power relationship. Moreover, they point out the importance of analyzing different subsystems and characterizing their dynamics, because they find that some plan-based coordination has been successful, while others have failed. Therefore, it would be risky to draw a comprehensive conclusion at this point. Although Heilmann and Melton (2013) notice the importance of subsystems and specific planning practices, they do not provide a detailed analysis on any subsystems or specific planning practices, which means their description of the dynamic system of Chinese planning practices lacks detail.

Instead of analyzing Chinese policymaking in a general level, some Chinese scholars concentrate on more specific policymaking themes. For China's housing policy, Jiang (2013) focuses on the participation of Chinese homeowners, pointing out that organised homeowner activists have entry into agenda setting and rule-making in the policymaking process. For education policy, Zhao (2018) examines the "Double World-Class Project",[18] indicating the risk that the project, in the context of existing policymaking processes in China's higher education, would limit the participation of local governments and non-governmental actors involved. Yu (2020) concentrates on the difficulties of rural migrant children caused by the restrictive schooling policy. For healthcare policy, Wang (2008) argues that market-oriented reform has undermined the equity of healthcare, because it reduces vulnerable people's access. In a review of Chinese scholars studying Chinese policymaking, conducted by Ma and Lin (2012), Chinese scholars also concentrate on policy actors, such as think tank policy experts and governmental bureaucrats; concluding that the budget and the knowledge policy actors use to make decisions impacts policymaking.

[18] The World First-Class University (世界一流大学建设) and First-Class Academic Discipline Construction (世界一流学科建设), combined and are known as the "Double First-Class Project" or "Double World-Class Project", started in September 2017 by The Ministry of Education of the People's Republic of China (中华人民共和国教育部).

However, this body of work loses sight of an important theme – the policymaking process of science and technology in China. This is not to say that Chinese scholars do not care about this topic, but rather focus on a different perspective. In fact, this omission is not only an issue for Chinese policymaking, but is also a global issue. Compared to other research on policymaking, studies on science and technology policy are problem-oriented instead of theory- or paradigm-driven (Morlacchi & Martin, 2009). That is to say, it concentrates on specific practical issues, such as R&D expenditures, personnel statistics, patent statistics, and bibliometric indicators (i.e., publication and citation) (Morlacchi & Martin, 2009). Taking China as an example, it examines the research questions of R&D expenditures (Chen *et al*., 2018; Ljungwall & Tingvall, 2015; Peng *et al.,* 2020; Wu *et al.,* 2007; Wu, 2017). Also, scholars investigate the impact of investments and policies related to international cooperation on the development of science and technology in China (Hu *et al*., 2005; Jin *et al*., 2014; Lu & Liu, 2004; Walsh, 2007; Zhou *et al*., 2011). While studies on science and technology policy hardly pay attention to the evolution of the relations between different government departments during the policymaking of science and technology (Sun, & Cao, 2018). To address this gap, Sun and Cao (2018) study sketches a contour of the innovation policy network at the central government level. They examine 463 innovation policy documents from central government ministries between 1980 and 2011 in China; however, this study does not provide a longitudinal analysis of how the relations between different levels of government evolve in science and technology policymaking.

In recent years, some researchers tried to address this gap by examining the offshore wind industry from the perspective of planning (Korsnes, 2016). Different from Heilmann and Melton (2013) study that focuses on the planning process, Korsnes (2016) concentrates on government development targets. Korsnes (2016) introduces two concepts from STS: expectations and sociotechnical imaginaries. The government development targets are seen as sociotechnical imaginaries, while the goals of the industry are construed as local expectations. Korsnes (2016) describes a dynamic between the government and the industry as “a strategic waiting game” (p.50). The most important feature of this strategic game is that the government’s intentions are ambitious and ambiguous to leave room for possible changes, which also provides opportunities for the industry to add their expectations into the government’s development targets. Importantly, Korsnes (2016) unfolds an interesting feature in the policymaking process – the ambiguity of the government’s targets for technology projects. However, Korsnes (2016) does not distinguish the central government’s or local governments’ development targets. To fully address the above-mentioned gap, the context of FA and fiscal decentralization should not be ignored when analyzing the policymaking process in China.

Similarly, some recent researches also identify this feature in the policymaking of science and technology in China. For example, Gohli and Fischer (2019) explore the smart grid industry in China and find borrow the concept of "intentional ambiguity" from the realm of diplomacy or military jargon to describe it. "Intentional ambiguity" refers to "a situation where two factions circumvent confrontation by using imprecisions to discuss a sensitive topic upon which each side possesses contrasting ideas" (Gohli & Fischer, 2019, p.109). By applying the theory of "strategic ambiguity", Gohli and Fischer (2019) reveal that the central government puts forward ill-defined policies intentionally to stimulate economic and technological development. More specifically, the ill-defined policies in this case refer not only to central government policies, but also the vague understanding of smart grids in the industry caused by policies. Gohli and Fischer (2019) try to conceptualize the ambiguity of governmental targets on technology projects unpacked by Korsnes (2016).

However, the concept "intentional ambiguity" is not a perfect term to describe the situation, because the actors in the policymaking process might be numerous, especially in the context of fragmented authoritarianism and fiscal decentralization. Moreover, the actors might not have contrasting ideas. Taking the local government into account, Liang *et al.* (2020) examines "the Sponge City Program" in Changde City and Zhuanghe City: a new implementation of Chinese water policy. Using policy-cycle analysis, Liang *et al.* (2020) concludes that "the central government orders local government to implement policy without clear direction on how to attract private sector participation" (p.1). Being aware of the unclearness of development direction at the central government level, Liang *et al.* (2020) updates the traditional "one-wheel" policy-cycle model in principal-agent theory to a "double-wheel" model in order to describe policy cycles at the level of central government and the local government. The double-wheel model shows different policy cycles. The policy cycle of the central government has three parts: problem identification, policy formulation and evaluation. And the policy cycle of the local government has four parts: problem identification, policy adjustment, policy implementation, and policy evaluation.

The evaluation system for local government prefers quantifiable and visible criteria for project selection. Yang's (2012) "The pressure system (压力型体制)", for example, sees the interaction between the central and local governments as a top-down system in which the operation of local governments is a response to developmental pressure from different sources. The pressure system consists of three components: (1) a quantitative task decomposition mechanism, (2) a problem-solving mechanism with the participation of all departments, and (3) a materialized, multi-level evaluation system. These local governments respond passively to this pressure and complete quantitative indicators assigned from the central government. For the Smart Transportation System, the components of its evaluation system have not changed and its emphasis is still on quantitative and material factors. The pressure system prefers quantitative estimations. For example, how many roads are built per year, or how many sensors and cameras are located in the streets.

In recent years, the shift in the evaluation system for local government has tended to be more conservative: focusing on ideological issues instead of economic issues. Indeed, Qi and Lin (2018) argue that the evaluation system for the performance of local governments could be divided into two different orientations: “control-oriented” and “development-oriented”. “Control-oriented” means that the evaluation system focuses on ideology and moral characteristics, while “development-oriented” concentrates on the economic dimensions. Since 2017, the evaluation system in China has been more “control-oriented” than “development-oriented”. For example, according to Qi and Lin’s (2018) quantitative analysis of 166 Chinese policies on the evaluation system over the past 40 years, control-oriented policies have accounted for 65.4% of the total number of policies since 2012, significantly more than development-oriented policies (23.1%). And this shift also coincides with the beginning of the development of the Smart Transportation System.

Liang *et al.* (2020) also point out the ambiguity of the government’s targets on technology projects. Specifically, the study clarifies different policy cycles of the central government and the local government and relates the ambiguity to the central government. Although the double-wheel model shows the top-down process and sheds light on the two policy cycles of the central government and the local government, the relations between these governmental levels are unexplored. Ultimately, the dynamic system of different levels of government remains unclear. It is also critical to think of how policy consensus is formed in this fragmented context (Ma & Lin, 2012).

From the above discussion, policymaking of technology in China features an ambiguity of governmental targets for technology projects (Korsnes (2016), “intentional ambiguity” (Gohli and Fischer (2019), and “the central government orders local government to implement policy without clear direction” (Liang et al. (2020). Yet, the existing research does not elaborate on the role that ambiguity plays in the dynamic between the central and local government. In my analysis of the Smart Transportation System, I also find this feature in the policymaking process. In the fieldwork the interviewees argue, for instance, that there is “the lack of Designed at The Top Level (缺乏顶层设计)” in the development of the Smart Transportation System, which indicates the missing role of the central government. “Designed at The Top Level” is a Chinese phrase. It used to be a term in engineering which means that people should consider every level and every element and then solve problems from the highest level. But it has gradually become a political term in the Chinese context. The term first appeared in the political context in the Twelfth Five-Year Plan. I prefer to use “the lack of Designed at The Top Level” to describe this feature, because it derives from the fieldwork material embedded in a unique Chinese political and cultural context. Inspired by Korsnes (2016) introducing the concepts – expectation and sociotechnical imaginary – into the study of science and technology policymaking, I also employ these two concepts to explore the dynamic system between different government levels and the role that "the lack of Designed at The Top Level" plays in such a dynamic.

1.3 Rethinking the Nature of Big Data

Big Data is at the heart of the Smart Transportation System. However, what is Big Data? Although experts and scholars have tried to define Big Data since it emerged, its definition and features are vague. Scholars, for instance, started to define Big Data in the 2000s, yet academia still called for a formal and holistic definition in the 2010s (Chen *et al.*, 2014). Despite this paucity, according to Favaretto *et al.* (2020), a study among 39 researchers shows that Big Data's definition remains unclear in 2020. The vagueness of the definition is not because it is too broad, but rather that too many definitions exist. Big Data was originally defined as data that cannot be stored, managed and analyzed by traditional data analysis methods because of its volume (Chen *et al.*, 2014; Kaisler *et al.*, 2013; Ylijoki & Porras, 2016). Traditional data analysis methods usually refer to the use of statistical methods to analyze data, extract laws and patterns and maximize its value (Chen *et al.*, 2014). The original definition can only give us a general understanding, more to draw a dividing line between traditional data analysis methods and the Big Data than to provide a comprehensive description.

The three V's (Volume, Variety and Velocity) can be considered the most basic definition of the technical aspects of Big Data. This definition was first proposed by Laney in 2001. Volume refers to large amounts of data that cannot be stored and analyzed in traditional ways (Hashem *et al.*, 2015; Wamba *et al.*, 2015; Ylijoki & Porras, 2016). Volume highlights that size is one a prominent feature of Big Data. Chen, Mao and Liu (2014) also argue that volume means that the size of Big Data changes over time as technology advances. Variety refers to the diversity of data sources and types. Some researchers consider variety to refer to data type. For example, Gandomi and Haider (2015) divide data into three types: structured, semi-structured, and unstructured. While researchers like Gandomi and Haider (2015) argue that data type causes diversity within Big Data, others reason that it is the data source that causes variety. For example, Hashem *et al.* (2015) mention mobile phones, sensors and social media. While variety marks a consensus in Big Data's definition, researchers have different opinions on data classification. Velocity refers to the speed of data generation and transmission (Wamba *et al.*, 2015), as well as the speed of data analysis (Gandomi & Haider, 2015). Big Data is used for real-time analytics and evidence-based planning (Gandomi & Haider, 2015), so the speed of transmission and analysis is critical to the value and efficiency of the data (Chen *et al.*, 2014; Ularu *et al.,* 2012). Moreover, the data's content is constantly changing (Hashem *et al.*, 2015), and requires the data to be collected and analyzed as timely as possible (Chen *et al.*, 2014). Gandomi and Haider (2015) consider the three V's to be a common framework. According to Ylijoki and Porras (2016), among papers focused on the definition of Big Data the most mentioned feature is volume (95% of the papers studied), followed by variety and velocity. Moreover, many definitions are built on the three V's. For example, IBM[19] adds "veracity", while Oracle considers "value" as the fourth V; additionally, SAS[20] adds two features: variability and complexity (Gandomi & Haider, 2015). Variability and complexity relate to the technical aspects of Big Data, and to "the fact that Big Data are generated through a myriad of sources" (Gandomi & Haider, 2015, p.139), which means that data from different sources needs to be transformed, matched and carefully selected. Thus, Big Data's technical aspects are mostly concluded as different "V's" (Favaretto *et al.*, 2020).

However, researchers point out that the technical aspects of Big Data ignore other aspects. For example, Ylijoki and Porras (2016) argue that business aspects are overlooked. So the researchers have proposed some additional features to provide a more complete picture of the operation of Big Data, mainly for judging the data. These features for the judgement of Big Data mainly refer to "value" and "veracity", mentioned above. Value refers to "the process of discovering huge

[19] International Business Machines Corporation
[20] Statistical Analysis System

hidden values from large datasets with various types and rapid generation" (Hashem *et al.*, 2015, p.100). According to Wamba *et al.* (2015), value emphasizes the importance of seeking economic benefits in data, which has been recognized by commercial companies. For example, IDC defines Big Data as Four V's, which are volume, variety, velocity, and value. Veracity refers to "the degree in which a leader trusts the used information in order to take decision[s]" (Ularu *et al.,* 2012, p.4). Veracity concerns the credibility of the results drawn from Big Data. The conclusions drawn from Big Data are sometimes not trusted by people. For example, according to LaValle (2009), 1 in 3 business leaders do not believe in the data which they use to make decisions. Such judgements features of Big Data make its definition more complete, but they also make it more complex. Mainly, because these features no longer point to the nature of data, but to its application. For example, Ylijoki and Porras (2016) argue that adding features, such as "value", make Big Data's definition vague and lose "coherency".

As the definition of Big Data becomes increasingly broad, a third segment of its definition has emerged which views Big Data as a phenomenon of social and political dimensions. This change is because the application of Big Data has been gradually expanding from the field of business to the field of science and technology, and then to the field of humanities and social science. According to Favaretto *et al*. (2020), the term Big Data first emerged in academic literature in the early-2000s, in the field of statistics and economics. As Big Data's fields of application increase, the definition of Big Data is deregulated from its technical and application aspects. For example, instead of “V features”, Lupton (2015) proposes “P features”, such as portentous, perverse, personal, political, predictive, etc. Some studies have categorized these additional definitions by starting from the basic definition of Big Data in terms of volume, and gradually adding subsequent features to the definition, to form a relatively holistic definition. For example, Gandomi and Haider (2015) extend the three V’s to the Six V’s, adding Veracity, Variability and Value. Ularu *et al.* (2012) also started with the three V’s, and expanded to the Four V’s (Volume, Variety, Velocity and Veracity). However, constantly adding new features to the definition still make it unclear as these continuous additions make the definition more lengthy and complex; while researchers still try to find missing perspectives (Ylijoki & Porras, 2016).

Therefore, based on the fieldwork materials, this thesis aims to explore the nature of Big Data. During fieldwork, the participants usually used metaphors to express their understanding of Big Data. This thesis examines these metaphors to investigate the understanding of Big Data in a Chinese context. The metaphor is a suitable way to analyze ideas such as Big Data. Researchers have explored metaphors in the study of new technologies emerging on the Internet because metaphors make abstract concepts easier to understand. For example, Wilken (2013) suggests a relationship between metaphors and “techno-social complexity”; namely, that through metaphors we can relate new emerging technologies to the concepts of everyday life, and explore the connections behind them. The use of metaphors also reflects the different cultural backgrounds and contexts of users. According to Puschmann and Burgess (2014), metaphors in Big Data are a topic worth investigating since the complexity of Big Data increases its abstraction, so people try to understand it through "familiar shapes". Their choice of "familiar shape" usually reflects the user's background. They conclude two metaphors about Big Data in their research: that it is "a natural force to be curbed and controlled" and "a resource to be consumed".

Conclusion

This thesis contributes to studies of the science and technology policymaking process, the STS and Chinese studies. In particular, this thesis focuses on a newly discovered feature: "the lack of Designed at The Top Level", which provides a detailed understanding of China's science and technology policymaking process. By exploring the role of "the lack of Designed at The Top Level" in the policymaking process, this thesis provides longitudinal analysis of relations between the central government and the local government. By showing the dynamic between different government levels, this thesis offers a detailed description of the dynamic system of Chinese planning practices from the perspective of science and technology policymaking. Cases which feature "the lack of Designed at The Top Level" are related to some cutting-edge technologies such as the smart grid, the Smart Transportation System and Sponge city. Further study is warranted to ascertain whether this feature is a unique one of the policymaking process of cutting-edge technologies in China, or a future trend for all technological projects. Moreover, this thesis distinguishes the two concepts "sociotechnical imaginary" and "future expectation" in the Chinese context. The mixed use of these two concepts has hindered STS research on future-oriented representations and anticipatory practices. The factors that might contribute to different future expectations and sociotechnical imaginaries are the key to distinguishing these two concepts. Additionally, the absence of empirical detail is also a major obstacle to the study of the future. Thus, on the one hand, drawing on the fieldwork material, this thesis examines the interaction between society and technology, especially in the policymaking of science and technology in China. On the other hand, through research related to the policymaking of science and technology, the thesis explores the key feature that makes sociotechnical imaginary differ from future expectation in order to advance the field of STS research on future-oriented representations and anticipatory practices. Moreover, as Big Data is at the centre of the Smart Transportation System this thesis explores metaphors used by the participants in the field to expand our understanding of Big Data.

Chapter 2. Methodology

This chapter will sketch the methodological framework which guided my research of the Smart Transportation System. In Section 2.1, I will introduce the research inspiration and discuss how the research questions and methodological strategies developed. In Section 2.2, I will illustrate the selection of the research sites in terms of their different economic levels, geographical environments, administrative divisions and the development of the Smart Transportation System. Also, I will provide a snapshot of the participants of the pilot interviews and the formal interviews. Finally, I will present the specific methods used in the research, showing their benefits and limitations.

2.1 The Research Theme, Research Questions and Methodology

This research was motivated by my passion for science and technology and a confusing project called the Smart Transportation System (智慧交通 Zhihuijiaotong) in China. My passionate for science and technology stems from two aspects: first, science and technology could be a good entry point to look into Chinese society; second, STS takes “a ‘post-critical’ stance emphasizing the local, small, and contingent" (McCarthy 2021) and employs the anthropological approach proposed by Latour and Woolgar (2013), which make it possible to probe Chinese society in a more detailed way from the perspective of science and technology. Chinese sociologists often try to take a close look at China in order to contribute to the accumulation of knowledge for sociology (Xie, 2018). Xie (2018) notes that one of the interesting but difficult aspects of studying Chinese society is the tension between China and the world. The reason is that Chinese society shares many similarities with other societies, while the differences lie in degrees rather than types (Xie, 2018). Thus, it is important to choose an appropriate entry point that is needed to be both relevant to China and the world. On the one hand, innovation in science and technology is "universally desirable and follows a quasi-universal pathway"; on the other hand, it would take different forms in different countries and regions (Pfotenhauer and Jasanoff, 2017). Therefore, science and technology could serve as a window to understand China, and it also provides a great opportunity to study the similarities and differences between China and the world. Moreover, STS aims to demonstrate the impact of social, political, and historical context on the development of science and technology in different countries, and its theory provides an effective framework for studying science and technology in China. Also, Latour and Woolgar (2013) apply an anthropological approach to study life in the laboratory in order to study the generation of scientific knowledge. This attempt also offers a practical way to understand the development of science and technology in China.

My passion for science and technology prompts me to pay attention to emerging technologies and inventions. Also, my passion for science and technology has led me to make many friends in the field of science and technology. One day in 2014, during a conversation with a friend, from the transportation system fields, they mentioned that they were about to start a new project called the Smart Transportation System. I was curious about the new project because it seemed to be some kind of sci-fi scenario. So I asked them what it was. I thought it was a very simple question at the time, similar to other difficult scientific terms my friends were always explaining to me. However, this simple question led to a heated debate. One of my friends said that it was a project that might completely change our city and our life, because it would lead us into a new era dominated by driverless cars on the streets. Another answer was that it would benefit from Big Data and would promote the development of algorithms instead of the driverless cars. Another friend thought that it was just a fancy new name for our existing transportation system. They did not reach an agreement, leaving me with a “simple” question that had no “simple” answer. I found this aspect interesting because this project, or technology, did not seem to be the same as other technological projects for which my friends were always be able to give a clear definition that everyone agreed with.

The Smart Transportation System was notable and interesting for three reasons:

1) This project was proposed at a turning point of China's transportation development strategy, and it could be seen as an important part of the new transportation development strategy. According to Ning (2020), the development of China's transportation since the Reform and Opening Up could be divided into three stages: market-oriented reform (市场化改革阶段 1992-2003), rapid development (快速发展阶段 2004-2013), and a country with strong transportation network (交通强国阶段 2014-present). From the second stage to the third one, the goals of transportation development have changed "from the pursuit of speed and scale to quality and efficiency, from a fragmented transportation system to an integrated transportation system, and from a traditional factor-driven system to an innovation-driven system" (Wu, Wu and Wang, 2019). In 2019, the policy document "Outline of developing a country with strong transportation network" (交通强国纲要)[21] released by the State Council pointed out that China should "develop the Smart Transportation System". Thus, the Smart Transportation System could be seen as an important part and a typical example of this new development strategy. 2) This project indicates "a shift in the development of transportation" (Zhang, 2018), which combines advanced technologies with traditional industries. Zhang (2018a) argues that new forms of transportation such as shared transportation and autonomous driving have emerged with the popularization of the Internet and Artificial Intelligence in the era of Industry 4.0. 3) The dispute between scientists and engineers about the

[21] http://www.gov.cn/zhengce/2019-09/19/content_5431432.htm

future of this project, on the one hand, agrees with Jasanoff's argument that different sociotechnical imaginaries would exist in parallel within a society (Jasanoff, 2015), emphasizing "the multilinear forms of socio-technical development" (McCarthy, 2021); on the other hand, it also provides a good opportunity to examine how the future of this project would be reached in the end, despite the many future expectations and imaginaries. And the study of this process could show us the co-production of science and society in a more detailed way.

I started to seek information related to the Smart Transportation System on the Internet. It is indeed an important project in the transportation system field, closely related to the idea of "smart cities" which first emerged in 2008, from IBM's idea of "Smart Planet" (Sun, Zhen, 2013). Ferreras (2017) suggests that smart cities are based on cutting-edge ICT. In other words, a city based on data (Wang & Li, 2014). Then several countries put forward a plan to develop "smart cities". For example, the UK has a plan called "Digital Britain" and Korea has "U-Korea" (Lu *et al.,* 2015). China started its development of the smart city around 2011. The Twelfth Five-Year Plan (2011–2015) announced the development of the Internet of Things (IoT) and related technologies such as "Digital City". According to the Center of Regional Science at the Vienna University of Technology, smart cities include six aspects: smart economy, smart environment, smart people, smart living, smart governance, and smart mobility (Meyer & Shaheen, 2017). Smart mobility refers to a combination of traditional transportation and new technology such as ICT and IoT (Meyer & Shaheen, 2017). The Smart Transportation System often contains several types of data such as map data, POI (Point of Information) data, GPS data and passenger flow data (Wang & Li, 2014). So the transportation system is usually a highly informationized part of cities. Therefore, the Smart Transportation System is included in the smart city, and it is often a key project. In 2011, when the term “Digital City” first appears in the Twelfth Five-Year Plan,[22] Shanghai released its plan called “Action Plan about Advancing the Construction of Smart City 2011–2013 (推进智慧城市建设 2011–2013 行动计划)”, including the Smart Transportation System[23] as a key project. In 2012, MOHURD opened applications for all cities in China to become experimental cities (试点城市)[24], and, in 2013, MOHURD announced the list of these experimental smart cities: 83 cities, 20 towns and 4 districts.[25] In 2014, the Minister of Ministry of Transport suggested a “Four Traffic” proposal towards future transportation development:[26] (1) comprehensive transportation, (2) intelligent transportation, (3) green transportation, and (4) safe transportation (综合交通、智慧交通、绿色交通、平安交通).

[22] Five-Year Plan: It is a series of social and economic development initiatives which started since 1953 in China.
[23] Action Plan for Advancing the Construction of Smart City 2011-2013
http://www.sheitc.gov.cn/szfgh/652766.htm
[24] Notice of selecting Experimental Cities of “Smart City”
http://www.mohurd.gov.cn/zxydt/201212/t20121210_212226.html
[25] List of Experimental Cities of “Smart City”
http://www.mohurd.gov.cn/wjfb/201308/t20130805_214634.html
[26] http://www.chinahighway.com/news/2015/930125.php

Compared to transportation management in the 19th and 20th Centuries, the fundamental difference of the Smart Transportation System is the extensive use of information technologies such as cloud computing, Big Data, and the Internet of Things (Zhang, 2018b; Zhao & Zhu, 2020). Zhao and Zhu (2020) divide the Smart Transportation System into four levels: 1) Intelligent Vehicles, including powertrain, electric vehicle, driver assistance system, and automatic drive; 2) Intelligent Transportation System (ITS), including traffic position system, traffic control system, and traffic management system; 3) Data Technologies for the Smart Transportation System such as data collection, storage, sorting, calculation and other technologies for residential travel information, logistics information, and transportation service status information; 4) Intelligent shared transportation service known as Mobility as a Service (Maas) such as shared travel, and user reservation travel. The first two levels of the Smart Transportation System could be seen as a continuation of the traffic management of the 19th and 20th Centuries that focuses on the development of roads and vehicles. The third level indicates that there is a new trend that integrates the traditional transportation system with information technologies. And the fourth level shows that information technologies are applied to social services. Therefore, Zhao and Zhu (2020) suggest that the Smart Transportation System is characterized by the combination of transportation technologies, information technologies, and social science such as "New Service" (新服务) and "New Business" (新商业). Furthermore, some researchers argue that the Smart Transportation should be considered as part of a Smart City (Zhang, 2018b; Zhao & Zhu, 2020), as it should not only be compatible with the development of the transportation system but also meet the needs of comsumption of the passengers.

In 2017, when I started my PhD in the UK, the Smart Transportation System had become a heated topic across China. In 2017, China's Ministry of Transport had released two documents about the Smart Transportation System: "The Action Scheme of Using Smart Transportation System to Make Travel Easier (2017–2020) (推进智慧交通发展行动计划 2017–2020 年)"[27] and "The Action Scheme for Promoting the Development of Smart Transportation System (2017–2020) (智慧交通让出行更便捷行动方案 2017–2020 年)".[28] Several provinces and cities followed this trend and released their own action schemes. For example, Beijing's "The Action Scheme for promoting the development of the Intelligent Connected Vehicles 2019–2022 (北京市智能网联汽车创新发展行动方案 2019 年–2022 年)"[29]. Accordingly, the Smart Transportation System started to become popular after the government's promotion of it. Almost all the leading Internet companies entered this newly emerging field. For example, at a digital transportation conference in 2016, Tencent presented "Smart Transportation System in the Age of Big Data" to elaborate on its ideas and research achievements based on its data.[30] In 2018. Didi, a Chinese company focusing on an online taxi-hailing service,

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27 http://xxgk.mot.gov.cn/jigou/zhghs/201702/t20170213_2976478.html
28 http://xxgk.mot.gov.cn/jigou/kjs/201709/t20170926_2975335.html
29 http://www.beijing.gov.cn/zhengce/zcjd/201905/t20190523_78903.html
30 https://cloud.tencent.com/developer/news/267258

released new ITS products “Didi Traffic Brain (滴滴交通大脑)” and a traffic-information platform called “Qunyan (群雁)” based on Didi’s existing AI and data analysis technologies.[31] When we look through Huawei’s homepage, we can also find an eye-catching section about the Smart Transportation System. It says: “Huawei will provide customers with innovative solutions, such as a digital railway, a digital underground, a smart airport, etc., through new ICT technologies such as cloud computing, Big Data, IoT, agile network, BYOD, eLTE, GSM-R, etc.”[32] Through the above news and documents, it feels like there might be a bright future for the Smart Transportation System; it might change our daily lives, our cities, and our mindsets. Yet, my curiosity surrounding this topic also started to generate some broad questions: What is the Smart Transportation System? How will it influence our everyday lives?

At the beginning of my research, I tried to ascertain the answer to “What is the Smart Transportation System?” from two aspects. One was the discussion of the transportation system, and another the discussion of “smart” that relates to Big Data, as the “smart city” is based on Big Data and ICT. Urry (2008) argues that the transportation system is a complex self-organising and non-linear system. Geels (2004) suggests that the transportation system belongs to large technical systems comprised of infrastructure with technology. Geels (2004) also talks about the complexity of the transportation system because it involves many different

[31] https://www.leiphone.com/news/201905/6UBjTNs54JTjZPHb.html
[32] https://e.huawei.com/cn/solutions/industries/transportation

components, such as physical artifacts, organisations, legislative artifacts and so on. Ottens *et al.* (2006) calls the transportation system a “complex engineering system”. According to information on the websites of the Systems Engineering Departments of Brunel University and University College of London, “complex engineering system” means the design, development and maintenance of large, complex, multidisciplinary systems (Ottens *et al.*, 2006). Ottens *et al.* (2006) suggest that the complexity of the system comes from people involved in it. Studies that focus on the complexity and instability of the transportation system employ complexity theory (Urry, 2008), game theory (Hausken & Zhuang, 2015) and systems theory (Ottens *et al.*, 2006). Some researchers suggest that the transportation system is a complex *and* a sociotechnical system (Geels, 2004, Ottens *et al.,* 2006) because the sociotechnical system involves technical and social aspects (Ottens *et al.*, 2006) which express interaction and interdependence (Geels, 2004). Such studies concentrate on the social elements in the Transportation System, such as user experience (Geels. 2004), and changes in regulations and standards (Ottens *et al.*, 2006). These studies also provide several social perspectives to study the transportation system from. They remind us of how complex the Smart Transportation System might be. Thus, I would like to pay particular attention to the social element of the Smart Transportation System.

However, after searching for documents about the Smart Transportation System, I realized that the system differs from general transportation system research, because the Smart Transportation System is not an existing infrastructure, and a lot of its ideas are still on paper. Inspired by Korsnes (2016) study that focuses on government development targets on science and technology, I started to view these plans and targets for the Smart Transportation System as future expectations and sociotechnical imaginaries in the STS. Hence, my analysis was guided by the methodology of future expectations and sociotechnical imaginaries. Documents feature in the research methods of sociotechnical imaginary, such as government documents (Berling *et al.*, 2021; Hassan, 2020; Jasanoff, 2015; Martins & Mawdsley, 2021; Pfotenhauer & Jasanoff, 2017; Rensfeldt *et al.*, 2020), professional literature (Graf & Sonnberger, 2020; Hockenhull & Cohn, 2021; Hodson & McMeekin, 2021) and visual materials (Martin, 2021). Also, in recent years, to shed light on the local level of expectations and sociotechnical imaginaries, researchers have conducted interviews (Brown *et al.*, 2001; Selin, 2007; Smallman, 2020). Therefore, this research was designed as a case study focusing on expectations and sociotechnical imaginaries based on a mixed-method approach using document research, such as governmental policies, and interviews with local actors (e.g. experts in the transportation field).

As the research progressed, I traced the history of the Smart Transportation System and found that my study should also be narrowed to the Chinese context. Two stages of the development of the Smart Transportation System exists in China: The first stage is from the 1990s to the 2000s and the second one is from the

2000s until now. Although they share the same English name, these phases have different Chinese names. The first could be called the "Intelligent Transportation System (智能交通, Zhi neng jiao tong)" (ITS) which is similar to its Western meaning. The second is much more related to the "Smart Transportation System (智慧交通 Zhi hui jiao tong)" which refers to its local understanding and creation. ITS is an idea that first came from the field of information and automation. The US first proposed this concept in the 1960s (An *et al.*, 2011) as "the future direction of the transportation system" (Zhu *et al.,* 2018, p.383). My thesis focuses on the second stage – the development of the Smart Transportation System from the 2000s until now. Yet to understand the Smart Transportation System requires some foundational knowledge of what proceeds it.

A typical definition of ITS is "a method of combining Information Technology (IT) and other advanced methods with transportation engineering to address transportation problems involving a complex interplay between technology; human perception; cognition and behavior; and social, economic, and political systems" (Leung *et al.*, 2011, p.2). In short, the ITS is a transportation infrastructure that would use advanced ICT to improve the efficiency and safety of transportation systems. An *et al.* (2011) agree with the idea that ITS works closely with ICT. ICT could be divided into different parts such as sensors, smart cards, GPS, social media, video detectors, and so on (Zhu *et al.*, 2018). These definitions are found in transportation information as well as transportation automation papers. Most of which are collected in the IEEE[33] database.

ITS commenced in the 1970s in the US (Qi, 2008). Major developments were made in the US, Europe and Japan. For example, from the late-1960s up to the 1970s, there were Electronic Route Guidance Systems in the US, the Comprehensive Automobile Traffic Control System in Japan and ALI (*Autofahrer Leit und Information System*) in Germany (Figueiredo *et al.*, 2001). From the 1980s to the 1990s, there were the Program for European Traffic with Efficiency and Unprecedented Safety in Europe, IVHS America (Intelligent Vehicle Highway Systems) in the USA and the Road Automobile Communication System in Japan (Figueiredo *et al.*, 2001). In recent years, the US has still taken the lead in ITS development. According to Li *et al.'s* (2010) study, from 2000 to 2010, US researchers published 34.8% of the IEEE's ITS papers; more than the combined sum of China's, Japan's, Taiwan's, Italy's and Spain's publications. Developed for almost two decades, ITS is gradually changing from a technology-driven system into a data-driven system concerning Big Data analytics and other related technologies (Zhang *et al.*, 2011). One reason is that there is a large amount of data collected from multiple ITS sources while old methods of IT are inefficient in analyzing it (Zhang *et al.*, 2011). Another reason is the influence of Big Data from other disciplines on ITS, such as the business field (Zhu *et al.,* 2018).

[33] **Institute of Electrical Electronics Engineers**: a professional association for electronic engineering, electrical engineering, telecommunications computer engineering, and allied disciplines.

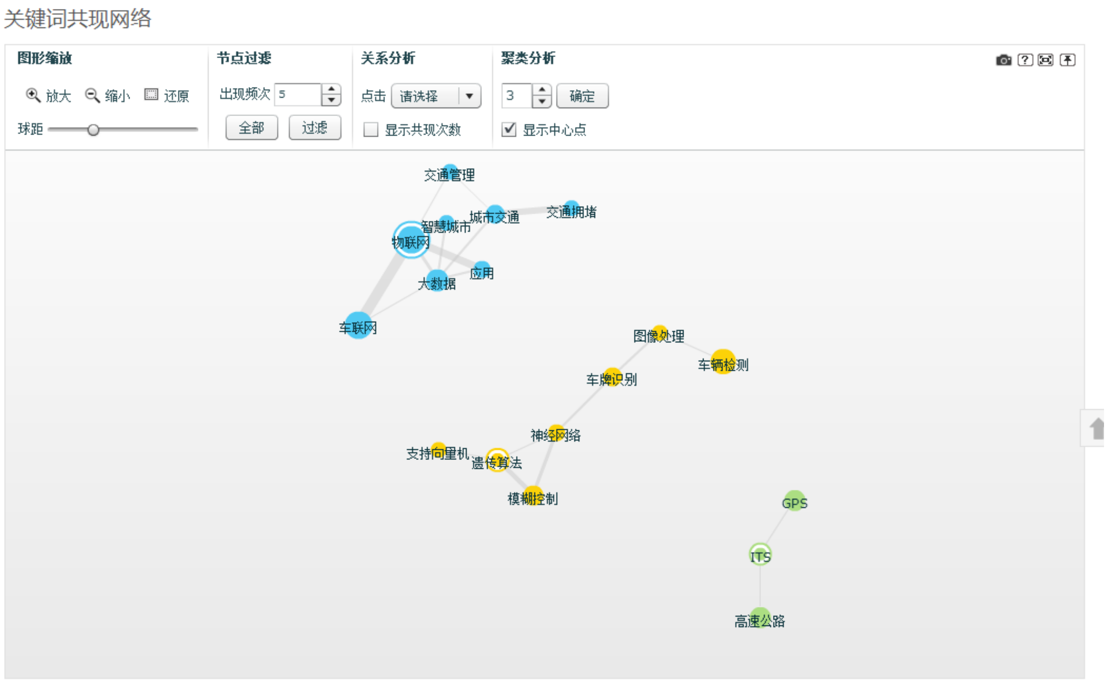
Considering the two stages of the development of ITS in China in more detail:

First Stage (1990s–2000s)：

The concept of the ITS (Zhi neng jiao tong) was first brought to China in the 1990s and focused on information and automation technology. According to the CNKI,[34] the top three keywords in ITS papers are the IoT, Algorithm and ITS divided into three isolated groups (see Graph 1).

[34] **China National Knowledge Infrastructure** (中国知网): it is a key national information construction project under the lead of Tsinghua University, and supported by PRC Ministry of Education, PRC Ministry of Science and so on. It provides an online database including journals, doctoral dissertations, master's theses, proceedings, newspapers, yearbooks, statistical yearbooks, e-books and so on.

Graph 1 – The First Stage (1990s–2000s) of ITS in China



Graph 1. Three isolated groups: 1) Blue group: the center is "IoT", and the rest are "traffic management" "Smart City" "Big Data" "Applications" "Internet of Vehicles" "Urban Traffic" "Traffic Congestions". 2) Yellow group: the center is "Algorithm", and the rest are "Fuzzy Control" "Neural Net" "Vehicle License Plate Recognition" "Picture Processing" "Vehicle Detection". 3) Green group: the center is "ITS", and the rest are "GPS" and "Highways".

Second Stage (2000s–now):

The concept Smart Transportation System emerged around 2005. According to CNKI, the top three keywords in Smart Transportation System papers are smart city, Big Data, IoT, but as a whole network (see Graph 2), rather than divided topic areas. Although the two networks seem to be different (see Graphs 1 and 2), their keywords are similar. The only new keyword that occurs in Graph 2 is "Internet". Also, the network of the Smart Transportation System pulls together the three isolated ITS groups. Therefore, the two concepts could be seen as different stages of the development of ITS.

Graph 2 – The Second Stage (2000s–Now) of ITS in China

Graph 2. The largest yellow bubble is "Smart Transportation System". 1) Top Three keywords in the yellow group: "IoT", "smart city", and "Big Data". 2) Green group: "Internet". 3) Blue group: "Smart" and "Transportation".

Despite these similarities, the use of different Chinese names means that people think that these are two distinct ITS stages in China. Translation may be a reason for this. According to Montgomery and Kumar (2015, p.331), "translation has been a major force in the history of science", especially in the communication between Eastern and Western culture, and thus translations help create new scientific cultures. The example Montgomery (2000) refers to in his book *Science in Translation*, is adapting Greek science culture and terms to Roman, where the translation transfers the scientific works into local languages, while also sparking creation when people add their ideas and understandings into the translation. For example, behind the Roman names of the stars, exist some fictions that are more suitable for Roman culture instead of Greek scientific tradition (Montgomery, 2000). Moreover, translation does not work only in ancient times. Montgomery argues that “technical dialects” exist in English papers published by non-native English speakers (Montgomery, 2000). English terms which are born in non-English speaking countries have local meanings which represent local scientific culture.

Similarly, the two differing Chinese translations of ITS indicate a change of content of the term “ITS”. A kind of “technical dialect”. Thus, the previous term ITS is localized and divided into two different Chinese translations. When Chinese scientists, researchers and governments use this English term (ITS), they are using the meaning in a Chinese context which they have added to during the development of ITS. Several reasons might exist for not changing the English term. First, English is a global language with a dominant position in the study of science and technology which may make some local elements invisible in the development of science. English for many non-English-speakers is “a skill of power, personal and professional” (Montgomery, 2009, p.7); a situation that occurs in China because Chinese scientists and researchers are required to publish papers in English. Moreover, English is a tool for scientists and researchers to communicate with communities around the world. So every term first needs to be translated into local languages and then translated back to English in order to share and spread ideas. This process is complicated and every translation process might add and lose some information. Montgomery says that the dominance of English might make people ignore some local elements in the development of science (Montgomery, 2009). ITS is one example of this, as a term that was imported to China from Western countries in the 1990s. After twenty years of development, Chinese scientists still use this term to communicate with the community in other countries. However, the meaning of this term has changed a lot in the past twenty years. So what is an "ITS" in the Chinese context? Is it a real technology, a science-fiction scene or something else? What role does it play in the development of transportation system in China? For ITS, at least there is a clear definition in English. However, the Chinese term derived from ITS – Smart Transportation System – has no clear definition leading us to also ask the same questions for Smart Transport System in a Chinese context.

Thus, this research does not try to find the answers to broad questions such as the definition of Big Data or the nature of ITS. Instead, it explores the understanding and practice of the Smart Transportation System in a specific cultural and social context – the Chinese context. So the research is located within the field of East Asia STS (EASTS). EASTS studies call for unique cases in East Asia contexts such as national R&D in East Asia (Hong, 2007), the governance of science and technology in Japan (Fujigaki, 2009) and public participation in science and technology in East Asia (Chen & Wu, 2007). Also, EASTS studies explore hidden figures in the development of science and technology, such as local engineers and workers. Moreover, EASTS highlights the importance of the distinctiveness of East Asia. Some EASTS studies try to find distinctiveness through the past and they track the history of technology and innovations, such as the Chinese technological study tracing the development of mobile commerce technologies over the past 30 years (Wang *et al.*, 2015). Others employ Bruno Latour's actor-network theory as an analytic frame, such as the study of urban (dis)connection in Mumbai (Wissink, 2013) and the coexistence of Western and Eastern in the Chinese medical practice (Lin & Law, 2014). However, their studies have been critiqued for simply applying Western theory to Asian cases (Fan, 2007) and ignoring the differences among many East Asian countries (Chen & Wu, 2007). Also, actor-network theory can only provide a theoretical perspective and it is not a practical procedure which can help find the actors and their interactions in a specific context (Wang *et al.*, 2015). Chen (2012) suggests that researchers need to find a new way to study distinctiveness.

The distinctive East Asian context is important to my research. More specifically, the distinctiveness of China through a technological project. The Smart Transportation System is shaped by the Chinese context. In turn, through it, it would be possible to gain a better understanding of the political, social and cultural factors involved. In this sense, the Smart Transportation System is serving as a window to see what is unique in China. While the distinctiveness of China is too broad to investigate. The thesis narrows down my areas of interest to three specific topics: policymaking and patterns, the foundation of sociotechnical imaginary and future expectations, and the unique understanding of Big Data in China. These three topics contribute to the features of the Smart Transportation System. First, in terms of policymaking, the transportation system plays an important role in the economic development of China, so the transportation system has always been a government-led field. Second, the idea of "smart" brings Big Data into the transportation system, introducing new social changes and new social actors into the government-led field. Third, Big Data could be viewed as a phenomenon, as discussed above, embedding specific understandings of new technology in China. These political, social, and cultural contexts of the Smart Transportation System will be discussed in Chapter 3.

Epistemologically, my research of the Smart Transportation System is a case study that seeks to provide some answers related to science and technology which are specific in the Chinese context. Ontologically, I view the development plans and targets of the Smart Transportation System as future expectations and sociotechnical imaginaries. Thus, this thesis shifts its gaze from exploring the nature of the Smart Transportation System or the nature of Big Data to *using* the Smart Transportation System as an entry point to consider modern China. Inspired by studies of future expectations and sociotechnical imaginaries, I used a mixed-method approach involving government policies (documents) and interviews. The process of data collection began with the analysis of the government documents and the papers on smart cities in general and on the Smart Transportation System in particular (September 2017–September 2018, May 2019–May 2020), followed by semi-structured interviews conducted in seven Chinese cities: Chengdu (成都), Chongqing (重庆), Shanghai (上海), Nanjing (南京), Hangzhou (杭州), Beijing (北京) and Tianjin (天津) (November 2018–March 2019). Also, I conducted some supplementary observations of projects that related to the Smart Transportation System, thanks to the access and permission of the participants. As the research developed, I especially focused on the political, social and cultural contexts that deeply impact the development of the Smart Transportation System. Therefore, I have structured my discussion around three specific themes: the Chinese policymaking process of science and technology, the constructing of sociotechnical imaginaries and future expectations in a Chinese context, and the impact of Traditional Chinese Science in modern China.

Thus, my research questions were finalised as follows:

1. What is the policymaking process shown by the Smart Transportation System? In particular, what is "the lack of Designed at The Top Level"? And what role does it play in the policymaking process?

2. How was the sociotechnical imaginary of the Smart Transportation System constructed in the Chinese context? In particular, what are the key features that

distinguish future expectations from sociotechnical imaginaries?

3. What is the nature of Big Data? How does it influence sociotechnical imaginary?

2.2 Specific Methods: Document Analysis, Interviews and Observations

The researches related to future expectations and sociotechnical imaginaries are usually conducted by semi-structured interviews, and the participants are the people who are related to the project (Brown et al., 2001; Rappert & Brown, 2000). Following this line, I used snowballing techniques to reach the relevant participants. However, in the pilot interviews (see Section 2.2.2.2), I found that the participants' recommendations were somewhat limited when not given some specific requests. For example, they would recommend their close friends and colleagues who worked in the same field, or even in the same office. However, the Smart Transportation System is constructed and operated in many cities that varied in geographical and economic conditions (see Section 2.2.1). Also, it involves more than one field of expertise as a major transportation project. Moreover, the comparison would be effective in studying future expectations and sociotechnical imaginaries. For example, Jasanoff (2015) suggests that comparing the nations would be a benefit to identify the content and contours of sociotechnical imaginaries. The comparison could also be used in different political sectors or over time (Jasanoff, 2015), which means that it could not only be used in different nations that have a different social, cultural and political background, but also could be used in different political sectors such as the central government and local government (Korsnes, 2016). Within a nation, the comparison could also be conducted between different fields such as genetics diagnostics and telemedicine in the UK (Rappert & Brown, 2000).

For the above reasons, besides the snowballing technique, I would also try to select the representative cities and fields in the Smart Transportation System. Qu (2019) suggests three criteria to find a typical example in China: spatial dimension, temporal dimension, and critical events. The critical event could be the release of the policy document "Action Plan about Advancing the Construction of Smart City 2011–2013 (推进智慧城市建设 2011–2013 行动计划)" in 2011, which could also be seen as a starting point of the Smart Transportation System. The spatial dimension was considered in three ways: the field of expertise of the participants, the participants' workplaces, and the regions or cities where the participants were located. According to the pilot interviews, the Smart Transportation System could be roughly divided into three fields: design, construction, and operation. So I tried to reach the participants in these three fields, by asking the participants to recommend people from these three areas. As for the selection of research sites, according to the list of these experimental smart cities released by MOHURD in 2012, the Smart Transportation System often started in the Capital Cities of the province and Municipalities (see Section 2.2.1). Besides this, the choice of research sites also pays attention to the geographical conditions such as the northern part, the western part, and the eastern part of China, and economic conditions such as Cheng-Yu Economic Zone, the Yangtze River Delta (YRD), and Beijing–Tianjin–Hebei Region (BTH) (see Section 2.2.1). Two to three cities were selected for each region. I would ask the participants to recommend people from these cities. However, as the study progressed, it revealed that the locations of the participants had little impact, as the participants would undertake projects in different regions. While the Smart Transportation System as a project varies from region to region because of different topographical, economic, and cultural factors. Therefore, investigations of different regions are still necessary.

The snowballing technique, combined with some specific requirements such as the specific fields and locations, made it easy to recruit different participants. However, there are some limitations to the snowballing technique. For example, there were no participants who recommended people in the Pearl River Delta Economic Zone (Guangzhou and Shenzhen) that had been planned at the beginning of the research, showing that snowballing techniques may have some omissions. And the actual participants' occupations in were not in an exact balance: many participants work in universities (10) and companies (16), but a few work in the government (3) (See Table 2). On the one hand, even with some specific requests, the participants still preferred to recommend friends and colleagues they knew well. On the other hand, it was difficult to reach government officials for a Ph.D. student. The recommendations from some interviewees were not enough in this situation. However, the analysis from the government level is essential to this study. According to Jasanoff (2015), “The languages of power, especially the official discourses of the state, have provided fertile ground for social theorists, but once again the coalescence of the collective imagination with scientific and technological production offers particular stream beds along which to direct the flow of such analysis”. Therefore, government documents could also be used to analyze future expectations and sociotechnical imaginaries. For example, Hassan (2020) uses policy reports produced by various government agencies as well as commercial and not-for-profit organizations to explore the sociotechnical imaginaries of digital platforms. Thus, this study would also investigate government documents, combined with semi-structured interviews, in order to compensate for the limited number of participants in the government agencies. The mixed method of interviews and the analysis of the related documents are also common in the studies of future expectations and sociotechnical imaginaries. For example, Selin (2007) explores representations of nanotechnology derived from personal interviews, newspapers, journal articles, assorted Web sites, white papers, and conference participation.

2.2.1 Research Sites

The choice of research sites is important because China is a country in which different areas develop unevenly. To understand the transportation system in China, we need to first look at China's geographical conditions. There are three standards used to divide China into three regions (Wu, 1998) based on different weather conditions and geographical conditions: the Eastern Monsoon Region (东部季风区), arid and semi-arid areas in the Northwest of China (西北干旱半干旱区), and the cold region of the Tibetan Plateau (青藏高寒区). The Eastern Monsoon Region accounts for around 45% of China's land area and about 95% of the total population. Divided by different agricultural conditions, China also has eight agricultural areas: Northeast China (东北区), the North China Plain (华北平原区), the Loess Plateau (黄土高原区), the Middle and Lower Reaches of the Yangtze River (长江中下游区), Southwest China (西南区), South China (华南区), the Inner Mongolia-Xinjiang Region (蒙新区), and the Tibetan Plateau (青藏高原).[35]

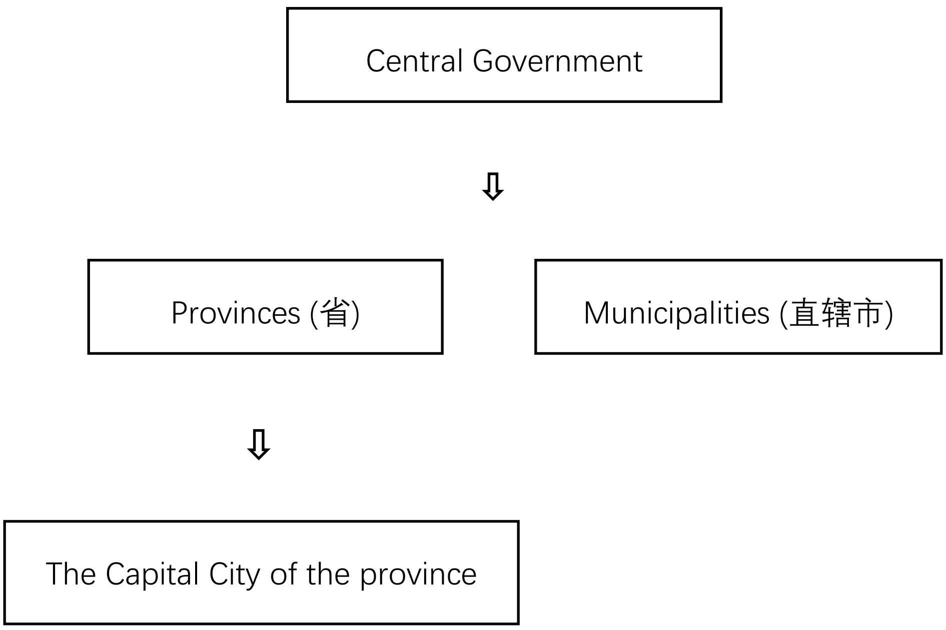
The most important division is one of economic zones because China formulates its economic and transport policies based on different economic conditions. In 1986, China released its Seventh Five-Year Plan (七五计划).[36] There are three major economic zones in this plan: the Eastern Regions (东部地区), the Central

[35] In 1981, the National Committee of Agricultural and Natural Resources and Agricultural Divisions (全国农业自然资源和农业区划委员会) reorganized China into 10 agricultural regions. In the document called 'China's Comprehensive Agricultural Divisions' (中国综合农业区划), the experts added the Marine Area, and the Eastern part of Inner Mongolia-Xinjiang Region became a new region because of its amount of precipitation.
[36] A series of social and economic development initiatives which started since 1953 in China.

Regions (中部地区), and the Western Regions (西部地区). These standards of the division were mainly based on the level of economic and technological development alongside geographical conditions. Nearby provinces with a similar level of economic and technological development are combined (Yang. 2007). The Eastern Regions include 12 provinces and municipalities (Beijing, Tianjin, Shanghai, Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Guangdong, Fujian, Guangxi, and Hainan). They are all in the Eastern Monsoon Region. Most of them are also in Northeast China, the North China Plain, the Middle and Lower Reaches of the Yangtze River, and South China. Most of the Eastern Regions are developed areas. The Central Regions includes 9 provinces and autonomous regions (Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Hubei, Hunan, Anhui, Jiangxi). Most provinces of the Central Regions are in Northeast China, the North China Plain, and the Loess Plateau. The Western Regions also includes 9 provinces and autonomous regions (Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, Sichuan, Yunnan, Guizhou, Tibet). Most of them are in Southwest China, the Inner Mongolia-Xinjiang Region, and the Tibetan Plateau. Most of the Western Regions contain less-developed areas because of their geographical conditions and for historical reasons.

Provincial-level administrative divisions in China comprise 23 “provinces (省)”, four “municipalities (直辖市)”, five “Autonomous Regions (自治区)”, and two “Special Administrative Regions (特别行政区)”, following sub-provincial divisions such as the capitals of the provinces. In 2012, MOHURD opened applications for all cities in China to become “pilot cities (试点城市)”.[37] And in August 2013, MOHURD announced the list of pilot smart cities in 83 cities and municipalities and 20 towns and four districts.[38] I selected a sample of typical cities for their Smart Transportation System. Thus, the fieldwork was conducted in seven different locations; all listed as pilot cities by MOHURD. Three are sub-provincial divisions: Chengdu (in Sichuan Province), Hangzhou (in Zhejiang Province), Nanjing (in Jiangsu Province). Four are municipalities: Beijing, Shanghai, Chongqing and Tianjin.

The relevant local government policies were searched for these cities and provinces.



[37] Notice of selecting Experimental Cities of “Smart City”
http://www.mohurd.gov.cn/zxydt/201212/t20121210_212226.html
[38] List of Experimental Cities of “Smart City”
http://www.mohurd.gov.cn/wjfb/201308/t20130805_214634.html

Figure 1. A sketch map of the administrative divisions of China

At provincial-level administrative divisions, the agency that manages the transportation system is called the “Department of Transportation (交通厅)”; in provinces, it is called the “Commission of Transport (交通委)”; and, in municipalities it is called, for example, the “Department of Transportation of Sichuan Province” and the “Beijing Municipal Commission of Transport”. At sub-provincial divisions, the transportation system agency is called the “Transportation Bureau (交通运输局)”, such as “Chengdu Transportation Bureau”. Therefore, to explore the expectations of local government, I searched policy documents and reports released by the Department of Transportation, the Commission of Transport and the Transportation Bureau.

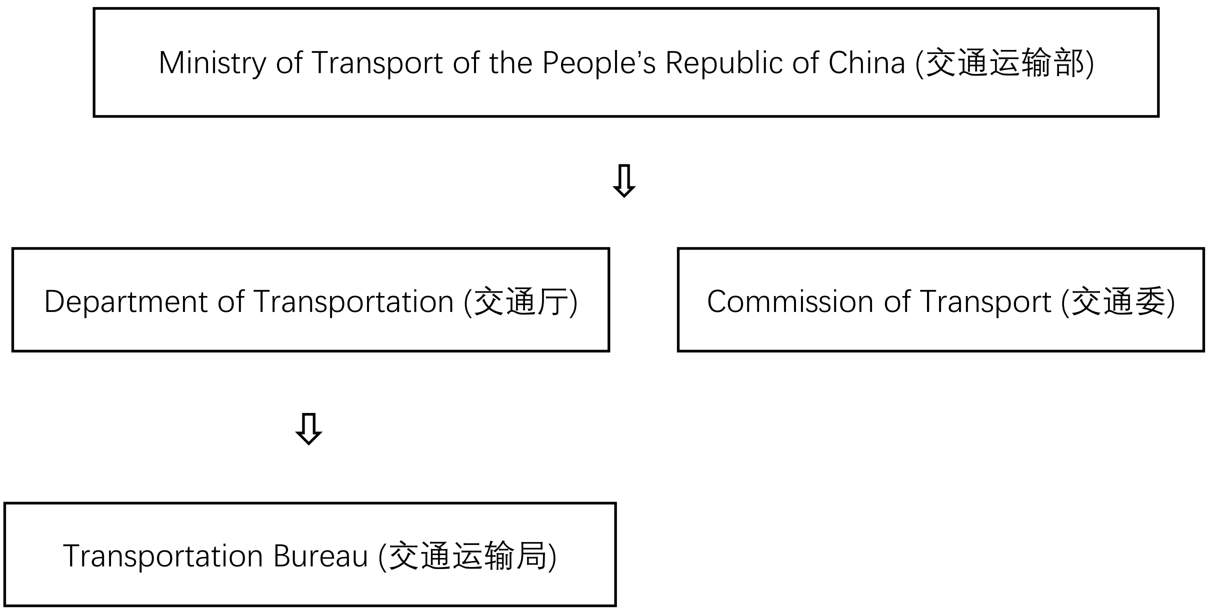


Figure 2. A sketch map of the transport sectors in the government

The data collecting process included fieldwork and some related secondary literatures and documents. The thesis was also based on 29 semi-structured interviews and some observations which were conducted from November 2018 to March 2019 in seven Chinese cities: Chengdu (成都), Chongqing (重庆), Shanghai (上海), Nanjing (南京), Hangzhou (杭州), Beijing (北京) and Tianjin (天津). These seven cities could be divided into three groups: Chengdu and Chongqing are cities in Southwest China known as the Cheng-Yu Economic Zone[39]; Nanjing, Hangzhou, and Shanghai are cities belonging to the Yangtze River Delta (YRD)[40]; Beijing and Tianjin are in the Beijing–Tianjin–Hebei Region (BTH).[41] Limited by time and practical reasons, the fieldwork did not take place in the "Pearl River Delta Economic Zone (珠三角经济区)". Each region was conducted around 10 interviews: seven in the Cheng-Yu Economic Zone, Nine in the YRD, and 11 in the BTH. According to China's administrative divisions, there are four municipalities: Beijing, Shanghai, Tianjin, and Chongqing. Three of the chosen cities are the capitals of their provinces. Chengdu is the capital of Sichuan Province. Nanjing is the capital of Jiangsu Province. Hangzhou is the capital of

39 **Cheng-Yu Economic Zone** is led by two cities: the capital of Sichuan (四川) Province Chengdu and the direct-controlled municipality (直辖市) Chongqing.

40 **Yangtze River Delta Economic Zone (长江三角洲经济区)** includes the direct-controlled municipality (直辖市) Shanghai and three provinces: Jiangsu (江苏), Anhui (安徽), and Zhejiang (浙江) Province. Nanjing is the capital of Jiangsu Province and Hangzhou is the capital of Zhejiang Province.

41 **Beijing–Tianjin–Hebei Region (京津冀经济区)** is the Capital Economic Zone leading by the cities: Beijing and Tianjin.

Zhejiang Province. Beijing and Tianjin are in the northern part of China, while the rest are in the southern part of China. Considering the differences between the Western and the Eastern part of China, Chengdu and Chongqing are in the west-east of China, while Nanjing, Hangzhou, and Shanghai are on the Eastern coast of China.

2.2.2 Document Analysis, Interviews and Observation

This thesis will employ the concepts of future expectations and sociotechnical imaginaries. Thus, the methods follow Jasanoff's suggestion that those "best suited" are "methods of interpretive research and analysis that probe the nature of structure-agency relationships through inquiries into meaning making" (Jasanoff, 2015, p.35). Thus, my analysis is designed as interpretive research to explore future expectations and sociotechnical imaginaries of the government and academia; informed by their goals, knowledge, cultural and political context. In doing so, I rely on government documents, interview materials and the analysis of papers. Moreover, as Jasanoff (2015) highlights, "the most indispensable method for studying sociotechnical imaginaries is comparison" (p.35). The comparison of sociotechnical imaginaries usually is conducted between different countries. Considering their different geographical environment and economic development level, the comparison between different provinces in China is also worthwhile. Also – as Jasanoff suggests, "imaginaries by definition are group achievements" (2015, p.36) – comparison could be conducted between different groups. Thus, as my analysis developed, comparison was also conducted between different scientific communities that emerged in the fieldwork. Additionally, the use of metaphors is important to the analysis of sociotechnical imaginaries (Graf & Sonnberger, 2020; Jasanoff & Kim, 2009; Martin, 2021). Thus, the thesis also pays attention to the metaphors that emerged in the fieldwork.

2.2.2.1 Document Analysis

As Jasanoff (2015, p.39) suggested, "Policy documents, no less than judicial opinions, can be mined for insights into the framing of desirable futures (or, as Dennis argues, for the "monsters" that policy seeks to keep at bay), as well as for specific verbal tropes and analogies that help identify the elements of the imaginary". Following this, I focus on policy documents of the central government and local governments from 2016 to 2020 (the period of Thirteenth Five-Year). In particular, I concentrate on plans of the Smart Transportation System put forward by the central government and the MOT. Also, I focus on plans and targets suggested by local governments, especially the Department of Transportation, the Commission of Transport and the Transportation Bureau. Policy documents are not released at the same time, so I kept collecting and analyzing policy documents from the beginning of my research to the writing up stage of the thesis.

2.2.2.2 The Participants

The main techniques used in the fieldwork were 29 semi-structured interviews, including 26 face-to-face interviews, 1 online-video interview and 2 telephone interviews. Most of interviews were face-to-face because I found that the participants were more involved in such interviews, and willing to share more related information. Interviews were conducted in Mandarin; the local language that many participants used.

According to the chosen regions, the 29 interviewees can be divided into seven groups (see Table 1). The participants can also be divided into roughly three groups according to their occupations: scientists from universities, engineers from state-owned and private companies, and local government officials responsible for transportation (see Table 2). The participants could also be divided into three parts according to different fields in which they worked: 24 participants focusing on the design of the transportation system, five responsible for construction, and five focused on its operation (see Table 3).

Table 1 – Location of the participants

Location	Beijing	Shanghai	Tianjin	Nanjing	Hangzhou	Chengdu	Chongqing

Number	9	3	3	2	4	4	4

Table 2 – Occupation of the participants

	Universities	Companies	Local government
Number	10	16	3

Table 3 – Fields in which the participants work

	Design	Construction	Operation/ Transport
Number	24	5	5

The fieldwork included three stages:

1) I conducted eight pilot interviews from 1st November 2018 to 15th November 2018 in Chengdu with some students in transportation system fields.

2) The formal physical fieldwork started in Chengdu with four interviewees (from 22nd November 2018 to 30th November 2018), followed by nine interviews in Beijing (from 20th December 2018 to 26th December 2018), three interviews in Tianjin (from 27th December 2018 to 30th December 2018), two interviews in

Nanjing (from 10th January 2019 to 15th January 2019), two interviews in Shanghai (22nd January 2019), three interviews in Hangzhou (from 23rd January 2019 to 25th January 2019), four interviews in Chongqing (from 4th March 2019 to 8th March 2019). I also conducted three online interviews due to the unavailability of the participants from Shanghai, Hangzhou and Chengdu. These online interviews were carried out on 7th January 2019, 28th January 2019 and 1st March 2019.

3) The transcription of the interviews started in May 2019 until September 2019.

I started my fieldwork with eight pilot interviews in Chengdu, because I did not have any previous fieldwork experience. The participants I planned to interview had a very tight schedule, often without a second chance to find them and find another hour slot for an interview. The pilot participants were recruited from my friends and their friends who were working and studying in the Smart Transportation System field. Pilot interviews strictly followed the process of the formal ones. I would send my CV, information sheets and informed consent sheets (in English and Chinese) to the participants before the interviews took place. The pilot interviews were mostly conducted face-to-face in empty classrooms, cafes, and common rooms of the library, which differed from the formal ones. Most pilot interviews lasted for half an hour to one hour which is similar to the formal ones. I listed three main questions/topic areas, with three or four specific questions for each topic area.

After reviewing the pilot interviews, I realized that the specific questions were unnecessary as they seemed to mislead the interviews, or provided some hints to give an answer that they thought the interviewer wanted. So in the formal interviews, I only listed three broad questions and let the interviewees talk about their experience at work. Also, I practiced my interview skills and tried to overcome anxiety and discomfort when contacting and interviewing strangers. Thanks to the pilot interviews, I revised my questions for the formal interviews, but also gained access to participants through my pilot interviewees. The pilot interviewees also recommended their supervisors and their senior colleagues to me for the formal interviews. Thus, participant recruitment for the formal interviews mostly used snowballing techniques. However, for the thesis I do not use the materials to analyze the Smart Transportation System from the pilot interviews. On the one hand, the participants of the pilot interviews took a very cautious attitude, and they thought that they are not the experts in the field, so it is better not to use their answers. On the other hand, due to lack of experience I had allowed two interviewees to come together because they asked to do so. These interviews were then influenced by each other. I learnt my lesson, and did not allow the same situation to happen in the formal meetings.

2.2.2.3 Semi-structured Interviews

In total, I conducted 29 semi-structured interviews in seven cities. Most of them were face-to-face interviews conducted in the participants' offices (14), meeting rooms (11) and a cafe (1). Three of them were conducted via telephone and a Chinese social media and messaging app called WeChat. Four of the participants are female, while 24 are male. As an area of civil engineering the Smart Transportation System field faces an underrepresentation of women, a common problem of Science, Technology, Engineering, and Mathematics (STEM) (Bottia *et al.*, 2015). More of the participants focus on the design of the Smart Transportation System (Table 3), because the project is in development, and many plans are on paper only. Also, my primary concerns involved the targets and plans of the Smart Transportation System; those that could be viewed as expectations and sociotechnical imaginaries. Therefore, I wanted to pay more attention to the design part than the construction and the operation parts. In China it is hard to get access to government officials, so the analysis of local governments and the central government relied on document analysis of governmental policies and plans.

All the interviews were scheduled beforehand. The participants were first approached via email, WeChat or text. Then they were provided with an overview of the project, a CV of the interviewer and informed consent sheets in English and

Chinese via email. However, due to the participants' tight schedules, the interviews were not conducted as planned. Some interviews were rearranged several times; some interviews relatively compactly, while others were the opposite.

2.2.2.4 Observations

Another element of the fieldwork was observations. Two kinds of observations occurred during fieldwork. First, observations accompanying the interviews, such as observations on the offices, the meeting rooms and the cities. Second, observations provided by the participants, such as their labs, the Big Data Center, and construction sites for the Smart Transportation System.

As the interview sites were chosen by the interviewees, most of them were busy and chose their offices or meeting rooms within their companies or institutions. With the permission of some participants, I took photos of some offices and meeting rooms, and these photos also became part of my analysis. I spent several days in the cities before conducting interviews. I wanted to get a general sense of the landscapes of each city by walking, taking public transport and paying attention to the surrounding environment, such as Beijing (see Photo 1) and Chongqing (see Photo 2 and 3). These observations assisted my understanding of the context of participants words in their interviews.

Photo 1. 2. 3. From left to right: **Photo 1.** Sensors and testing devices in an intersection in Beijing; **Photo 2.** A demo center of a Smart Construction site in Chongqing: the progress of construction; **Photo 3.** A demo center of a Smart Construction site in Chongqing: Safety demonstration used VR.

2.2.3 Ethics

The research followed the ethical guidelines of the British Sociological Association (BSA) and Warwick University's Research Code of Practice, paying special attention to confidentiality, anonymity, private matters, gender issues, power relationships and personal experience. The information gathered was treated in the strictest confidence. Although some interviewees agreed to be referred to by their real names, I changed their original names when quoting their opinions to protect individuals' identities.

All participants were able to consent freely. The information and informed consent sheets were in English and Chinese suitable for the Chinese participants. The research aims and plans of the study were explained in the information sheet, which was provided to participants a week in advance of their interviews, so that they had time to consider their participation. Also, I reminded the participants to look at the questions to be asked before the interviews to ensure correct interpretation. During the interviews, all participants were given bilingual informed-consent sheets at the beginning to ensure that consent was informed and voluntary. Also, they were provided with a verbal overview before we commenced to ensure all details of the project had been understood, and make assurances that participants' confidentiality will be protected. Then I asked permission before any instance where I recorded the participants or took photographs. Sometimes, the participants did not allow the photographing of their offices due to privacy concerns. Occasionally, participants would ask for a pause from recording during the interviews, but then say something of relevance to my study. These kinds of materials were abandoned because of the participants' requests.

2.2.4 Data Analysis and Presentation

The collected data were analyzed through NVivo software. This included government policies and plans, interview transcripts, photos and fieldnotes.

Phillips and Hardy (2002a) define discourse as "an interrelated set of texts, and the practices of their production, dissemination, and reception, that brings an object into being". Thus, discourse analysis is "interested in ascertaining the constructive effects of discourse through the structured and systematic study of texts" (Phillips & Hardy, 2002a, p.4). This definition is broad and includes many different approaches that could be viewed as discourse analysis. Considering the continuum between text and context, Phillips and Hardy (2002b) distinguish four kinds of discourse analysis: interpretive structuralism, critical discourse analysis, social linguistic analysis and critical linguistic analysis. Although it is sometimes hard to draw a clear line between these techniques, this thesis utilised interpretive structuralism focused on "the analysis of the social context and the discourse that supports it" (Phillips & Hardy, 2002b, p.6), which mostly relies on interviews or archival materials to provide insiders' interpretations of the research context. Moreover, this technique is concerned with "the way in which broader discursive contexts come into being and the possibilities to which they give rise, but without a direct concern with power" (Phillips & Hardy, 2002b, p.6).

All Chinese-language sources cited in this thesis – government policies, government plans, interview transcripts, papers, photographs and fieldnotes – were translated into English by myself as accurately as possible and checked by a native-English speaker.

Conclusion

This chapter has discussed the methodological foundations of this thesis. Motivated by my passion for science and technology and curiosity about the

“Smart Transportation System (智慧交通 Zhihuijiaotong)”, the research questions have gradually shifted from exploring the nature of the Smart Transportation System to investigating the political, social and cultural issues associated with it. Thus, the Smart Transportation System serves as an entry point to examine science and technology in a Chinese context. As the Smart Transportation System is still under development, its plans and targets could be seen as “sociotechnical imaginary” at a collective and central level, and “future expectation” at a local level, which leads to STS research methods on future-oriented representations and anticipatory practices. Following Jasanoff’s (2015) suggestion for studying sociotechnical imaginary, this research relied on government documents, interview materials and the analysis of papers, and made a comparison between different regions of China. The research sites were carefully chosen according to their different economic levels, geographical environments and administrative divisions, and all of them were pilot “smart cities” that had started to develop their Smart Transportation System. The fieldwork comprised of three stages. The first stage included 8 pilot interviews, which refined the interview technique and aided the recruitment of participants for the formal interviews. The second stage included 29 semi-structured interviews. Along side the interviews, I also conducted supplementary observations of the projects related to the Smart Transportation System. The third stage was data analysis using NVivo software and various discourse analysis techniques.

Chapter 3. The Political, Social and Cultural Context of the Smart Transportation System's Emergence

This chapter takes a close look at the political, social and cultural context in which the Smart Transportation System is embedded. Section 3.1 presents the history of the transportation system, showing the shift of the leading actor in the development of the transportation system in the Reform era (1978–now). The brief history of fiscal decentralization sheds light on the political context of the Smart Transportation System's emergence, and highlights the relationship between central government and those local governments that have deeply influenced the creation of the Smart Transportation System's sociotechnical imaginary. Section 3.2 outlines the new changes and new meanings that Big Data provides. The collision of new technologies and traditional technology areas allows us to discover the influence of Big Data on sociotechnical imaginary, as yet unexplored in STS. Section 3.3 draws attention to traditional Chinese science and technology. The cultural context contributes to a better understanding of the nature of Big Data from the participants' perspectives. While several different perspectives and contexts contribute towards exploring what happened in China in the Reform era through the Smart Transportation System, this chapter seeks to identify the three contexts most closely related to the Smart Transportation

System.

3.1 The Development of the Chinese Transportation System in the Reform era (1978–Now)

In comparison with the transportation system in the UK, US, and France, the transportation system in China shows a government-led character. First, the transportation system in the US has always been dominated by private ownership, though the transportation system is defined as one of the natural monopoly industries by traditional economic theory (Li, 2004). The transportation system was a government-led field in most countries from the 1930s to the 1980s (Yang, 2012). For example, according to Li (2010), the share of state-owned enterprises in the railways was 100% in China, France, and the UK in 1977. However, in the early 1980s, except for the postal service and highways that were all state-owned, the share of the state-owned sector in railways and electricity was only 25% in the US, and the number of people who worked in the state-owned enterprises was only 1.5% of the total number of people employed nationwide (Li, 2004). Second, from the 1980s to the 2000s, China, the UK, and France experienced reforms in the state-owned economies, especially in the transportation system. However, the results were different. For example, in 2003, the share of state-owned enterprises in GDP fell from 16% to 1.9% in the UK and from 24% to 10% in France (Li, 2010). This trend could also be seen in the transportation system. According to Wu

(2007), in 1996, British Rail sold 98% of its shares. The reform of state-owned enterprises in China began in the 1990s. However, such reforms are not common in the transportation system in China. For example, the railways are still monopolized by state-owned enterprises, and SASAC (国务院国资委) requires absolute state control over seven major industries such as power grids, electricity, telecommunications, civil aviation, and shipping (Li, 2010). According to Li (2017), many cities in China tries to bring in private bus companies to provide public services in the 1990s, however, in around 2000, most of them returned to state-owned enterprises, which is a phenomenon that scholars called “Ebb of Marketization” (市场化退潮).

3.1.1. The Transportation System and the Development of Economy in China

In 1978, China started the “Reform and Opening-up (改革开放)”. Since then, the development of the transportation system began to accelerate. In the 1980s, the development of the transportation system in China focused on expanding the road network. At its centre was the construction of main lines (mainly distributed in the Eastern Regions). From 1980 to 1990, 195,000 kilometres of highways were constructed in the Eastern regions, accounting for 42.3% of the nation’s newly constructed highways (Jin & Chen. 2019). In the 1990s, the main concern shifted to the Central and Western Regions. The proportion of newly constructed highways in the Central and Western Regions accounted for 35% and 32% of the nation’s newly constructed highways, respectively (Jin & Chen. 2019). By the late-

1990s, a highway network crossed the Eastern, Central and Western Regions. In 2018 (except for Tibet, Hainan and Taiwan), the highway networks in other regions were all connected (Jin & Chen. 2019). In the 2000s, China concentrated on its high-speed railway network. In 2008, the Ministry of Railways (MOR, 铁道部)[42] released a plan "Medium and long-term railway network planning (adjusted in 2008 (中长期铁路网规划(2008 年调整)" to build a high-speed railway network based on eight main lines: four of which are from east to the west and the rest from north to south. By the end of 2019, seven main lines were in operation and the last plans were completed in December 2020. These infrastructural changes have revolutionised travel times across China. For instance, according to Jin and Chen (2019), in 1985, the shortest average land travel time between 337 Chinese cities was 26.37 hours; in 2003, the time decreased to 18.71 hours; and in 2016, the travel time fell to 12.07 hours.

The transportation system was very important for economic development in China. Several studies have confirmed this conclusion. Démurger (2001) collected data from 24 Chinese provinces from 1985 to 1998, and concludes that geographical location and infrastructure investment influence different growth rates between provinces, and are thus important to the economic development of different provinces. Démurger also concludes that transport facilities are a key differentiating factor in explaining the growth gap between provinces and points

[42] On 10 March 2013, it was dissolved into three departments: the Ministry of Transport (交通运输部), the National Railway Administration (国家铁路局) and the China Railway Corporation (中国铁路总公司).

to the role of telecommunication in reducing the burden of isolation. Another long-term study (Liu & Hu, 2010) collected data from 1987 to 2007 in 28 provinces in China, and also conclude that transportation infrastructure has an important positive effect on the economy. Wang and Ni's (2016) study focusing on the data from 284 prefecture-level cities (地级市) between 2008 and 2015 proves that the transportation system improves economic development, as regions with a high level of economic development and economic agglomeration exactly match the completed high-speed rail lines. Also, Zhou and Zheng (2012) compare the GDP of non-speed-up railway stations with the speed-up railway stations from 1997 to 2007. The GDP of speed-up railway stations and their related regions increased by about 3.7%. They also conclude that the speed-up program in the railway system has played an important role in promoting economic growth.

The above research reflects that the rural areas and Western Regions of China are especially benefiting from the development of the transportation system. Liu and Hu's (2008) study shows that the improvement of transportation infrastructure significantly promoted the increase in the volume of trade between regions. Liu and Hu (2010) point out that transportation infrastructure is important to these areas which are usually undeveloped. For example, "The Grand Western Development Program (西部大开发)" started in 2000. Showing the relationship between transportation investment and economic development, according to Liu and Hu (2010), from 1999 to 2007, the average annual growth rate of transportation investment in Western China was 20.7%, while the average annual growth rate of Central and Eastern Regions was 19.7%. Accordingly, the economic growth rate in the Western Region was 1.5% higher than the Central and Eastern Regions between 2000 and 2007. Thus, the development of the transportation system is very important to China as China's economy was benefiting from the development of the transportation system, especially in its rural areas and the Western Regions.

After almost 30 years of the rapid development of transport infrastructure, it faces a turning point. Both the interviewees of this study and the scientific findings concur that the Chinese transportation system should change from an era of establishment into an era of upgrading or maintenance. Démurger (2001) suggests that the positive effect of transport equipment will decrease with its development. For developed regions, it is more important to upgrade or to make quality-improvements for existing facilities. This result suggests that transport infrastructure needs to change its mode of operation when it develops to a certain extent. Also, according to Zhang (2012), in 2004 and 2009, investments in the transportation system of the Central and Western Regions were higher than in the Eastern Regions. The transportation system in China needs to change from a construction mentality into an upgrade or quality-improvement one. And the Smart Transportation System is the specific goal of this shift.

3.1.2 Fiscal Decentralization and the Transportation System

The transportation system witnessed a period of rapid development during the "Reform and Opening-up". The transportation system has been deeply influenced by the "Reform and Opening-up". During this period, two political features were closely related to the development of the transportation system: fiscal and political centralization. For the case of the Smart Transportation System, political centralization is a feature attached to fiscal decentralization. To explain this relationship, I will briefly introduce the history of fiscal decentralization, before proceeding, in Subsection 3.1.3, to show how fiscal decentralization influences the relationship between the central government and the local governments, and the effect of fiscal decentralization on the transportation infrastructure system.

The history of fiscal decentralization and China's financial relationship reform can be generally divided into three periods: 1949–1978, 1979–1993, 1993–now (Gong *et al.,* 2011; Ma & Xiao, 2018). Xu (2011), however, divides this reform into five periods: 1949–1957, 1958–1961, 1962–1978, 1979–1993, 1999–now. I agree that it could be divided into five periods because 1958 to 1976 could be seen as a continuous process of fiscal decentralization, and there was further tax reform in 2012. These five periods clearly show the relationship and dynamic between local governments and the central government.

1949–1957: This period saw the establishment of the People's Republic of China and its First Five-Year Plan. During this period, China was following the Soviet model where central government was in the dominant position in the economy, while local governments were executing agencies. After the "Three Great Remolding (三大改造)",[43] the "state-operated economy (国营经济)", "cooperative economy (合作经济)" and "public-private joint economy (公私合营经济)" accounted for 92.9% of China's total national economy at the end of 1957. Central government-owned enterprises rose from around 2,800 in 1953 to about 9,300 in 1957 (Chen & Gao, 2012). Most income and profit from those enterprises were dominated by central government (Zhou, 2009). According to Chen and Gao (2012), the share of local governments in both fiscal revenue and expenditure was lower than 30%.

1958–1978: The period of the "Great Leap Forward (大跃进)" and the "Cultural Revolution (文化大革命)". China started its first fiscal decentralization attempt following the idea of Mao that China is a country with a large population and decentralization would work better than centralization (Su, 2004). In 1958, the State Council of the People's Republic of China released the "The Regulations for Improving the Tax Administration System (关于改进税收管理体制的规定)" and "The Regulations for Improving the Management System (关于改进计划管理体制的规定)". In these documents, seven types of taxes are classified as fixed income

[43] The socialist transformations in agricultural, handicraft and capitalist industry and commerce (1953–1956).

where local governments would have more autonomous rights in tax policy. As a result, the fiscal revenue of local governments' accounts (total revenue) rose sharply from 19.6% in 1958 to 78.5% in 1961 (Chen & Gao, 2012). However, the Great Leap Forward caused serious economic difficulties. The central government then took back some of the autonomous rights from the local government, including some enterprises. However, during the Cultural Revolution, fiscal decentralization continued and became more radical. The fiscal revenue of local governments' accounts rose from 64.8% in 1966 to 88% in 1975 (Chen & Gao, 2012). Only 3% of enterprises were owned by the central government at this time (Huang, 1996).

1979–1993: In 1978, China started "Reform and Opening-up" and the fiscal system used was called the "fiscal responsibility system (财政包干)". Central government checked and ratified a certain amount of fiscal revenue and expenditure from each province every year, known as "Bao Gan (包干)". And local government organized its revenue and expenditure within this designated scope. Local governments sought their own balance in revenue and expenditure and handed a certain percentage of its revenue to the central government, if fiscal revenue exceeded expenditure in its designated scope. Whereas, if fiscal revenue was less than expenditure central government subsidized local governments instead. Revenue which exceeded the Bao Gan belonged to the local government, so did the loss. This fiscal responsibility system stimulated local governments to be more willing to develop the economy. For example, the fiscal revenue of Zhejiang Province in 1979 was 2.57 billion Yuan while it reached 16.66 billion Yuan in 1993; the revenue of Jiangsu Province was 5.928 billion Yuan in 1979 and 22.13 billion Yuan in 1993; Shandong Province had 5.699 billion Yuan in 1979 and 19.44 billion Yuan in 1993; the revenue of Guangdong Province was 3.428 billion Yuan and it rose sharply to 34.656 billion Yuan in 1993 (Wang & Wu, 2018). However, one side effect of this system was that local governments started to hide tax sources, so that the central government could not get enough revenue. The fiscal revenue of the central government rose from 24.5% in 1980 to 40.5% in 1984, and then it fell to 22% in 1993 (Chen & Gao, 2012).

1994–2012: China introduced the “Tax-sharing Reform (分税制改革)” in 1994. In 1993, the State Council released a government document called “The Decision on the Implementation of the Tax-Sharing Fiscal Management System (关于实行分税制财政管理体制的决定)”. This document classified the terms “Central Tax (中央税)”, “Local Tax (地方税)” and “Central-Local Shared Tax (中央地方共享税)”. Central Tax designated taxes on issues of national security and “macro-control (宏观调控)”.[44] Taxes directly related to the economy were the Central-Local Shared Tax, 75% of which was assigned to the central government and the rest as local government revenue. Finally, those taxes suitable for local governments to collect and manage were classified as Local Tax. This document clearly divided the

[44] ‘Macroeconomic Regulation and Control’ (宏观调控): It means the use of direct government intervention by the centrol government to cool down the overheated economy.

use of financial funds by the central and local governments.[45] The central government was responsible for national security, diplomacy, the operation of the central government, expenditures for "Macroeconomic Regulation and Control (宏观调控)", and expenditures for services directly managed by the central government. The local government was responsible for the operation of themselves and expenditures for the economy and public services in their region. According to "The Decision on Implementation of Tax-Sharing Fiscal Management System", expenditures for transport infrastructure could be the divided responsibility of the central and local governments.

2012–now: In 2012, China continued its fiscal reform with "Ying Gai Zeng (营改增)", a VAT reform to replace the "sales tax (营业税)" with "VAT (增值税)". Several reasons led to the introduction of Ying Gai Zeng. First, the financial crisis of 2008 continued into 2011, China's economy met "unbalanced, uncoordinated and unsustainable contradictions" (Gao, 2013, p.4), so there was an urgent need to reform its fiscal system. Ying Gai Zeng is a tax reduction measure because enterprises have not needed to pay VAT when buying fixed assets since 2009. Second, VAT and sales tax were included in the Central-Local Shared Tax and the Local Tax respectively. Some of them overlapped, causing conflicts between "National Tax (国税)" and "Local Tax (地税)" (Gao, 2013). Third, one practical reason was that replacing sales tax with a VAT was much easier than others. Three

[45] Local government in this section refers to the government of each province.

types of taxes account for a large share in China's tax revenue: sales tax, VAT, and "Consumption Tax (消费税)". In 2012, the proportion of sales tax, VAT and consumption tax of the total tax revenue were 39.8%, 15.6%, and 9.0% (Gao, 2013). Sales tax and VAT had some overlaps and VAT could maximize the effect of tax reduction. Consumption tax is related to luxury goods and the goods related to energy and resource which are hard to reform. In November 2011, the Ministry of Finance and the State Administration of Taxation released a plan called "The Pilot Scheme for Replacing the Sales Tax with VAT (营业税改征增值税试点方案)". This plan announced that Shanghai would replace sales tax with a VAT in the transportation industry, and some modern services from 1st January 2012 (Wang *et al.*, 2014). In January 2014, VAT expanded to the transportation industry, postal services, and some modern services nationwide (Wang & Li, 2014). On 1st May 2016, it became a national policy (Ma, Xiao. 2018).

3.1.3 Fiscal Decentralization and the Relationship between the Central Government and Local Governments

Fiscal decentralization directly influences the relationship between the central government and local government. Through fiscal reform, local governments gain more autonomy in the economy. After 1994, the proportion of local fiscal expenditure in China's total fiscal expenditure remained around 70% (Wang & Wu, 2018). Since 2009, local fiscal expenditure accounted for 80% of China's total fiscal expenditure, and above 85% since 2012 (Wang & Wu, 2018). Moreover, fiscal decentralization boosts economic development. Through an economic data study from 1986 to 2002, Zhang and Gong (2005) show that the economy was benefiting from fiscal reform. Yet, local government took more responsibility in public services, so that local government would be on a tight budget. Before the Ying Gai Zeng, sales tax was the only main tax in the hands of local government. Sales tax accounts for more than half of local government tax revenue (Gao, 2013). At the end of 2015, Ying Gai Zeng was a national policy that covered all regions and all industries, while VAT was the Central-Local Shared Tax. The share of local government became smaller than before. Moreover, while local government enjoyed more autonomy, many investments and programs were also affected by local government preferences. Infrastructures are deeply influenced by local government investments and preferences. While the preferences of local government are euphemistically affected by the central government through incentive systems. According to Zhao (2008), fiscal decentralization has changed incentives for local government officials. Chen *et al*. (2002) also argue that the relationship between the central government and the local government could influence local government officials through the incentive system, and influence the economic growth, investment and efficiency of local areas.

A shift in the transportation system's investors is the biggest change of the reform era. The infrastructure, especially of the transportation system, is deeply influenced by the choices of local government. During the process of fiscal decentralization, the local government obtained more power concerning infrastructure expenditure and the selection of PPP programs, which influenced the development of the transportation system. During fiscal decentralization, a major infrastructure investor becomes local governments. According to Zhang (2007), the central government's infrastructure investment decreased from 32.6% in 1987 to about 10% in the mid-1990s, bank loans remain at 23%–25%, and the investment from local governments around 65%–67%. But differences occurred among the Western Regions, the Central Regions, and the Eastern Regions. For example, in 1998, the central government's infrastructure investment in Xinjiang reached 55.9%, yet less than 15% in Hainan (Zhang, 2007).

The transportation infrastructure is also invested in by the central government and the local government. Local governments are the major investors. According to "The China Statistical Yearbook (中国统计年鉴)", from 2007 to 2018 expenditure on transportation has increased yearly; before 2006, expenditure for transportation was not listed, however 2011 is a clear dividing year – also the year preceding Ying Gai Zeng. Before 2011, almost one-third of transportation expenditure came from the central government and the rest from local governments. After 2011, central government investment accounts for one-eighth or less of the total transportation expenditure. Therefore, expenditure from local governments has risen sharply.

Table 4 – Expenditure on Transportation from The China Statistical Yearbook （Unit: 100 million Yuan）

Year	Central Government	Local Government	Total
2018	1313.17	9969.05	11282.76
2017	1156.42	9517.56	10673.98
2016	812.12	9686.59	10498.71
2015	853.00	11503.27	12356.27
2014	731.16	9669.26	10400.42
2013	722.99	8625.83	9348.82
2012	863.59	7332.57	8196.16
2011	331.11	7166.69	7497.80
2010	1489.58	3998.89	5488.47
2009	1069.22	3578.37	4647.59
2008	913.20	1440.80	2354.00
2007	782.25	1133.13	1915.38

When we follow the branches of the transportation system's investment strategy, the situation is much the same. Localized management of the transportation system first occurred through the highway investment. According to Jin and Chen (2019), the share of local investment in highways has been more than 40% since 2003, and it reached 50% in some years. Thus local governments have been a key influential factor in the transportation system. Moreover, Ying Gai Zeng has also had a profound influence. After Ying Gai Zeng, tax on the transportation system rose. For example, Li (2013) points out that the largest increase in tax burden is in the area of transportation after 'Ying Gai Zeng'. Local governments are responsible for more expenditure on infrastructure than central government, but the tax they gain from infrastructure operations are less than before.

The local governments are on a tight budget. So there is a new reform coming to the area of infrastructure. The "Public-Private Partnership" (PPP program) has four features in China: public-private partnership, providing public goods or services, benefit-sharing and shared risk (Chen et al., 2015). Since 2003, the PPP program has experienced rapid development. In 2003, a document called "The Decision on Several issues of Perfecting the Socialist Market Economy System (关于完善社会主义市场经济体制若干问题的决定)" announced that it would allow non-public capital into the field of infrastructure and public services and facilities. In 2014, "The Report on the Central and Local Draft Budget in 2014 (关于 2014 年中央和地方预算草案的报告)" released by the Ministry of Finance was the first time that the Chinese government used the concept of "PPP program" in a government document. This document promoted the PPP program. From 2014 to 2015, there were 1,043 PPP programs in China, and these programs covered many areas such as water utility, municipal engineering, transportation, public services and the environment (Chen *et al.,* 2015). In 2015, a document called "The Guidance on the Model of Cooperation between Government and Social Capital in Public Services (关于在公共服务领域推广政府和社会资本合作模式的指导意见)" points out that the PPP program would be widely adopted in the field of public services, such as transportation. And the Ministry of Finance defines the PPP program as a long-term partnership in the area of infrastructure and public services. In China, the PPP program refers to cooperation between the local government and social capital. The common method of cooperation is that the social capital designs, constructs, operates and maintains transport infrastructure, and also that the social capital would gain investment return through "user payment (使用者付费)", such as ticket prices, and "government payment (政府付费)", such as tax investment. Local governments are responsible for regulations, such as the prices and quality of the infrastructure, to guarantee maximum public interest (Chen *et al.,* 2015). The deep effect of local governments is apparent in all PPP programs. According to Chen *et al.* (2015), the leaders of the local government have great power in project selection and political performance which are some leaders main concern, instead of the public's needs (e.g. transportation to and from work).

So in the reform era, the transportation infrastructure system was influenced by local government. During the process of fiscal decentralization, the local government held more power on infrastructure expenditure and the selection of PPP programs, which influenced the development of the transportation system.

3.2 Big Data

3.2.1 E-Government

E-government is when Big Data is used for government decision-making and management. According to Bhatnagar (2010), “E-government is about a process of reform in the way Governments work, share information and deliver services to external and internal clients.” Bhatnagar (2010) points out that e-government mainly applies IT in order to improve the relationship between the public, business and governmental departments. Wang (2014) argues that e-government is shifting the paradigm of governance from a state-only governance model to a pluralistic one because of the use of Big Data.

According to Bhatnagar (2010), e-government provides less corruption, increased transparency, greater convenience, revenue growth and cost reduction. Generally speaking, e-government provides three recompenses. First, the e-government can improve government efficiency. According to Hardy and Maurushat (2017), opening data to the public can improve “transparency and accountability” and the public can be more involved in the government's decision-making process. For example, opening up agriculture-related data, such as weather and geographical data, would improve agricultural productivity. Second, e-government can enable public participation and help promote democratic decision-making, as because of the openness of data, the public can be more involved in the government decision-making process (Hardy & Maurushat, 2017). Thus, it may improve democratic participation. Third, e-government has led to a change in the national governance model, from state-only to pluralistic governance. In addition to the public, some researchers also suggest that Big Data allows more institutions and social groups to join the decision-making process. For example, Wang (2014) studied a case where the US Department of Transportation (DOT) collaborates with INRIX. Using signals and data from GPS in cars and mobiles, they collect speed data on the roads. They could also alert the New Jersey Department of Transportation in real time of hazardous conditions on roads, and send alerts to drivers' in-car GPS or mobiles to alert them about hazardous conditions. Wang (2014) argues that this case could be due to companies sharing the government's power of public transportation governance.

At the same time, there are some drawbacks to e-government. Researchers are concerned about individual privacy when data is opened to the public. For example, Hardy and Maurushat (2017) point out that an opening of government data has "the possibility of re-identification" (p.33), so individual privacy is at risk.

In the practice of e-government, accessible data, such as real-time traffic information, is an important aspect of a smooth transportation system. However, opening up government data to the public is a double-edged sword. On the one hand, government data could improve policymaking as well as technological innovation. On the other hand, individual privacy is at risk. According to Hardy and Maurushat (2017), opening up government data could improve policymaking as well as innovation because data is knowledge, and sharing data is also one of the features of Big Data. For example, Welch, Feeney and Park (2016) argue that "government is major collector and sharer of data" (p.393), because the government plays a prominent role in national security, weather forecasting and so on. Most e-government theories are based on the premise that the government needs to provide data access because the government holds the largest amount.

However, the current situation in China is different from the ideal state of e-government proposed by the researchers, especially in the case of the Smart Transportation System. Compared to the US and European countries, the Chinese government does not have enough data based on its total amount of data resources which are 7% of that of the US and 12% of that of Europe (Wang, 2014). For the Smart Transportation System, research institutions and government departments need to turn to Internet companies to obtain data. Internet companies have more data that the Chinese government in terms of quantity and variety.

3.2.2 The Epistemologies of Big Data

The understanding of Big Data is an epistemological process. Firstly, Big Data could be considered a new paradigm. According to Jim Gray (see Kitchin, 2014), the evolution of science can be described as four paradigms based on the kind of data they use and their different analytical methods. For example, Gray (see Kitchin, 2014) argues that the fourth paradigm is “exploratory science” which is data-intensive and includes statistical exploration and data mining. The third one is computational science and it could simulate complex phenomena. The second one is called theoretical science and it focuses on modelling and generalization. And the first one is experimental science which is based on empiricism. These differences in analytical approach implies a beginning of a new research path: an epistemological turning point.

Secondly, there is no such thing as raw data in Big Data (Gitelman, 2013). For example, as Gitelman (2013) suggests, “Data too need to be understood as framed and framing, understood, that is, according to the uses to which they are and can be put.” In other words, all data analysis has a certain theoretical framework. Therefore, the understanding of Big Data is an epistemological process according to one’s knowledge structure.

Thirdly, data is selected before analysis, and it is analyzed based on certain theories and purpose, so the selection and analysis stages are where the different epistemologies enter. As Dobbe et al. (2018) says, "Epistemologies differ tremendously from application to application and ultimately shape the way a decision-maker justifies decisions and affects individuals."(p.4) Thus, the understanding of Big Data is not only an epistemological process, but also a place where many different epistemologies may coexist.

There are two different views on how Big Data arrives at its results. The first one is "data-driven", which means that people will first have a theoretical framework or hypothesis before they analyze the data. In other words, being data-driven requires a theoretical framework or a goal before analysis, and it validates results to test its initial hypothesis. For example, Kitchin (2014) argues that the data-driven method is "a hybrid combination of abductive, inductive and deductive approaches" (p.5). Canali (2016) also explores a case study called "EXPOsOMICS", a program funded by the European Commission, intended to advance our understanding of the relation between exposure and disease. Canali (2016) concludes that not only causal knowledge is used in the data analysis, but also theoretical considerations, which supports and extends Kitchin's (2014) idea that there is theory and causal knowledge in Big Data. The second way Big Data attains results is through its units: its large amount of data. Some researchers call this kind of idea "the end of theory" (Kitchin, 2014). This idea argues that the increase in data volume will make the results more and more credible. In other words, theory does not play a role in data analysis. This idea is often combined with empiricism and is considered as a rebirth of empiricist epistemology. The amount of data becomes a criterion of the accuracy of the results, and the larger the amount of data, the more accurate the results will become.

Kitchin (2014) is critical of "the end of theory" because it has four shortcomings. First, the data are influenced by people's thoughts, sample selection, and other factors. Thus, it is not "an all-seeing, infallible God's eye view" (Kitchin, 2014, p.4). Second, data is analyzed under theoretical frameworks which is linked to the third shortcoming that the data cannot speak for itself as interpretations of the results require the involvement of theory. Fourth, the idea that the data could speak for itself implies that one can interpret the data without "context or domain-specific knowledge" (Kitchin, 2014, p.5). So Kitchin (2014) concludes that this kind of epistemological idea is "anaemic or unhelpful"; that even the idea of "the end of theory" could not avoid people's thoughts, because all the data are "cooked" as Gitelman (2013) notes.

Some studies suggest that these two ideas are due to the different communities to which they belong. For example, Kitchin (2014) argues that the idea of "the end of theory" is trusted by the business community, such as data brokers, data analytic providers, software vendors, consultancies, etc. While the idea of data-driven research is upheld by academia. He also argues that the business community uses data as a kind of rhetoric to convince others, while the scientific community introduces definitions, features and epistemologies of Big Data to show that there might not be a well-established, widely accepted definition of Big Data. And that the epistemologies of Big Data are also controversial. Additionally, as discussed above, specific understandings of new technology exist in China. So what is our understanding of Big Data in China? And do Chinese scientists and engineers have unique insights?

3.3 Cultural Context

3.3.1 Traditional Chinese Medicine and Ancient Chinese Science and Technology

As I begin to explore the participants' use of Traditional Chinese Medicine (TCM) as a metaphor for Big Data, I find that the participants are not referring specifically to TCM. In fact, they are referring to traditional Chinese science and technology ideas, which are represented here by TCM. Medicine, agriculture and astronomy are representative of ancient Chinese science and technology, all of which share a common intellectual foundation derived from Chinese philosophy. According to Qian's (2005) research, the vast majority of scientists in ancient China, 85% or more, have been astronomers, agronomists or medical scientists (excluding mathematicians and artisans), while very few have been physicists, chemists and biologists. Because all three disciplines are closely related to social practice, they adopted a Confucianism emphasis on practicality.

Nowadays in China, the closest connection of traditional Chinese science and technology with current life is TCM. Although traditional astronomy and agronomy were once closely associated with people's everyday lives, they are now largely withdrawn from Chinese people's lives, and we can usually find them in museums. However, TCM remains active in the daily lives of Chinese people. There are TCM hospitals in almost every province and city in China. For instance, Wuhan's TCM Hospital played an important role in the COVID-19 outbreak in the early-2020s.[46] Every Chinese province has a TCM university, such as Shanghai University of TCM and Beijing University of Chinese Medicine, with tens of thousands of undergraduates each year. Therefore, we can say that TCM is representative of ancient Chinese science and technology in modern China. On the one hand, it has the closest connection with our everyday life; on the other hand, it is also a perfect example of traditional Chinese scientific and technological ideas.

Ancient Chinese science is also a unique and self-consistent system of science.

[46] http://www.whtcm.com/index.php?a=shows&catid=14&id=590

Ancient Chinese science and technology all share the same theoretical system, which is based on the Theory of Qi (元气论) and the Theory of Yin and Yang (阴阳理论). Liu Shengli (2011) summarized this theoretical system as “phenomenal science”, while Western science is “objective science”. Wu and Tong (2005) refer to it as a paradigm. TCM is typical of this paradigm. Through the study of ancient Chinese medical texts, Wu and Tong (2005) note that Qi and Yin and Yang determine how Chinese medicine observes and thinks about the structure of the human body. At the same time, TCM also embodies two important features of this paradigm.

3.3.1.1 The Holistic Unity of Humanity and Nature（tian ren heyi，天人合一）

The first feature of the ancient Chinese scientific paradigm is that it is based on the cosmology of “the holistic unity of humanity and nature”（tian ren heyi，天人合一） (Liu, 2011; Li & Huang, 2001; Ma, 2019; Qu, 2010; Shao & Yan, 2007; Yang, 2001). In ancient China, nature and human were regarded as an organic whole, emphasizing the connection and seeking a harmonious relationship between the two. This is also reflected in the two main streams of Chinese philosophy; for example, Ma Bailian (2019) points out that Taoism prefers to see human beings as models for heaven, while Confucianism prefers to look at heaven in a human model. Although Confucianism and Taoism disagree on how to unite humanity and nature, there is no doubt that they both advocate viewing humanity and nature as an organic whole.

Cosmology of “the holistic unity of humanity and nature” is also reflected in TCM. TCM argues that the human body is closely connected and unified with the external environment and the climate. So TCM thinks that heaven and earth form a large universe, while the human body is a small universe. For example, in an ancient Chinese text called “Huainanzi”（淮南子）,[47] it says：“The head is round like the sky, while the feet are square like the earth.[48] The holistic unity of humanity and nature is also reflected in the way that people think about the issues of the transportation system as well as the Smart Transportation System. For example, in the interviews, the participants argued that the Big Data centers played a role similar to that of a “brain”.

Participants analogize Big Data centers to the human brain, while the transportation system is analogized to the human body. Therefore, it is unsurprising that the participants draw analogies between Big Data and TCM. Because the transportation system is viewed by participants as the human body, the solutions to traffic congestion are comparable to that of a doctor’s practice. This reflects the idea of the holistic unity of humanity and nature, which means the laws of the world are similar to the laws of the human body.

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[47] A collection of essays in several different topics such as politics, nature, and philosophy.

[48] “故頭之圓也象天，足之方也象地.” The ancient Chinese believed that the sky was round and the earth was square.

3.3.1.2 A Holistic View of Things and Phenomena

Since heaven and humanity form an organic whole, nature and the human body were also understood as a whole in ancient Chinese science and technology. Qian (2005) argues that ancient Chinese science prefers to take a holistic view of things and phenomena. It does not adopt an analytical approach that divides the whole into pieces and then examines those pieces to understand the whole. Qian (2005) points out that the holistic view of ancient Chinese science represents an emphasis on the connections between things and phenomena and a neglect of the internal structure of them. Yuan Yunkai (2002) traces this holistic view back to the I Ching (The Book of Changes, 易經). For example, the eight trigrams (symbols) represent heaven, earth, thunder, wind, water, fire, mountains and marsh, but combine to form sixty-four hexagrams.

The idea of “focusing on the whole” is also reflected in TCM. As Shao and Yan (2007) note, TCM views the human body and the environment as a spatially connected whole, and it constructs a model which connect heaven, earth, and the human body. Yet, from a temporal perspective, TCM treats the entire life process as a whole, emphasizing the influence of the earlier stages on the later stages. In TCM practice, for example, Wu and Tong (2005) argue that TCM often uses the external environment to infer the physiological and pathological mechanisms of the human body, and it does not emphasize anatomy and pathological analysis like modern medicine. The holistic view in TCM is in response to a complex system such as the human body. Also, in the practice of the Smart Transportation System, most participants believe that the system is a complex one and cannot be viewed in isolated sections.

Conclusion

This chapter has mapped the political, social and cultural contexts in which the Smart Transportation System emerged. It has shown that the Smart Transportation System is, on the one hand, a project that is deeply influenced by the government, especially the local government in the context of fiscal decentralization. On the other hand, Big Data is at the heart of the Smart Transportation System, adding new changes and new meanings. Although two different ideas oppose each other about how Big Data reaches its results, how Big Data draws its conclusions influences its credibility, and even influences the policymaking process, because people choose to trust the results or not according to their credibility. However, the two competing epistemologies fail to grasp the nature of Big Data, raising the important question about Big Data's credibility. In order to demonstrate Big Data's credibility the Chinese participants of this study juxtapose Big Data with TCM, adding to a new attempt to compare the two, and to understand the nature of Big Data. Thus, the cultural context elaborates the two basic features of traditional Chinese science and technology: the Holistic Unity of Humanity and Nature and a holistic view of things and phenomena. Further chapters will deepen the analysis of this hybrid of the transportation system and Big Data – the Smart Transportation System, focusing on the future expectation and sociotechnical imaginary of Big Data (Chapter 4), the policymaking process of Big Data (Chapter 5), and the nature of Big Data (Chapter 6).

Chapter 4. Scattered Future Expectations and A Collective Sociotechnical Imaginary

This chapter illustrates the factors that contribute to future expectations and sociotechnical imaginary in order to distinguish the two concepts. To do so it draws on the fieldwork material and the research paper analysis of the Smart Transportation System, in light of Kuhn's (1970) paradigm, fiscal decentralization in China and the algorithmic episteme proposed by Fisher (2020). Section 4.1 demonstrates the lack of a field of academia called the Smart Transportation System, but instead two scientific communities: Road and Waterway Transportation and Computers and Computer Applications. The two different scientific communities are not only varied in the paradigms, but also in the future expectations, indicating a linkage between future expectations, the paradigms and the interests. Section 4.2 illuminates the sociotechnical imaginary of the Smart Transportation System based on the scientists' and engineers' epistemologies, and fights against the algorithmic episteme, which indicates that sociotechnical imaginary could also be related to knowledge used in the decision-making process.

4.1 Different Scientific Communities, Different Expectations

Drawing on fieldwork materials and research paper analysis of the Smart Transportation System, this section demonstrates that there is not an academic field called the Smart Transportation System, but two different scientific communities: Road and Waterway Transportation and Computers and Computer Applications. These two different scientific communities are not only varied in their paradigms, but also in their future expectations. With Kuhn's paradigm, this section illuminates that the future expectation of the Smart Transportation System could be construed as a series of shared future beliefs derived from the paradigms of different scientific communities. Also, considering the fiscal decentralization in China, this section indicates that the future expectation is related to the interest of the scientific community.This section is divided into three parts: first, to identify the different scientific communities arising in the interview materials and paper analysis; second, to analyze different future expectations related to these different scientific communities; third, to shed light on the factors that contribute towards the future expectations of different scientific communities.

4.1.1 There is not an Academia of the Smart Transportation System, but Different Scientific Communities

During the fieldwork, interviewees pointed out the existence of different scientific communities in the Smart Transportation System field. Therefore, in this section, I will describe the different scientific communities mentioned by the participants. Then, I will analyze research papers in this area to see whether different scientific communities are also apparent.

4.1.1.1 From Interviewees

According to the interviewees, different scientific communities exist in t the Smart Transportation System area. Importantly, these different scientific communities cannot be seen as one academy as a whole. For example, Ms Sheng is a senior expert in the field of driverless vehicles. She works in a research institution for the MOT in Beijing and suggests that the earliest research on the Smart Transportation System in Chinese academia started in the field of civil engineering.

> *When the Intelligent Transportation System [the Smart Transportation System's earliest name in Chinese] was proposed [...] At that time the researchers in this field were from civil engineering, and they were engaged in constructing facilities [...] In our country, it was the civil engineering department in Tsinghua University that was first studying these concepts. (Ms Sheng, Beijing)*

Some interviewees thought that two main scientific communities exist. For example, Prof. Ti is a professor focusing on transportation infrastructure in one of Shanghai's universities. He argues that there are two major areas in the Smart Transportation System field: civil engineering and traffic management. Civil engineering was the first to enter this field, while professionals in traffic management may have more suitable skills for this field than civil engineering.

> *Traditional civil engineering has a different understanding of information technology, so their pursuit will be different from traffic management. Traffic management concentrates on mobile objects such as vehicles and people. While civil engineering focuses on immobile facilities [...] The quality or educational background of employees in traffic management is better than that of civil engineering (Prof. Ti, Shanghai)*

Mr Guo works in a research institution serving the Chongqing Commission of Transport. He is a senior expert in the field of traffic management. For him the scientific communities are divided into another two groups: traffic management and information engineering. He says:

As urban traffic management, our concern is whether complete traffic behaviour is the most efficient and safest. For example, if it is easy to take the metro but you have to walk a long way to get to the metro station. There is definitely a problem for us [...] On the other hand, there are some people focused on other things in the Smart Transportation System. They are majors in automation or information control. They care more about the equipment and devices, such as communication signals and transmission networks. They think about the Smart Transportation System in these terms. I will give you an example. It's strange. At first, people who participate in the China Smart Transportation System Association major in signal control, the Internet and transmission, rather than the people who are concerned about traffic management. People who engage in automation and information transmission, including the Internet, look at the Smart Transportation System from their point of view. For example, if this intersection has four-way signal control, how can we achieve it most efficiently? What is the shortest delay in each direction of the queue? They care about these kinds of questions. How to make the equipment, such as telesemes and switches, much smarter? So these are the two different directions [...] So I'd like to say that these are two different areas in China.

> *Now it should be said that they are merging. However, there will still be differences. (Mr Guo, Chongqing)*

The professionals cited above, realize that different fields exist and that they have different goals, and that the combination of these goals would be difficult. Their difficulty indicates that there are barriers between different scientific communities. According to Prof. Ti, different professionals have their own characteristics:

> *Now people who work on transportation construction are from traditional civil engineering. The understanding of the Smart Transportation System from them is different from the people who focus on traffic management. Civil engineering relies on fixed infrastructure while traffic management cares about moving objects such as vehicles. So, in my opinion, they will have different perceptions. (Prof. Ti, Shanghai)*

Thus, one challenge that the Smart Transportation field faces is a lack of talents with multidisciplinary knowledge:

> *We feel that the bottleneck may still be a problem of talent. We now need a person who has knowledge about information technology and artificial intelligence and he could also combine it with our expertise (transportation management). (Prof. Huan,*

Shanghai).

> *People who work on information management should also know some civil engineering in the future. I think students should minor in civil engineering and then they could engage in traffic management. (Mr Guo, Chongqing)*

Some interviewees think that people with multidisciplinary knowledge may appear in the future, but the emerge of a person with multidisciplinary knowledge is difficult due to existing barriers and professional subdivision. So the action that may help these future workers now is negotiation between disciplines. For example, Dr Yi is a senior engineer working for a state-owned company of transportation system design in Hangzhou.

> *I think it is right but it is too idealistic. The requirement is too high. I don't think the future is to cultivate people with multidisciplinary knowledge. On the other hand, people who know traffic and people who know Big Data could sit together and then they will come up with some new ideas and develop some new products. (Dr Yi, Hangzhou)*

We have seen that Ms Sheng thinks that the Smart Transportation System started in the field of civil engineering, Prof. Ti states that two main areas are civil engineering and traffic management, while Mr Guo talks about traffic management and information engineering. Although these professionals have different understandings about the areas emerging in the Smart Transportation System, one thing is certain: the semi-structured interviews reveal that there are different scientific communities within the Smart Transportation System. From the above answers, these different scientific communities hold different goals. Scientific communities based on civil engineering are interested in infrastructure and hardware, while experts focused on traffic management are more likely to use Big Data and IT to help solve their problems. Moreover, all these experts think that there are barriers between different groups. And the negotiation between different scientific communities is tricky because people with multidisciplinary knowledge do not, or rarely, exist. Due to varied viewpoints communication between these scientific communities is problematic, so the experts I interviewed want to have a chance to *"sit together"* and *"come up with some new ideas".* However, the participants have different opinions on what communities there are within the field of the Smart Transportation System. Therefore, to define the different scientific communities in this field I turn to the China National Knowledge Infrastructure (CNKI) to analyze papers published within the Smart Transportation System field.

4.1.1.2 From Papers

I used two keywords: “智能交通 (The Intelligent Transportation System)” and “智慧交通 (The Smart Transportation System)” to analyze the papers published on CNKI. The two keywords refer to the Smart Transportation System in the Chinese context. Drawing on the papers published on CNKI, the results show two different scientific communities in the Smart Transportation System: Road and Waterway Transportation which focuses on hardware facilities, while Computers and Computer Applications concentrates on software.

The participants argue that these two names refer to the same thing – the Smart Transportation System. However, the first name that appeared historically was the ITS. For example, Mr Guo says:

> *In my understanding, the Smart Transportation System, we used to call it the Intelligent Transportation System (Mr Guo, Chongqing)*

Second, the participants talked about the history of the Smart Transportation System in China, and that there has not been a lot of change in the people who work in the field. For example, Prof. Huan is a professor in the transportation system field, focusing on data analysis of the transportation system. He says:

Prof. Huan: The Smart Transportation System is the Intelligent Transportation System. Actually, this concept is quite old. This research was started when we were in college, which was twenty years ago [...] In the last two years, because of the emergence of concepts, such as the Internet of Things, Intelligent Connected Vehicles, and so on, we feel the need to redefine it.

Q: Is it very different from the definition of 20 years ago?

Prof. Huan: In fact, I think there may not be a big difference, except that it may be clearer than before.

Ms Zhao is an expert in traffic signals. She currently works for a traffic signal equipment supply company in Chengdu. She mentions that there was a name change when she applied for fundings and grants.

Ms Zhao: In around 2016 and 2017, we started to use the Smart Transportation System when we applied for research fundings.

Q: So you did not use the concept before 2016?

Ms Zhao: We didn't. For the previous projects, we used the Intelligent

Transportation System.

Third, the Smart Transportation System developed from ITS, and they both have the same core. Thus, the participants called the Smart Transportation System an "upgrade" or "a new version". For example, Prof. Di – a professor in the transportation system field at a university in Beijing – says:

> *The Smart Transportation System is an integrator [...] Intelligent Transportation System combined sensor technology, communication technology, automatic control technology, information technology, and so on. Now, in China, we use Big Data, cloud platform, Internet of Things (IoT), etc. And we combine them together and apply them to the transportation system. The purpose is very simple. We want to promote the capacity and efficiency of our transportation system. (Prof. Di, Beijing)*

Mr Shan, a senior engineer in the Smart Transportation System, argues that the Smart Transportation System can be called ITS *"V2.0"*. He says:

> *I think we can call it [the Smart Transportation System] the*

> *Intelligent Transportation System V2.0. For example, in the first few years, or the first five years, we used the concept "the Intelligent Transportation System" [...] The goal of the Smart Transportation System is to improve the experience of travel and improve the efficiency of travel, so it studies the experience of people. While the Intelligent Transportation System studied from the perspective of vehicles [...] The Smart Transportation System, also, is linked to the idea of smart city [...] Smart Cities, smart communities, etc., are also people-centerd. From such a perspective, we think that it [the Smart Transportation System] would be the Intelligent Transportation System V2.0. (Mr Shan, Chongqing)*

Fourth, there is a slight difference between the two terms in Chinese; however, according to Prof. An, the two concepts are from the same English term:

> *The Smart Transportation System, in fact, the concept is mainly used in China. But in foreign countries, it is actually called the Intelligent Transportation System (Prof. An, Nanjing)*

Ms Bu is a senior expert in the Smart Transportation System field. She works for a state-owned company of transportation system design. She also talks about her experience:

> *When we first learnt about this thing before the year 2000, we called it the Intelligent Transportation System. This was the name when it came into China from abroad (Ms Bu, Shanghai)*

These two Chinese terms are the translation products of the localization of the English term, as they use the same English term one would think that their meanings should be similar as “technical dialects” (Montgomery (2000). According to Montgomery (2000), the translation process can add new information into the previous English term which might be localized in its translation and hold different meanings. Such English terms born in non-English speaking countries have local/repurposed meanings representing their local scientific culture. Here, these two Chinese terms can be considered as “technical dialects”. The English term is localized and divided into two different Chinese translations. Therefore, I used the two keywords The Intelligent Transportation System (ITS) and the Smart Transportation System to analyze the papers published in this field to identify different scientific groups. In order to obtain more accurate results, I directly used a visual analysis tool on the CNKI website, so the results are shown in Chinese. I will translate the results in English.

The first paper with the keyword “The Intelligent Transportation System” appeared in 1963. However, the number of relevant articles began to increase in the 1990s, and experienced a sharp increase since 2000 (see Figure 3). The first paper with the keyword the Smart Transportation System appeared in 1996. The number of papers started to increase around 2007, and started to rise steeply around 2010 (see Figure 4). This situation is consistent with what the interviewees have said: that the term “the Intelligent Transportation System” entered China much earlier, while in recent years, people use the term the Smart Transportation System more frequently.

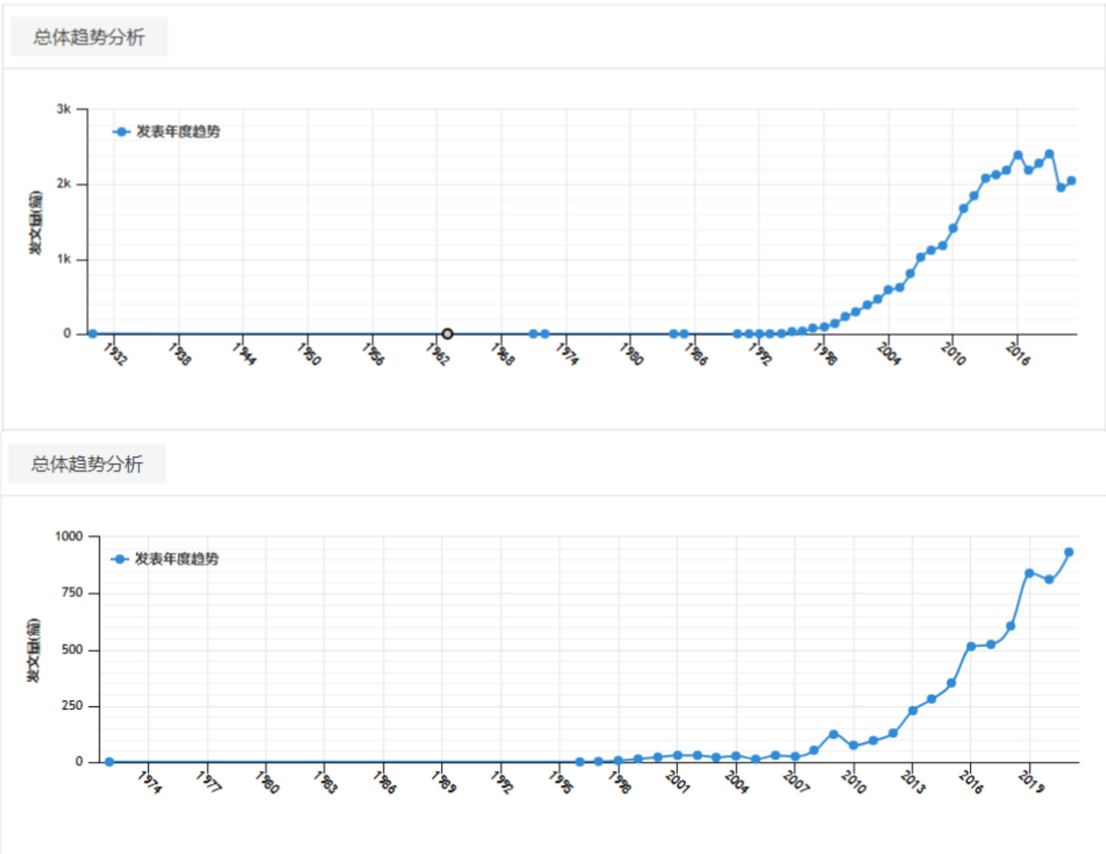


Figure 3. 4. From top to bottom: **Figure 3.** The Intelligent Transportation System: the number of relevant articles began to increase in the 1990s, and experienced a sharp increase since 2000; **Figure 4.** The Smart Transportation System: the number of papers started to increase around 2007, and started to rise steeply around 2010.

Using "the Intelligent Transportation System" as a keyword, the top three disciplines to which the articles belonged are: Road and Waterway Transportation (32.88%), Computer Software and Computer Applications (26.84%), and Automation Technology (8.01%) (see Figure 5). Using the Smart Transportation System (see Figure 6) as a keyword, the top three disciplines to which the articles belonged are: Road and Waterway Transportation (22.75%), Computer Software and Computer Applications (19.70%), and Transportation Economics (9.07%); while the share of Automation Technology is only (4.75%). Thus, the main disciplines in this field are Road and Waterway Transportation and Computer Software and Computer Applications, regardless of which keywords are used for analysis.

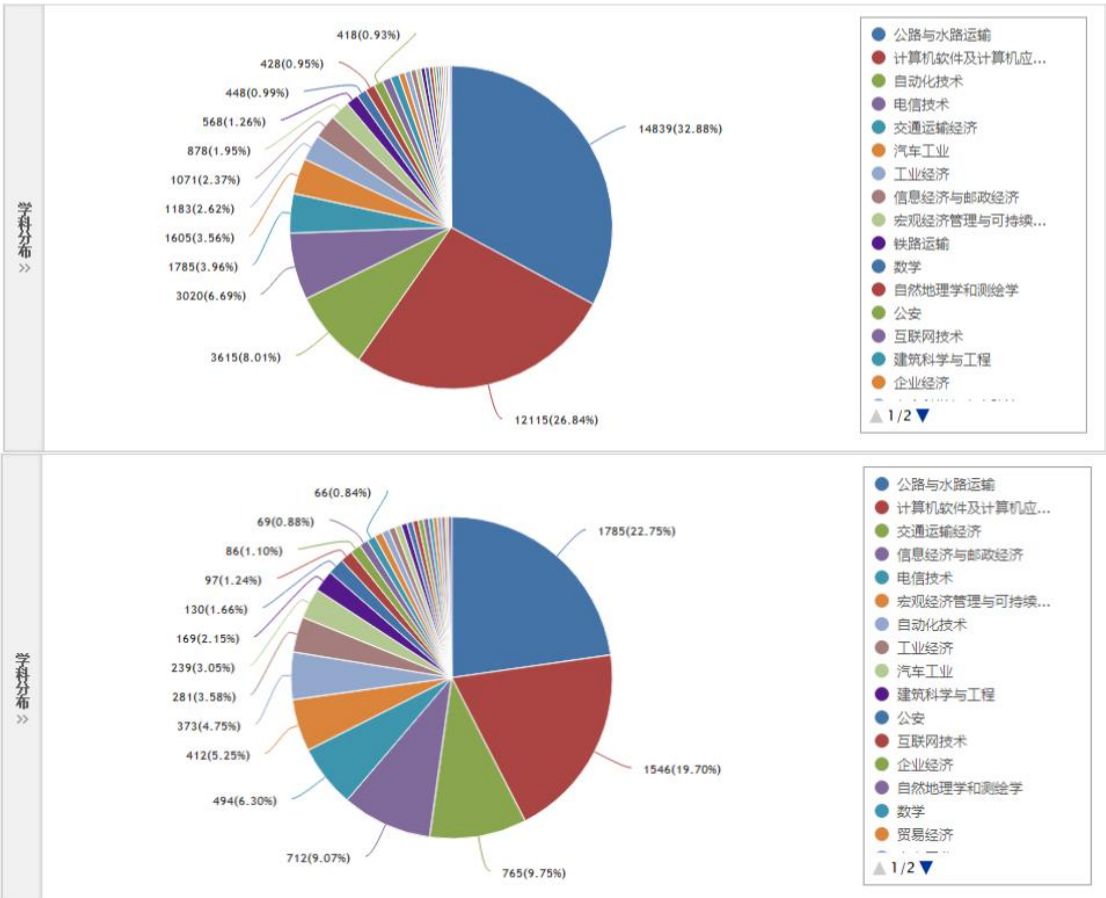
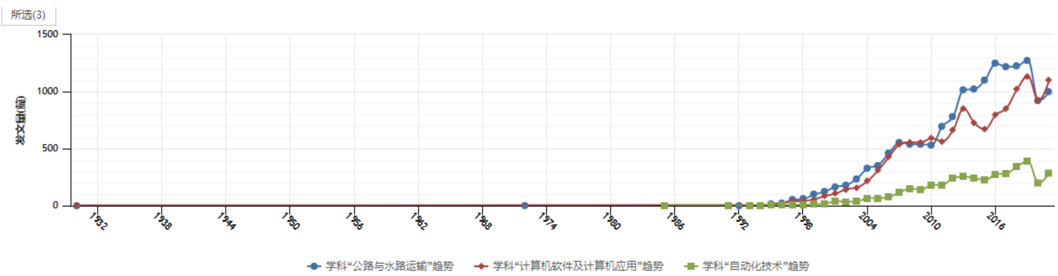


Figure 5. 6. From top to bottom: **Figure 5.** The Intelligent Transportation System: the top three disciplines to which the articles belonged are: Road and Waterway Transportation

(32.88%), Computer Software and Computer Applications (26.84%), and Automation Technology (8.01%); **Figure 6.** The Smart Transportation System: the top three disciplines to which the articles belonged are: Road and Waterway Transportation (22.75%), Computer Software and Computer Applications (19.70%), and Transportation Economics (9.07%).

I further explored the curve of the number of papers published in the top three disciplines. The two main disciplines appeared in the field almost simultaneously, instead of one replacing the other. Using "The Intelligent Transportation System" as a keyword, papers in both disciplines have been growing since 1992 (see Figure 7). And using "The Intelligent Transportation System" as a keyword, they started around 1997 (see Figure 8).



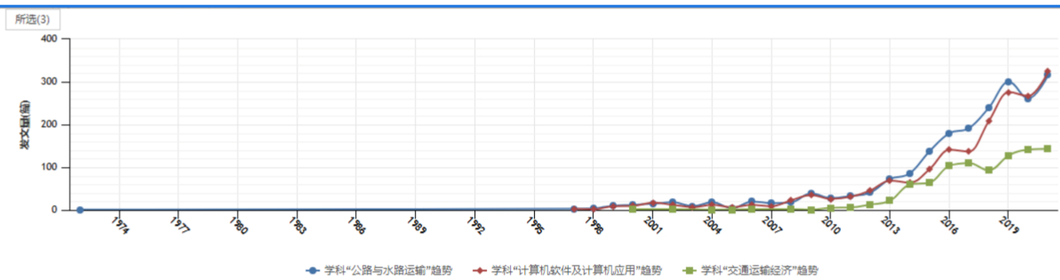


Figure 7. 8. From top to bottom: **Figure 7.** The Intelligent Transportation System: the curve of the number of papers published in the top three disciplines, and papers in both disciplines have been growing since 1992; **Figure 8.** The Smart Transportation System: the curve of the number of papers published in the top three disciplines, and papers in both disciplines have been growing since 1997.

"Road and Waterway Transportation" and "Computers and Computer Applications" are two different disciplines. For example, in CNKI's classification of journals, "Road and Waterway Transportation" belongs to Engineering

Technology 2 (see Figure 9), while “Computers and Computer Applications” belongs to IT (see Figure 10).

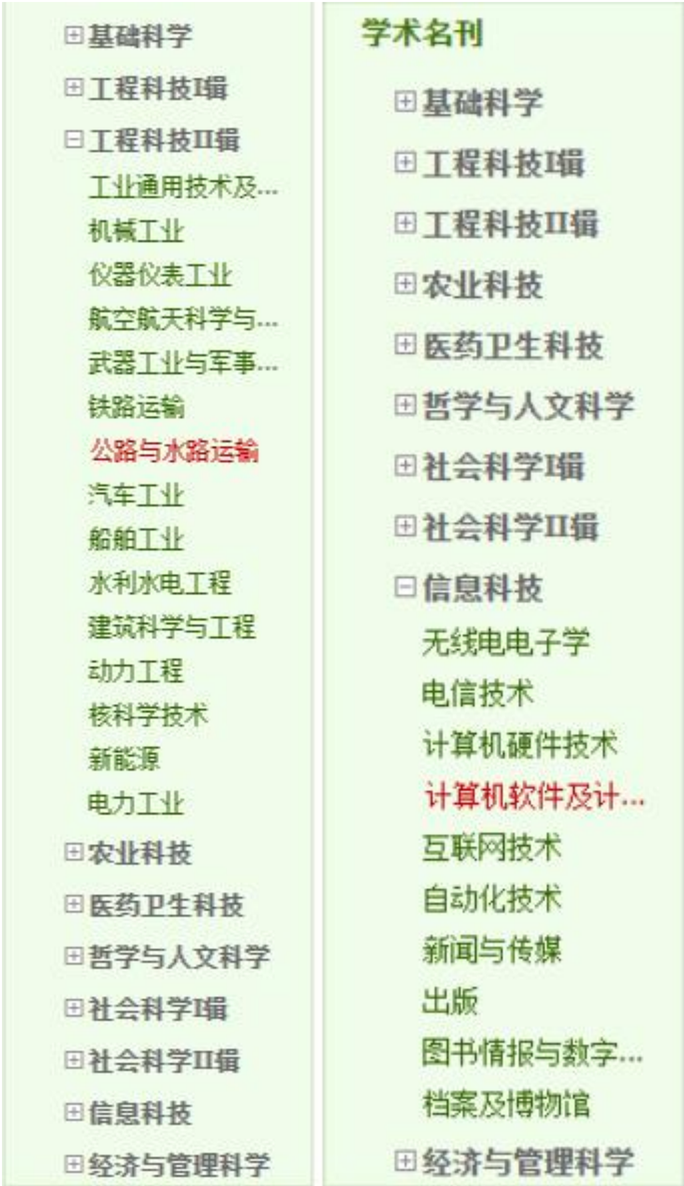


Figure 9. 10. From left to right: **Figure 9.** “Road and Waterway Transportation” belongs to Engineering Technology 2, and the rest are “General Industrial Technology”, “Engineering Industry” “Instrument and Meter Industry” “Aerospace Science” “Arms Industry” “Rail Transport” “Automobile Industry” “Shipping Industry” “Water Engineering” “Architecture” “Power Engineering” “Nuclear Science and Technology” “New Energy” “Electric Power Industry” (From top to bottom); **Figure 10.** “Computers and Computer Applications” belongs to IT, and the rest are “Radioelectronics” “Telecommunication Technology” “Computer Hardware” “Internet” “Automation Technology” “Journalism and Communications” “Publishing” “Library and Information Science” “Archives and Museology” (From top to bottom).

Moreover, the focuses of these two areas are also different. For example, according to CNKI, the top 10 cited journals of "Road and Waterway Transportation" concentrate on hardware facilities, such as roads (4), railways (2), bridges (1) and transportation (3). While the top 10 cited journals of "Computers and Computer Applications" focus on software, such as computer applications (3), software (2), simulation (2), graphics and images (2) and computers (1).

The interview materials show that different scientific communities exist in the Smart Transportation System. Additionally, participants share that there are several barriers between different scientific communities, so that collaboration between them is difficult. However, the participants of different disciplinary backgrounds did not have a clear idea about the specific scientific communities in the Smart Transportation System. I identified two main scientific communities through the CNKI paper analysis: "Road and Waterway Transportation" and "Computers and Computer Applications". "Road and Waterway Transportation" focuses on hardware facilities, while "Computers and Computer Applications" concentrates on software. These two scientific communities have different focuses which lead to different research questions and related solutions. For civil engineering experts, for instance, they develop infrastructures such as roads and sensors. While traffic management scientists emphasize the necessity of service and management using IT. Moreover, this different emphasis actually shows different world views. As Prof. Ti indicates: "*they will have different perceptions*", which means that the scientists and engineers in civil engineering think that hardware facilities, such as upgrading roads, adding more surveillance probes and sensors, are more important. This is also where they see the future of the Smart Transportation System heading. While scientists in traffic management believe that the future of the Smart Transportation System lies in better services which comes from the analysis of data, not the construction of hardware facilities. For example, Mr Guo says: "*The concept such as automation has not yet achieved the level of the concept of 'mobility as a service*".

4.1.1.3 Political Power

Besides evidence from the interviews and research papers, political power also plays an important role in forming the Smart Transportation System field, which means that the field does not form spontaneously, but is put together by administrative forces. The first step to form this field is to create the concept – the Smart Transportation System. The interviewees note that the concept of the Smart Transportation System started to appear in the 2000s with a set of national regulations. Prof. Di is a professor in the transportation system field in Beijing. According to him, the concept comes from central government:

> *In around 1998 and 1999, China starts to have the concept of the Smart Transportation System. The government started to put*

forward the frame of the concept. In 2003, China published a book called "China's Smart Transportation System Framework" and it was a milestone for the development of the Smart Transportation System. (Prof. Di, Beijing)

The above framework was a milestone for the field, because it provided the concept and used it as a goal towards future development. Before the 2000s, scientists and experts had no idea what a Smart Transportation System consisted of. Ms Bu is a senior expert in the Smart Transportation System field. She now works for a state-owned company of transportation system design in Shanghai. She also mentions the importance of the framework:

In around 2000, we had the first version of China's Smart Transportation System Framework. At that time, people did not know anything about the Smart Transportation System. In fact, the framework was based on ITS Architecture from the USA and we made some changes to adapt to China's situation. It is a significant guide for the whole country. (Ms Bu, Shanghai)

From both answers above, we can see that concept of the Smart Transportation System was first put forward by the government, and that the idea was borrowed from the US. Local scientists and engineers were unfamiliar with the concept at first. And then it was spread to the whole country. In other words, the Smart Transportation System field has been formed from a top to bottom movement. After this, different scientific communities come into the field. Despite "China's Smart Transportation System Framework", there were more policies and regulations about the Smart Transportation System were released. In 2001, the MOHURD first mentioned the Smart Transportation System in its plan "Key Points of the Science and Technology Department of MOHURD in 2001 (建设部科技司 2001 年工作思路及要点)".[49] According to this document, research about the Smart Transportation System in cities were one of the "soft topics which are global, strategic and policy". In 2015, the MOT also released 38 "Key Points"[50]. The 33rd was to study the Smart Transportation System's framework. This project was assigned to the subordinate departments of the MOT: the Department of Science and Technology (科技司) and the Department of Comprehensive Planning (综合规划司). The concept of the Smart Transportation System still remained vague *and* comprehensive because practical plans were assigned to the Department of Transport (运输司), the Bureau of Public Roads (公路局) and the Bureau of Waterways (水运局), which gave scientists and experts a good opportunity to interpret these concepts from their own understanding.

Scientific research funds are another motivation for scientists and experts to

[49] http://www.mohurd.gov.cn/gongkai/fdzdgknr/tzgg/200104/20010406_158380.html
[50] https://xxgk.mot.gov.cn/2020/jigou/zcyjs/202006/t20200623_3307263.html

interpret the concept into their discipline. Ms Zhao, an expert in traffic signals working for a traffic signal equipment supply company in Chengdu, talks about changes in applying for research funds:

> *Around 2016 and 2017, we started to apply for research funds with titles like "Smart Transportation Platform" or "Big Data". In the past, our title was something like "Research on Intelligent Monitoring System on Highways". (Ms Zhao, Chengdu)*

Ms Zhao indicates that the government will support the research of the Smart Transportation System by providing research funds. However, the content of research proposals does not change very much. The real difference were their titles. They interpret the concept of "Smart Transportation" into their familiar area instead of the new area of the Smart Transportation System.

According to Kuhn (1970), a scientific community is a group of people who could be recognised separately; for instance, practitioners in a scientific speciality (Wernick & Hall, 2004). Members of a scientific community hold a series of shared beliefs, and "to an extent unparalleled in most other fields, they have undergone similar educations and professional initiations; in the process they have absorbed the same technical literature and drawn many of the same lessons from it." (Kuhn, 1970, p.177). And these shared beliefs held by members are called “paradigms” by Kuhn (1970). In other words, different scientific communities have different paradigms. From the interviews and analysis of research papers, there are two different scientific communities in the Smart Transportation System – Road and Waterway Transportation and Computers and Computer Applications. According to the participants, these areas have different “perceptions”, which means that they have different paradigms. On the other hand, a paradigm for scientists and engineers of the Smart Transportation System field is lacking. So an academic field has not been formed yet.

The field of the Smart Transportation System might be at a pre-paradigm stage (Kuhn, 1970), the starting point of a scientific discipline, and there can be many schools within a pre-paradigm discipline. Wernick and Hall (2004) add that different schools means that they are in competition with each other, because different schools have different paradigms that contribute to disagreements in the interpretation of observations and the definitions of key concepts. In the Smart Transportation System, the two competing scientific communities try to interpret the concept of the Smart Transportation System within their paradigm. However, different from the life cycle of a scientific discipline proposed by Kuhn, the Smart Transportation System field did not appear spontaneously. Instead, it is formed by a series of regulations and policy documents as well as research funding from the government. This situation makes the scientific communities in the Smart

Transportation System even more competitive. Concurrently, these differences between scientific communities are also significant. This is the barriers mentioned by the participants.

4.1.2 Different Scientific Communities Have Different, Even Divergent, Ideas About the Future of the Smart Transportation System

As mentioned in the previous section, different scientific communities have different paradigms and different ideas about the future of the Smart Transportation System. As this section will explain, when the interviewees talked about future expectations of the Smart Transportation System in the next five to ten years, the participants gave answers in detailed ways and had different concerns, indicating that they have different future expectations.

4.1.2.1 Hardware Facilities

Some interviewees are interested in improving hardware facilities. These facilities could be vehicles, subways and machines used in construction. For example, Prof. Di – a professor in the transportation system field, focusing on the Smart Transportation System –concentrates on the driverless car and related facilities.

Figure 11. A Model of the Traffic System of Driverless Cars and Related Facilities in Prof. Di's Lab.

From Prof. Di's perspective, he shares that the future of the Smart Transportation System would be the upgrading of roads, toll stations and stations:

> *Data collection facilities, communication facilities, and other facilities need to be developed in the future. And they are related to the development of roads. (Prof. Di, Beijing)*

4.1.2.2 Data

Some interviewees think that data usage would be a key point. For example, Prof. An is a professor in the transportation system field, focusing on the use of Big Data in the transportation system. He works at a university in Nanjing. He talks about the future of the Smart Transportation System and 5G:

> *[In the next five years], I think the main change will be the emerging of Intelligent Connected Vehicles [ICV ...] And more and more new cars will be driverless and they will also be equipped with the intelligent connected facilities. And 5G will come soon. For example, 5G is already being used in the Jiangsu Province. They will help the development of ICV. (Prof. An, Nanjing)*

Also, the same idea is expressed by Ms Bu, a senior expert in the Smart Transportation System field, working for a state-owned company of transportation system design in Shanghai. She thinks that one key factor is to improve the analysis process of data:

> *I think we will improve the ability to process data in the future. Because the equipment in the field is good enough and we don't*

have new facilities emerging. In the future, every city will have a center and we could see the real-time data in the center. The key is the computing ability of the center. And our goal is to improve the computing ability. It is like a person. Now we have eyes and we have collected data. But it cannot tell us how to use my hands and feet. So we improve the computing ability so it can help us make decisions. (Ms Bu, Shanghai)

4.1.2.3 Service

Some interviewees think that the development of Smart Transportation System will be future services. For example, Mr Guo is a senior expert in the field of traffic management. He works in a research institution serving the Chongqing Commission of Transport.

I think we will realize the goal "Mobility as a Service" in the next five to ten years. (Mr Guo, Chongqing)

Also, Dr Yi expresses a similar opinion. He is a senior engineer working for a state-owned company of transportation system design in Hangzhou.

Actually, the choice of technology is no longer important in the Smart Transportation System. I think it will be service-oriented. For example, we will make driving easier for everyone […] The missing part in the Smart Transportation System is the "soft part". It is not the software or the problem of APP. It is the service […] I think the service is an important direction for further development of the Smart Transportation System. (Dr Yi, Hangzhou)

This emphasis on service shows that the experts think the technology is no longer creating a barrier to the development of the Smart Transportation System. They are looking for the social aspects, such as service, to develop the program. And the idea of service also indicates that they realize that the Smart Transportation System needs to consider social dimensions and people's needs. This focus on the service will also lead to changes of lifestyle and urban design.

I think the next five to ten years will be the key point for the transportation system and even the city […] There will be a great change in the relationship between people, our living environment, and spatial organization of our cities. The next five to ten years will be a critical period of the Smart Transportation

System and it might experience a sudden change. (Dr Yi, Hangzhou)

Thus, different scientific communities have different ideas about the future of the Smart Transportation System. For example, the experts who work on driverless cars and their related facilities think that the future involves the development of facilities for collecting data and communication. The reason given is that driverless cars need to collect data and communicate with the road system. In other words, driverless cars might need a new road system that can collect data and communicate it to the cars. Alternatively, experts working on Big Data think the future involves improving the data analysis process. And experts of traffic management argue that the future involves improving services for passengers and drivers. Nevertheless, some participants think that the future of the Smart Transportation System does not depend on technology, but on economic and political factors. In other words, they do not think that there will be much difference in technology, either in terms of hardware facilities or software. For example, Ms Sheng is a senior expert in the field of driverless vehicles. She works in a research institution under the MOT in Beijing. She thinks the greatest difficulty is China's economy:

In the next five years, there will be a high probability that China's *economy will face a downward pressure. Companies and governments will be rational. Therefore, there won't be many programs about the Smart Transportation System in the next ten years because the bubble will disappear. Finally, there will be some really useful applications remaining in the area. I think it will be good for the area and everyone becomes rational. (Ms Sheng, Beijing)*

Ms Sheng indicates that although she suspects that there will be less programs in the future, she remains confident in the development of the Smart Transportation System. Especially, as the market will pick up some really useful applications as investors become rational. She sees the collapse of the economic bubble as a great opportunity for the Smart Transportation System to discard the dross and select the essential. She is quite optimistic about the development in the next twenty years instead of the next ten years. Prof. Ci is working on the test technologies in the Smart Transportation System. He thinks the greatest difficulty is data sharing:

I don't think the system of sharing data will differ much in the next ten years. The key to Smart Transportation System is to share data so that we can have a better judgement based on the *data. However, we don't see any changes in sharing data. The data could not be shared because of the current system of sharing data. (Prof. Ci, Chengdu)*

Prof. Ci argues that the key for the development of the Smart Transportation System is to improve the current system of sharing data, which means that there are new policies of data sharing needed in this area. Ms Sheng, however, worries about the economy, arguing that economic factors will influence the future of the Smart Transportation System, instead of technology. Interestingly, these disparate ideas are unrelated to these experts' disciplines in the development of technology, but to the economy and the politics of China. However, the previous ideas closely links to the backgound of the experts. One is to develop the hardware and another is to develop data. And the development of service is related to the usage of data, which emphasizes that the future is to provide service with the usage of data.

Thus, two main ideas arise from my research about the future of the Smart Transportation System: 1) the development of hardware which could be the vehicles and roads, and 2) the development of software. These two ideas belong to two different scientific communities, which are consistent with their interests. Road and Waterway Transportation focuses on hardware facilities, so its scientists see the future of the Smart Transportation System as a series of infrastructure and hardware facilities. On the other hand, scientists from Computers and Computer

Applications are interested in software and would like to make full use of a large amount data. So different scientific communities not only hold different paradigms, but have different ideas about the future of the technology. And at the pre-paradigm stage, not only are these scientific communities competing, but different ideas about the future are also competing.

4.1.3 Different Scientific Communities and Different Future Expectations: the Paradigm and the Interest

Van Lente (2012) defines future expectation as statements about the future of a technology. In other words, the participants' ideas about the future of the Smart Transportation System could be construed as future expectations of the Smart Transportation System. Two different future expectations emerged in the fieldwork. The future expectation of the scientific community of Road and Waterway Transportation is to advance data collection facilities, communication facilities, and other facilities related to the road system. While the scientific community of Computers and Computer Applications support the full use of a large amount of data. That different scientific communities have different future expectations, supports the findings of Brown, Rip and van Lente (2003) that possible variations occur across scientific and technological domains. Moreover, future expectation of a technology could also be seen as promise-disappointment cycles, as Brown, Rip and van Lente (2003) propose that actors motivate and attract other actors with “hopes” and “hypes” at the early stage of future expectation. It also helps the actors to position themselves and compete in the field as the two different future expectations compete with each other.

As discussed in the previous sections, the Smart Transportation System field is at a pre-paradigm stage, as Kuhn (1970) defined. There is not an academic discipline called the Smart Transportation System, because two different scientific communities within the field and their paradigms are in competition. The paradigms are varied, because different scientific communities hold different shared beliefs due to the participants’ intellectual backgrounds, such as the same/disparate technical literature or lessons. Furthermore, the shared beliefs help form the paradigm of the scientific communities. Meanwhile, according to Brown, Rip and van Lente (2003), future expectation is “a nested phenomenon”, which means that a promise and its related expectations should be accepted at once. Thus, the future expectations might be viewed as a series of shared beliefs about the future. In other words, the future expectations and the paradigms are all shared beliefs of the scientific communities. The paradigms are the shared beliefs that the scientific communities currently hold. However, the future expectation could be the previous shared beliefs of the scientific communities, because the future expectations could change over time. Yet, in the case of the Smart Transportation System, the statements about the future are hold by the participants at the time. In other words, they are the real-time shared beliefs of future that are derived from the paradigms of the scientific communities. Hence, the future expectations, in the Smart Transportation System, are derived from the paradigms.

In addition, interests should also be taken into account. According to Brown, Rip and van Lente (2003), the future expectations could exchange as tradable assets. In other words, future expectations not only represent the paradigm of the scientific communities, but also the interest of the scientific communities. So the competition between the future expectations of “Road and Waterway Transportation” and “Computers and Computer Applications” is not only about the paradigms, but also about the future interests. In Chapter 3, I demonstrate that the local governments now is the main investor for the transportation system. And after fiscal decentralization, local governments need to be self-financing. In other words, local governments would be more cautious in considering the investments in transport projects. The two future expectations are actually two different projects of the transportation system, and the scientific communities try to sell them to the local governments. Hence, the future expectation of the Smart Transportation System is about gaining investments, which is related to the interests of the scientific communities. Therefore, in the case of the Smart Transportation System, I demonstrate that the future expectations are varied due to different scientific communities. And the differences are derived from the paradigms and the interests of the scientific communities.

4.2 A Collective Sociotechnical Imaginary – An Emphasis on Expertise

In the first section, I demonstrated the lack of an academic discipline called the Smart Transportation System, but rather two different scientific communities: "Road and Waterway Transportation" and "Computers and Computer Applications", which hold different paradigms and interests. However, in the fieldwork, the participants also present a common idea about the future of the Smart Transportation System. Based on the fieldwork material, Section 4.2 illuminates the sociotechnical imaginary of the Smart Transportation System based on scientists' and engineers' epistemology, and fight against the algorithmic episteme, which indicates that sociotechnical imaginary could also link to the knowledge used in the decision-making process. This section is divided into five parts: first, it introduces a commonly held idea for the future development of the Smart Transportation System. Second, it illustrates the common ground for this idea. Third, it sheds light on the reason why this common idea formed. Forth, it introduces a new epistemology called the "algorithmic episteme". Finally, it demonstrates the factors that contribute to the formation of sociotechnical imaginary in the Smart Transportation System.

4.2.1 A Common Idea for the Future Development of the Smart Transportation System

The interviewees argue that the results of Big Data need to be validated before the data can be used for transportation projects. And people will use the data and its results selectively according to their discipline and training. Therefore, this technology can only be used as a supplementary tool. At the same time, the interviewees believe that the Smart Transportation System plays an important role in coordinating traffic, and that the Smart Transportation System could be considered as an aid to help us improve the efficiency of the transportation system. Interviewees have their doubts about the results generated by Big Data. They argue that validation is an essential part of the process of drawing conclusions from Big Data, to make the entire logic chain of Big Data complete. For example, Dr Yi is a senior engineer working for a state-owned company of transportation system design in Hangzhou. He argues that the conclusions drawn from Big Data must be validated before they can be used as a basis for decision-making:

> *The use of a single piece of data to draw a conclusion is logically flawed. For example, as I just said, you can have thousands of cases from hospitals, but it doesn't mean you can be a doctor. Now we often have a misunderstanding in Big Data: as long as I have data I can solve all the problems using this data. However,*

I think that we have the data, and then we need to find its principles. Then we need to verify it. Finally, we can use these principles to make a product for other people. There are several parts within this process. The situation is different. People have data and then they brag. They think they can make it. I think there are several missing parts of the logical link. (Dr Yi, Hangzhou)

Dr Yi also mentions that the conclusions drawn from Big Data may be wrong, as the use of new technology does not necessarily mean that we are closer to the truth or that the results it draws are more credible. We find that the use of Big Data makes the conclusions it produces more questionable than the other way around. So people need to validate these conclusions. He says:

Now there are many platforms or Apps. They will deposit a lot of data. The data can only be used after we judge and verify it. You can't use the data directly, because there is a large amount of data and the information you find may be wrong. For example, I want to find out whether a certain area is a crowded area or not, and then I find a large amount of data from that area. However, it is quite possible that this place has many base stations or there is only one base station around, and all the information around *has to be linked through this base station. So we have to use the data after verifying it. And there has to be a cleaning and sifting process before using the data. (Dr Yi, Hangzhou)*

Because the results need to be verified and traffic conditions are complex, people need to make decisions about its validity. For example, Prof. Yun is a professor in the transportation system field, focusing on the Smart Railway. He says:

In fact, it is an integration of data. Making decisions is the process of making decisions. The final decisions are made based on the data. It is usually the project department that makes the decisions, for example, the project general manager. (Prof. Yun, Beijing)

Because of the complexity of the traffic situation, the conclusions generated by Big Data may be inaccurate. So people still need to use standardized methods for data gathering and interpretation. For example, Mr Cai is a senior expert on the construction of transportation system in a state-owned enterprise in Beijing. He says:

Now there are a lot of zero-labour factories. However, there are *few zero-labour construction sites. The reason is that the construction of transportation infrastructure has a lot of uncertainties. Maybe the situation of housing construction is a little better. Every place you will build is different in basic conditions, such as the terrain, the hills, the rivers and roads. It's the uncertainty of geological conditions. There're also environmental conditions such as a lot of buildings and pipelines, especially dealing with them in cities. It's an external environment. There is also the internal environment such as different machines, people from different departments, different working processes in different companies. They also vary greatly [...] But you have to realize that the prerequisite for automation is standardization [...] A lot of the construction sites of our transportation infrastructure may still be largely dependent on people to decide. Mr Cai, Beijing)*

The above quotation illustrates that the accuracy of Big Data also depends on people's perspectives, and relies on the goals that people set. For example, Mr Wan is a senior expert in the Smart Transportation System field. He works in a research institution for transportation system design in Chongqing. He says:

Big Data is definitely useful. Its accuracy depends on your skills. In other words, it depends on your skills to be able to use it well. For example, we assume that the information is composed of M and G. M is the original source of information. G is the dimension of information development. Then MG as a whole means its value after information circulation. The different position it is in means that it has a different G. For information, you develop it from different dimensions and you will surely get different values. It is a matter of whether you use information well or poorly. If you use it well, you may just go through a little bit of data, and then you immediately discover its essence. (Mr Wan, Chongqing)

As Big Data depends on people's perspectives, the Smart Transportation System is a supplementary tool for the transportation system. For example, Dr Yi says:

Many traditional industries, such as traffic and urban planning, if you do not use new technologies like Big Data, you will be weak in grasping the situation. If you don't use technologies, such as Big Data or other intelligent technologies, to understand the world, the horizon will narrow. However, technologies like Big Data, I think are like a walking stick or a supplementary tool. For example, gasoline and other energy sources are important for a car, but they cannot replace the car. So I do think it has an auxiliary role. And if *we don't use Big Data, we might not be competitive. However, this auxiliary role cannot replace the thing itself.*

4.2.2 This Common Idea about the Future Lies in the Emphasis on Expertise

The future of the Smart Transportation System cannot bear fruit without human intervention. This idea shows that people play an important part in selecting data and verifying the results. Also, that people have a theoretical framework before they start to analyze data. Thus, professional knowledge or expertise is needed in data selection and verification. For example, Prof. An focuses on the use of Big Data in the transportation system. He argues that we should think about specific requirements when we talk about the accuracy of data simulation. And all these specific requirements involve expertise. He says:

> *[The accuracy of data simulation] depends on a specific demand, or what you want to do [...] For example, we want to build a commercial complex; in other words, a shopping mall. How many doors are there in this shopping mall? And where are these doors? How to design the organization of traffic? Where the vehicles should enter and exit from? And then how the vehicles are cycled? All these things require theoretical arguments, and they are impossible to imagine.*

Therefore, Prof. An implies that people need to have professional knowledge. First, he stresses the expertise held by scientists and engineers who have the professional knowledge to select data and verify results. Second, according to the interviews, scientists and experts argue that not everyone is capable of doing this job. In other words, the government, the public, and Internet companies do not have this professional knowledge. Dr Yi, for instance, is a senior engineer working for a state-owned company of transportation system design in Hangzhou. He says:

> *Traffic is a very specialized field. For example, for the judgement of the flow of people and the construction of the OD [Origin – Destination], etc., you have to be in the field for more than a decade, and constantly study it. Then you might have some experience. However, all these Big Data companies all release an index and evaluation of traffic. Those of them who, to put it bluntly, don't even have the expertise [in the transportation system], are posting this stuff. But they also have a strong brand endorsement and the ability to extract data, so it's easy for people to trust them. Their shortcoming is that they are unprofessional in this field. For example, the congestion index, what is the congestion index? How do you define it? Experts from all over the world have studied it for a long time. How to evaluate*

congestion is something that needs a very strong technical background. However, Big Data companies, such as Baidu (百度) and Amap (高德), can also release a congestion index: this year Hangzhou ranked first. Next year it might rank second, and then might rank twentieth. I think the Internet companies which have a powerful database have one big shortcoming: their understanding of transportation seems to be a bit weak. (Dr Yi, Hangzhou)

Hence, there is a common idea among the participants that stresses professional knowledge. From their perspective, the Smart Transportation System is a supplementary tool to improve the efficiency of the transportation system. It cannot work without human intervention which shows that people play an important part in selecting data and verifying results. Also, that people will have a theoretical framework before they start to analyze data.

4.2.3 The Emphasis on Expertise Counters Data-Centric Internet Companies

In the first section, I demonstrated that different scientific communities in the Smart Transportation System hold varied paradigms, interests and the future expectations. Therefore, a new question now arises as to why a common idea occurs among these different scientific communities?

4.2.3.1 The Smart Transportation System Will Unify Different Transport Sectors

According to the interviewees, the Smart Transportation System will become a new traffic regulation agency, by integrating the current traffic management agencies and different technologies. For example, Prof. Di, focusing on the Smart Transportation System, defines the Smart Transportation System as a new technology combining several new information technologies:

> *The Smart Transportation System is a synthesizer. From my professional point of view, it is a collection of sensor technology, communication technology, computer technology, and automatic control technology in the early stage of its development. Nowadays, in China, it also combines Big Data, cloud platforms, cloud computing, the Internet of Things, and they are applied to the transportation system [...] Therefore, the Smart Transportation System is mainly the inheritance of traditional and basic technologies: data is obtained by sensor technology and detection technology, and finally collected in the Big Data Center or cloud platform, and then given to the administrator and to the public by the means of the Internet. The aim is to improve the efficiency of traffic operations. (Prof. Di, Beijing)*

The Smart Transportation System also involves the combination of several transportation activities. For example, it will combine metro, car, bus, cycling journeys, etc., which will require integrating different transportation sectors. At this stage, in China, metro and bus companies, the department of city roads and the department of city tunnels are all separated and the Smart Transport System would bring these departments together. For example, Mr Guo describes this idea:

> *A lot of transportation activities, whether it's by car or by rail, or by walking or by bus, we want to arrange them in a smart way. Let's assume that there is such a system or a platform or whatever Internet service that could schedule the whole trip from A to B (Mr Guo, Chongqing)*

Mr Zhu puts this point more bluntly; that traffic activities currently managed by different departments will be regulated by one department in the future:

> *I think it is crucial for the city to make up its mind to do or not to do. Because when you make it as a Smart Transportation System, you need to tell the control center from the beginning to the end so that the control center can control it (Mr Zhu, Hangzhou)*

Prof. Ci, working on testing technologies using in the Smart Transportation System, argues that currently traffic problems are not easy to solve because different departments are responsible for them. In other words, traffic issues need to be handled by a highly integrated agency by integrating different departments into one institution. Prof. Ci says:

> *[...] the reason why it is not easy to deal with is that it is divided into different departments [...] For example, the Traffic Management Bureau [交通管理局] is in charge of specific traffic intersections and vehicle management. The Municipal Commission of Transportation [市交通委员会] is responsible for taxis, buses, metros, toll stations, etc. However, there are bus companies for buses and subway companies for the metro. Traffic is highly in need of a systematic and integrated way to deal with it. Only then is it possible to have a good solution. However, traffic is now divided into different departments, which have led to our solutions being usually separated.*

The use of Big Data is becoming a trend not only in the field of transportation but also in other areas of government decision-making and management, which is called "e-government". Its advantages and disadvantages were summarized in

Chapter 3 (Section 3.2.1), including that the Chinese government does not have enough data resources at its disposal. Internet companies have more data in terms of quantity and variety. Moreover, the Chinese technology giants, involved in this new trend, have started working on the ITS. For example, Alibaba (阿里巴巴)[51] corporating with Hangzhou's (杭州) local government developed a system using Big Data to help manage the transportation system – "ET City Brain (阿里云城市大脑)".[52]

4.2.3.2 The Internet Companies – Comprehensive Platforms

As discussed above, Internet companies are involved in the Smart Transportation System due the large amount of data they hold in China. The participants talk about their worries about Internet companies such as Baidu, Alibaba, Didi (滴滴), and Amap (高德). Before I start this discussion, however, I would like to clarify some features of the Internet companies in this context. First, most of the Internet companies that participants discuss are not state-owned enterprises. Second, the businesses of these Internet companies are so integrated that it is difficult to simply categorize them as navigation, communication, or shopping. For example, Baidu is famous for its search engine. After Google withdrew from China, Baidu became the largest search engine in China. Additionally, Baidu plays a significant

[51] **Alibaba Group Holding Limited** is a Chinese technology company in Hangzhou (杭州) focusing on e-commerce, the Internet and retail, and famous for its electronic payment service Alipay, the online shopping search engine Taobao, and cloud computing services Aliyun.
[52] The website of "ET City Brain": https://et.aliyun.com/brain/city

role in developing driverless cars and digital maps. Another example is Amap that belongs to the Internet company Alibaba. Amap is famous for its digital mapping; while Alibaba is famous for its e-commence. Also, Alibaba has launched a bike-sharing business. The data owned by these Internet companies, as the participants mention, are also diverse. It is difficult to categorize this data into a single area, such as traffic data, personal information, and so on, as the data collected by these Internet companies involves all kinds of data which are drawn together. For example, traffic data is collected when people use digital maps. However, people will use the same app from the same company to shop online and use shared bikes.

Figure 12. Screenshot of the APP of Alipay. Screenshot taken by the author, September 2019.

For example, Alipay (支付宝) is an app developed by Alibaba. It was originally a payment software, similar to PayPal. Now Alipay (see Figure 12), enables a user to track their parcel (the logo of an orange truck), check medical services (green heart logo), and transportation services (two blue arrows), including buses, shared bikes, metros and taxis. Thus, although I will refer to these companies as Internet companies in this thesis, these Internet companies are involved in many aspects of our daily lives. It is difficult to distinguish between them as "Internet companies with traffic data" and "Internet companies with other data" as they have developed comprehensive businesses from e-commerce to digital mapping.

From the perspective of the interviewees, such Internet companies try to make people believe that the Smart Transportation System is about a large amount of data that could work independently; that the organizations with the most data will be able to draw the most accurate conclusions. While the only ones who have access to a large amount of data on every aspect of our daily lives are actually the Internet companies. In the Smart Transportation System, organizations with the most data usually are enterprises such as the Internet and telephone companies. According to Prof. Huan, focusing on data analysis in the transportation system, only these large Internet companies can now hold such a large amount of data:

> *For example, Baidu [百度] has built a set of things based on his own deep learning technology of Big Data in Beijing. And then they said that they are able to reduce the average waiting time per vehicle. They want to reduce it by 30%. [...] This involves*

installing a new system, like upgrading the accessories of the signal in the area, which can monitor traffic conditions in real time. Then it goes through a complex set of models, based on several models it was previously trained on. And then it can change the traffic signals to match the real time traffic conditions [...] So maybe only companies like Baidu and Ali [阿里] are able to achieve such a goal. Thus, we can say that it is profitable for companies with a large amount of data to set the validation criteria – as the more data they have, the more credible they are, whether or not they consider the conclusions drawn from Big Data to be reliable. (Prof. Huan, Shanghai)

Chinese universities and research institutes get their data from these companies. For example, Prof. Ci, who works at a university in Chengdu, talks about the difficulties he faced in gaining data from these companies:

The data is difficult to obtain. For example, we need data from mobile phones for our study. Therefore, we need to contact with China Mobile and China Unicom. We need to get the data from their databases. In the past, they were reluctant to give us the data, because they felt there was a security risk. Now they are *willing to give us the data, but they sell it at a very high price. For example, our college needs a lot of data. It would be better to have a few months or a year of data. While the companies will sell it in 700,000 to 800,000 Yuan (almost 100,000 US dollars) per month. This price is too expensive for our research project, and the project fundings cannot cover it. (Prof. Ci, Chengdu)*

Government departments also need to access data through these companies. For example, Mr Guo, a senior expert in the field of traffic management, thinks one barrier in accessing data from companies is because of the data's commercial profits. He works in a research institution under Chongqing Commission of Transport. He says:

Now the government is strengthening its management in the data sharing area. That is to say, the government requires companies to protect the underlying data. There are privacy controls. But, you know, a lot of companies have its interests (in selling data). However, social institutions like us find it hard to get data from them. For example, China Unicom, it definitely has all the underlying data. So the companies it is associated with, or its subsidiaries, must be using the data at a greater depth than we are. They don't inform the public, but they can analyze and *get the results [...] We are now using their published data for some projects as well. However, these major Internet companies may think that our* analyzes *are not meaningful to them, because we focus on the transportation system. They don't think that the study is meaningful, so they are less willing to work with us or less willing to provide the data [...] We can now get access to some data from the Internet, all of which is opened to the public. However, if you want to dig further, they are not willing to open the database to us. On the one hand, they see little benefit in these projects. On the other hand, from my point of view, they may think that if one day they want to find something from the data, they can easily reach that goal. (Mr Guo, Chongqing)*

According to the interviewees, the Internet companies try to convince people that the results released by them are accurate and authoritative, because they own the largest amount of data. For example, Mr Guo says:

Yes, not only is there no way to verify it [the conclusions given by the Internet companies], but it is also riddled with errors. From our professional point of view or a mathematical point of view, in order to do any evaluation, there is a basic logic: we must first have a statistical scope. Then we have statistical standards, *including time and frequency. And then you can say that we have established an evaluation system, and we can draw a conclusion. This is the basic logic of doing any evaluation. Now you [the Internet companies] don't tell me anything, and you just say that the transport in this city is better than that one or that city is worse than another one according to your evaluations. It's definitely a problem. Because something can be seen on the surface, that it's problematic.*

The Big Data companies, such as Baidu [百度] and Amap [高德], release the congestion index of Chinese cities every year [...] The congestion index cannot be verified and it is full of errors [...] However, now in China, one of the characters is that capital power is very strong. The companies have a louder voice than us. And all cities cannot argue with these companies. For example, if you talk with them that there are special situations in Chongqing and Chongqing cannot be compared with Chengdu [another Western Region City]. The index is wrong. The companies will answer that, "I have data from all cities and how much data do you have? And we also have our index." As I understand these companies, they are quite simple. They don't *want to earn profits by releasing the index. They only want to hold the power of speech. If the city uses their index as an assessment standard in the future, it will be terrible. Now it is the trend. Now many mayors are facing pressure because of the congestion index. For example, in 2018, Chongqing was in the top three according to the congestion index. Whether it is right or wrong, the mayor of Chongqing was under great pressure. So what will this pressure bring? Many departments will contact these companies. To put it plainly, they will talk with these companies about whether they need to adjust or something, you know the truth. It is what I have. Through this means, they have cooperation programs in many cities [...] So this is the power of this capital. It doesn't matter whether the index they released is right or wrong. It is not important. When they continue to release the index, it will surely put pressure on the leaders of many cities or their related departments. While it [the results of Big Data] is released to the whole of society. So this kind of pressure will quickly translate into a lot of practical movements, and then there is a chance that we might do wrong and end up having some problems, and that's my concern. For example, this city will pay them [the companies] some money and another city will do the same thing.*

The detail of his opinions is important here, so I quote him in full to emphasize he is not simply talking about technology but the influence of power (being in the hands of Internet companies), which means that government decisions about transportation are being made on inaccurate, or unverifiable, results. And Mr Guo continues to talk about how the results can influence the public:

Q: So will people believe it [the conclusions made by the Internet companies]?

Mr Guo: Our area of expertise is very simple. It has a feature: all people are associated with transportation, including seniors and children. For example, as a senior citizen, I can still feel whether it is convenient and safe even if I leave home once a day. Since it's relevant to the whole society. Any kind of information released will be of interest to the whole society. If you publish a sociological opinion, people probably won't pay attention to it. But traffic is everyone's concern, and it is the biggest problem. So these companies have caught the hotspot of people's attention. Any information that they post on the traffic in Chongqing, for example, is sent to the whole city. And the

Internet is so developed now. People will soon comment that the traffic in Chongqing is terrible and it is all messed up, dropping from, for example, third to ten. Have a look at the other city, Chengdu. We then will face great pressure. But we don't feel that way. For example, we feel that we are doing better than Chengdu in some places. However, you can't explain to the public why we're ranked behind Chengdu. Because it [the ranking] is specially aimed at the public, the public feels that they have a high level of authority.

Q: Can you come up with an evaluation system [for the traffic] too?

Mr Guo: We have launched our own evaluation system, but for the public, it can't be compared to someone else's [the Internet companies] credibility. The public definitely believes in them [Internet companies].

Moreover, Mr Guo provides an example about how far from the index, real situations in China's cities are:

The Big Data companies have a ridiculous indicator. For example, *a core indicator of theirs is the congestion index. How does the congestion index work? It is quite simple. For example, we make an assumption that you drive from Jiefangbei [the city centre of Chongqing] to here, or you take a taxi. You may need 15 minutes in off-peak time while you may spend 30 minutes at peak time because you may be in a traffic jam. So we divide 30 minutes by 15 minutes, which is 2.0. It assumes that the time you spend at off-peak time is 1 and then you spend 1.2 times, 1.3 times at peak time. Then we get the congestion index, for example, 2.0. It is the evaluation system. It is simple. And you may think that it is pretty right. However, from the perspective of experts, it is totally wrong because the basic logic is wrong. For example, the off-peak time and the peak time in every city are different. For some cities, the difference between the off-peak time and the peak time is slight because they are congested all day long. So you will see that the congestion index of these cities is quite low so the index of Beijing might be the lowest. However, in Chongqing, we don't have traffic jams in the off-peak time. And the congestion index of Chongqing is much higher than in Beijing. But you know which situation is better.*

The evaluation given by the Internet companies is a despecialized one. However, Mr Guo provides examples why that to improve the traffic situation, it is better to adapt to local conditions. Therefore, the evaluation released by the Internet companies may not be useful in providing information about how to avoid traffic congestion. Also, the interviewees expert opinions demonstrate that the meaning of the data cannot be determined by the data itself, it requires expert interpretation. Thus, invalidating the idea that 'the greater the amount of data, the more accurate the results'.

In this case, it is the Internet companies that determine the significance of the data. For example, some Internet companies organize yearly competitions to explore how to use data. Prof. Yuan is a professor in transportation system signal control and has been involved in many local projects. He works at a university in Nanjing. He gives us an example of one such competition:

> *Sometimes the data are objective. Now another argument for why people want to invest in those [Internet] companies is that we all know the data are useful, but we haven't found a good selling point yet. So it's not like the way that I will give you the data you need. It might be the other way around. Anyway I started this company. I just need to be able to keep it running. I will feed everyone on illusions and make people feel that the data are useful. So how does the data work? For example, Didi [滴滴],*

it announces some contests about how to use the data every year. I will leave it to you. Let's go ahead and try it. Let's do some brainstorm. Whoever has some good ideas, it will use them. For the companies, it is perfect, right? I think it is the pattern now.

4.2.4 The Algorithmic Episteme: A New Type of Knowledge

4.2.4.1 The Algorithmic Episteme

Technocracy argues that scientists and technologists could use their expertise to manage the society. As discussed in the previous subsection, people play an important part in selecting data and verifying results. Data selection, verification of the results and selection of the theoretical framework requires expertise. In contrast, Internet companies rely on data, which could be seen as a new kind of knowledge or as Fisher (2020) defines "the algorithmic episteme". Fisher (2020) argues that the knowledge generated by Big Data should be considered a new type of knowledge, as algorithms of Big Data would see the reality in a different way, which is also called "the data gaze" by David Beer (2018). So it could be seen as an epistemic object. Moreover, Fisher argues that algorithms "re-conceptualize and redefine that which they see" (Fisher, 2020, p.5). For example, Fisher concludes from the use of Waze (satellite navigation software), in Israeli cities, that the algorithm provides "new knowledge about space" (Fisher, 2020, p.4).

In this case, the algorithmic episteme of the Internet companies involved offer a new knowledge of traffic conditions; they redefine traffic conditions, generating a new understanding of traffic congestion. This new definition collects traffic data from across China, and divides the cities' peak-hour travel time by their off-peak hour travel time to produce a "congestion index (拥堵指数)". Then cities are ranked according to this index. For example, the companies Baidu and Amap release their congestion index every year. As introduced in the previous subsection, the problem with this definition is that it does not take into account the specificity of different places. For example, according to Mr Guo, a senior expert in the field of traffic management, Beijing is jammed with traffic during both off-peak and peak hours. However, according to the definition of Internet companies, it has a small congestion index. In comparison, Chongqing does not have traffic congestion during off-peak hours, but only during peak hours. However, according to the definition of Internet companies, Chongqing has a big congestion index and is placed ahead in of Beijing in the congestion ranking. Although this algorithmic episteme has such obvious flaws it has gained public trust. As Fisher (2020) concludes, the algorithmic episteme is viewed by the public as "a much more objective, less political episteme" because "it evades biases, stemming from human-centric normative and epistemic predispositions; what's more, since it requires no hypotheses it is less susceptible to central planning and to the power of a sovereign (such as a political authority or a scientist)" (2020, p.5).

In addition, Internet companies participate in the city's traffic management and the decision-making process of the Smart Transportation System based on their algorithmic episteme. For example, as I cited Mr Guo saying, in the previous subsection, the Internet companies' motivation is not to earn profits but to retain *"the power of speech"*, despite their data releases putting pressure on local mayors to make changes, based on potentially incorrect recommendations/data, and *"there is a chance that we might do wrong and end up having some problems".*

That these companies *"want to hold the power of speech"* could be seen as a right to participate in urban transportation governance and decision-making processes. It could also be seen as an obstruction through control of the data because the algorithmic episteme is "opaque, proprietary and subject to frequent change" (Fisher, 2020, p.5). In this case, the algorithmic episteme of the Internet companies cannot be verified. For example, Mr Guo says:

> *Because it's not a fair conclusion. It's a mandatory thing. It doesn't need to tell us the standard of its data collection or anything like that, and it doesn't need to let you know. or anything like that, and they don't need to let you know. They don't even talk to you, and they just give you a ranking of city's transportation conditions: "The traffic in this city is worse than*

that one". So I think it is wrong because they are not a third-party company, and they are not the fair ones. Because these companies need to release all their standards, including the data collection. You need to be open and transparent. And then anyone can verify your standards. Now they are not, and they just release the conclusion. There is no reasoning with them. (Mr Guo, Chongqing)

Therefore, the algorithmic episteme is as a part of decision-making process as the empirical knowledge that local governments rely on, and the expertise/resource that the scientists rely on. Thus, the algorithmic episteme should be seen not only as a new epistemology, but with its presence in social life and political decisions can also be seen as a new claim to political rights, as Fisher (2020) suggested. Thus, the participants interpret the Smart Transportation System on the basis of their own knowledge to make the interpretation favourable to themselves, and the interpretation would further influence the decisions.

4.2.4.2 Digital Discourse

Inspired by discussions and studies on the topic of digital labour, I argue that Big Data could be seen as a new technology discourse that is called "digital discourse". A discourse which is at the center of contemporary society, which reshapes social, political and cultural activities, so it is “the paradigmatic architecture of social action” (Fisher, 2010, p.236). A digital discourse first works as an episteme, and then the episteme works as a legitimation discourse that could legitimize a new power structure through a new technological framework. The digital discourse is difficult to criticize, because the link between the algorithmic episteme and the interests of Internet companies is hidden as the Internet companies are involved in the transportation governance in a covert way. So it remains difficult to regulate under the existing mechanism.

Three theoretical frameworks describe the relationship between technology and society. The first is technological determinism, which means that technology can shape society. While the second is an objection to technological determinism, which argues that technology is shaped by society. Although these frameworks have different views on the relationship between society and technology, they both view technology as an instrument (Fisher, 2010). From above discussion, Big Data has become more than just a technology or an instrument. It is more than a new epistemology, but is also a new claim to political rights. Internet companies are using the algorithmic episteme to intervene in social life and political activities. Therefore, in this case, the relationship between technology and society is the third kind of approach – technology as discourse.

The “technology as discourse” approach concurs that technology is at the center of modern society: one that “plays a constitutive role” (Fisher, 2010, p.231). Namely, that people are revisiting political, social and economic activities through technology. This new technology discourse brings a new framework that people can use to reorganize social life. Furthermore, “technology discourse is seen as central in shaping the political, cultural, and social Zeitgeist.” (Fisher, 2010, p.231). Here, Big Data could be seen as a new technology discourse or “digital discourse”, as proposed by Fisher (2010). According to Fisher (2010), the digital discourse is “a hegemonic body of knowledge that explains the structure and dynamics of contemporary society as arising from the structure and dynamics of network technology, or information and communication technology” (p.235). Fisher’s (2010) digital discourse is based on the idea of “technology as discourse”, and takes the strongest version of this approach developed from the Frankfurt School: one of ideology which means that “technology discourse has come to play a central role in the legitimation of a techno-political order” (Fisher, 2010, p.231). So the technology discourse is one of legitimation. Simultaneously, Fisher suggests that the dominant technology of contemporary society has shifted from mechanical technology to IT which helped develop a new capitalism. Thus, the digital discourse is closely related to new capitalism based on IT.

Fisher (2010) proposes three characteristics to this digital discourse. First, the digital discourse is based on IT, so it has the characteristics of IT which differ from previous dominant technologies, such as being “socially transformative” (Fisher, 2010, p.235). Second, the digital discourse indicates "a radical historical break" (p.235) as postindustrialism, postmodernism and posthumanism. Third, the concept of networks is at the centre of digital discourse. Comparable to other technology discourses, Fisher argues that the digital discourse is not only a kind of technological paradigm, but also "the paradigmatic architecture of social action" (Fisher, 2010, p.236).

How does this digital discourse work in contemporary society? First, the digital discourse is an episteme; that is, "a body of knowledge that is inextricably intertwined with technological reality, social structures, and everyday practices" (Fisher, 2010, p.235). Second, as previously argued, the digital discourse is a legitimation discourse that could legitimize a new power structure through a new technological framework. For instance, Big Data platforms want to participate in social governance and the political decision-making process with the algorithmic episteme, thus changing the current power structure. For example, Fisher (2020) finds that Waze created its algorithmic episteme about space, and it claimed its "right to the city" through this digital discourse. Therefore, Waze becomes an additional actor to the experts, the public, and local government in the decision-making process.

In the Smart Transportation System, the congestion index provided by the Internet companies could be seen as a digital discourse. The Internet companies redefine the meaning of traffic congestion with their congestion index – a new form of knowledge about traffic congestion. This new kind of knowledge is a digital discourse. It is accepted by the public, and forms public opinion that could further influence the decision-making process. In this way, the Internet companies have become a part of urban transportation governance in China.

The digital discourse is difficult to criticize. As discussed above, it seems at first to be objective, because the data source and analysis are opaque as the Internet companies make the data speak for them. Thus, the link between the algorithmic episteme and the interests of Internet companies is hidden, so that they are involved in the transportation governance in a covert way. They participate in the decision-making process by influencing the public, but they do not take the responsibility. They could influence final decisions, but they are not responsible when those decisions do not work. This phenomenon is even more evident in digital labour, which is one of means by which digital discourse reshapes social life. Under the traditional wage-labour systems, employers provided long-term labour rights protection for their employees. However, the emergence of Big Data platforms has led to the replacement of permanent employment contracts with labour contracts such as “pay as you go”. Therefore, Internet companies can focus only on the benefits, for their company, without providing long-term labour rights protection for their employees. Thus, while digital discourse is reshaping every aspect of society and politics, it is still difficult to regulate under existing policy mechanisms.

In conclusion, Big Data as a new technology discourse (digital discourse). The digital discourse first works as an episteme, and then the episteme works as a legitimation discourse that legitimizes the new power structure through a new technological framework. Moreover, the Internet companies are involved in transportation governance in a covert way. So it is still difficult to regulate them under existing law.

4.2.5 Sociotechnical Imaginary: Epistemology and the Knowledge Used in the Policymaking Process

As discussed earlier in this chapter, different scientific communities hold a common idea around the necessity of expertise for the future development of the Smart Transportation System, despite their different future expectations. In section 4.1, I illuminated that this idea is commonly held despite the differing paradigms and interests of the scientific community, and it is also an idea about the future of the Smart Transportation System, but not the same as future expectations. Another concept which could be used to describe these ideas about the future of a technology is sociotechnical imaginary. According to Jasanoff's (2015) definition of sociotechnical imaginary (Section 1.1), an important aspect is "shared understandings"; a collective vision held by the engineers and scientists of the Smart Transportation System field.

Recalling, Zhu and Tian (2008) four types of knowledge used in the Chinese decision-making process (from Section 1.1), the experts of the Smart Transportation System would take part in the decision-making process under “expert knowledge”. Meanwhile, Jasanoff (2015) definition of sociotechnical imaginary shows that sociotechnical imaginary needs to be “institutional stabilized” which often refers to policy documents in case studies. Yet, according to Jasanoff (2015), instrumental political action could also refer to politics – the government’s decision-making process. Thus, the commonly held idea about the role of expertise in the future of the Smart Transportation System could be construed as a sociotechnical imaginary, closely related to governmental decision-making processes.

Alternatively, this emphasis on expertise fights against an epistemology held by the Internet companies – the algorithmic episteme (Fisher, 2020). And the algorithmic episteme is usually held by the Internet companies in China, because it is a form of knowledge derived from the study of large amounts of data, and Internet companies collect a large amount of data due on the comprehensive platforms they own. Obviously, the algorithmic episteme is quite different from the sociotechnical imaginary of the engineers and scientists. Thus, the sociotechnical imaginary is related to the epistmology of a group of people. In this case, the sociotechnical imaginary of the Smart Transportation System is based on the scientists' and engineers' epistemology, and fight against the algorithmic episteme.

As discussed above, the sociotechnical imaginary is closely related to politics. In this case, the sociotechnical imaginary of the scientists and engineers indicates that the decision-making process calls for expertise. The algorithmic episteme also links to politics. As part of the digital discourse Internet companies try to involve themselves in the decision-making process with their algorithmic episteme. Therefore, the sociotechnical imaginary of the scientists and engineers attempts to exclude the algorithmic episteme from the decision-making process which indicates that sociotechnical imaginary could also link to the knowledge used in the decision-making process.

Conclusion

My aim in this chapter was to distinguish two important concepts – future expectation and sociotechnical imaginary – in light of (1) Kuhn's (1970) paradigm, (2) the algorithmic episteme proposed by Fisher (2020), as evidenced by my interviews and research paper analysis of the Smart Transportation System. As Berkhout (2006) points out, varied and unclear concepts have hindered STS research on future-oriented representations and anticipatory practices. In particular, the mixed use of two concepts – future expectation and sociotechnical imaginary – are applied directly in case studies. Hence, in this chapter, I argue that future expectations, in the Smart Transportation System, are derived from the paradigms and the interests of two scientific communities: Road and Waterway Transportation, and Computers and Computer Applications. And the sociotechnical imaginary of the Smart Transportation System is based on the scientists' and engineers' epistemology, and fight against the algorithmic episteme. Also, sociotechnical imaginary could also link to the knowledge used in the decision-making process.

First, I identified through interview materials and the analysis of papers that different *future expectations* relate to two scientific communities in the Smart Transportation System field. I employed Kuhn's paradigm to demonstrate that their future expectations might be viewed as a series real-time shared beliefs of the future, which are derived from different community paradigms. Moreover, in the context of fiscal decentralization in the Reform era (1978 – Now), local governments would be more cautious in considering investments in transport projects, because they need to be self-financing. The two future expectations are "tradable assets" (Brown, Rip, and van Lente, 2003) that are related to the interests of the scientific communities, and the scientific communities try to sell them to the local governments. Therefore, the future expectations are derived from the paradigms and the interests of the scientific communities in this case.

Second, *sociotechnical imaginaries* link to epistemology and knowledge used in the decision-making process. Drawing on the interview materials, the collective sociotechnical imaginary of the Smart Transportation System is seen as a supplementary tool to improve the efficiency of the transportation system. This collective sociotechnical imaginary emphasizes expertise in selecting data and verifying results. Experts take part in the decision-making process in China along with internal government, public and media knowledge. Moreover, the emphasis on expertise is to fight against the algorithmic episteme and digital discourse (Fisher, 2020), at the epistemological level and at the political level. Thus, it indicates a link between sociotechnical imaginary, epistemology and knowledge used in the decision-making process.

Chapter 5. The Dynamic between Local Governments and Central Government

The political and economic background reveals that the development of China's transportation system could be seen a political and social space in which central government and local governments interact. Also, it is clear that the transportation system has always been a government-led field. In this chapter, I analyze the sociotechnical imaginary of the central government, and the future expectations of local governments through governmental documents and fieldwork materials. Chapter four is divided into three sections. Section 5.1 introduces the sociotechnical imaginary held by central government and the future expectations of local governments. Section 5.2 analyzes these sociotechnical imaginary and future expectations to demonstrate that the sociotechnical imaginary of the central government is positive, which is influenced by the idea of The Third Wave. While the future expectation of the local governments is comprised of a positive attitude combined with negative expectations that lead to realistic choices being made. Section 5.3 explores the reasons for these future expectations. Finally, Section 5.4 proposes a new sociotechnical imaginary for the next five years.

5.1 A Sociotechnical Imaginary and Future Expectations – From Central Government to Local Governments

In this section, I will analyze the sociotechnical imaginary of China's central government and the future expectations of the local government through governmental documents and fieldwork materials. I argue that the sociotechnical imaginary of the central government is partly ambiguous, broad and vague (Subsection 5.1.1). However, this ambiguous sociotechnical imaginary is a kind of "Designed at The Top Level (顶层设计)" approach, as the goal of central government is to attract as many supporters as possible in order to be able to access more resources and explore more possibilities for new technological development. While the local governments' future expectations (Subsection 5.1.2) are specific, focusing on infrastructure development. As the sociotechnical imaginary of the central government is vague, the local governments develop their future expectations to construct different smart facilities. However, the future expectations of the local government have one thing in common: the future expectation could be evaluated in a quantitative way.

As discussed in Chapter 3, the transportation system has always been a central government or local government-led field. So the development of transportation system could be seen as a political and social space where central government and local governments communicate, fight and compromise. Conflicts between the central and local governments show that these jurisdictions have different interests and concerns. Therefore, in this chapter, I discuss sociotechnical imaginaries from central and local government levels (Subsection 5.1.3).

Different interests and perspectives lead to different sociotechnical imaginary as well as different actions. In the study of an offshore wind project in China, Korsnes (2016) distinguishes between long-term imaginary and specific expectations. According to Korsnes (2016), expectations

> "are connected more 'locally' to a specific technological project, whereas sociotechnical imaginaries are long-term, state-induced desirable futures. Expectations can work to break new ground, create protected spaces, be self-fulfilling and mobilise new actors to support or oppose a technology. We can assume that collective expectations are malleable and can be drawn upon by governments. Expectations can also be contradictory, and we can expect the Chinese government and industry stakeholders to attempt to make certain expectations more credible than others. These expectations, in turn, impact the government supported imaginaries. We can expect sociotechnical imaginaries to be present as general understandings of good and desirable futures in the social world

writ large." (p.56)

Likewise, in order to distinguish the sociotechnical imaginaries between central and local governments, I will follow his distinction between imaginary and expectation. I will use "imaginary" to define the central government's ideas of the future of the Smart Transportation System, and "expectation" to define the local government's ideas.

5.1.1 Central Government: An Ambiguous Sociotechnical Imaginary

Exploring the sociotechnical imaginary of the central government through documents released by the MOT and my interviews, the sociotechnical imaginary of the central government is partly ambiguous. Central government proposes developing future infrastructure for the Smart Transportation System. Yet the central government does not propose specific projects; for example, the term "smart facilities" in their documents could be interpreted in multiple ways. Half of the goals proposed by central government, that I extracted from their documents, are broad. As the interviewees note, there is no clear direction given, but three general directions: management, service and decision-making. Therefore interviewees argue that there is a lack of direction "Designed at The Top Level (顶层设计)", which indicates the missing of the role of the central government in this new technology. However, I argue that this ambiguous sociotechnical imaginary could also be a kind of “Designed at The Top Level (顶层设计)” approach. Meaning that central government’s sociotechnical imaginary is relatively broad and vague on purpose, as their goal is to recruit as many supporters and to explore as many possibilities as possible to be able to access more resources. Thus, the sociotechnical imaginary of the central government is not about setting a clear future goal.

According to Jasanoff’s (2015) “sociotechnical imaginary”, a sociotechnical imaginary of the Smart Transportation System can be found in the documents released by the departments of central government. Policy documents on the Smart Transportation System, for instance, are therefore mainly released by the MOT department which manages the development of the transportation system in China, including railway, road, air and water transportation. The “Five-Year Plans (五年计划)” are a set of social and economic development initiatives which, since 1953, have been developed every five years to guide the nation’s development. These documents are called the “First Five-Year Plan (1953–1957) (一五计划)”, the “Second Five-Year Plan (1958–1962) (二五计划)”, and so on. The “Thirteenth Five-Year Plan (2016 – 2020)”, released in March 2016, and its connected policies are closely related to the development of the Smart Transportation System. In September 2016, China also released “The Proposal on Accelerating the Construction of the Smart Transportation System (关于加快推进智慧交通建设的建议)”. This document states that the Smart Transportation

System is the strategic direction and goal to achieve an information-based transportation system in the future".

In January 2017, the MOT released another plan based on the goal of Thirteenth Five-Year Plan – "Action Plan to Promote the Smart Transportation System (2017-2020) (推进智慧交通行动计划 [2017–2020])". The four goals in this plan could be seen as the central government's imaginary for the development of the Smart Transportation System. The four goals, to be achieved by 2020, proposed using Big Data to improve: (1) *Smart Infrastructure*, with a focus on transportation infrastructure construction; (2) *Smart Production Organization*, with a focus on management; (3) *Smart Transportation Services,* with a focus on service; and (4) *Smart Decision-making,* with a focus on the decision-making process. These four goals encompass four areas (construction, management, service and decision-making), and there are 12 specific tasks related to the four goals given in the document. First, in order to achieve Smart Infrastructure, the document suggests using Building Information Modelling (BIM) during construction and to upgrade transportation infrastructure with smart devices. Second, to achieve Smart Production Organization, the document suggests five specific tasks including four in construction (smart logistic parks, transportation hubs, ports and transportation equipment) and one task to improve business management. Third, to achieve improvements in Smart Transportation Services, two tasks are given to improve information services and develop new modes of transportation service. Forth, in order to achieve Smart Decision-making, the document proposes three tasks: to improve the support capabilities for decision-making, enhance the handling capabilities for accidents, and improve traffic enforcement. Among these 12 specific tasks, only six of them are about construction and relatively clear, including constructing a BIM system, upgrading infrastructure, and building several smart facilities. The other 6 tasks are not that transparent; for example, we might not know how to improve the support capabilities for decision-making, and we might also have questions about how to improve business management.

The fact that the four goals of the plan fall into four different areas also poses difficulties at the practical level. In the interviews, the participants mention that the goal of the Smart Transportation System is unclear, and they do not know which direction to go in. For example, Prof. Huan, focusing on data analysis in the transportation system at a university in Shanghai, expresses his confusion and worries about the future of the Smart Transportation System:

> *There is another problem. Now everyone thinks that the Smart Transportation System is promising, right? It will be well developed in the future, right? However, which direction will it choose? For example, what kind of function could it achieve in the future? Whether or not it will solve problems, such as congestion, and improve road safety to a higher level. I think it*

all remains unknown, right? What kind of goal do you want to achieve in the end? I don't think it [the new technology] is goal-oriented. In other words, you must know that to what extent you can achieve and then you try to achieve the goal. However, we don't have an overall plan or goal of future development. I think that everyone is not clear now, nor is there a very accurate expectation. And then everyone just THINKS [emphasized word] that it is the future and it is a trend. (Prof. Huan, Shanghai)

Additionally, Mr Cai, a senior expert on the construction of the transportation system in a state-owned enterprise in Beijing, expressed his lack of guidance in detail:

Now we all know that the central government is promoting the Smart Transportation System. However, you have to know that if you really want to make it done, you must have a series of plans. First, you should change the assessment system, right? For example, the Ministry of Industry and Information Technology of the People's Republic China [工业与信息化部, MIIT] should draw up a plan and release the guidance. It needs to be designed at the top level [顶层设计]. For example, what kind of software are *you going to develop and how do you promote it? And another question, do you train people to meet the needs? You should have financial support. [...] You have to do it like this. In China, if the leaders don't care about the program, it cannot be developed. (Mr Cai, Beijing)*

Mr Li, a senior expert in the metro system in Beijing, thinks that this uncertainty about the future of the Smart Transportation System will affect investors' motivations:

First, in China, we don't have a clear definition of the Smart Transportation System [...] There are several definitions [...] For example, for the subway, any changes must be planned at the beginning [...] We have to plan ahead, but we don't know whether we will achieve the goals or to what extent can we achieve [...] In theory, the Smart Transportation System will reduce the cost in the end. But in the beginning stage, it will raise the cost. Only when it reaches a certain stage can it reduce the entire cost [...] The biggest problem now is that who is willing to lead the initial investment to a newly emerging technology [...] Investing huge amounts of money is not always rewarding. (Mr

Li, Beijing)

From the above plans and interviews we find that the direction of the Smart Transportation System is unclear. So it is difficult to predict its final results; if, for example, investors will step into this area. Moreover, the duration of it is not clear. Investors are hesitant because of the uncertainty. For participants, these problems can be concluded as the lack of “Designed at The Top Level (顶层设计)” approach. “Designed at The Top Level” is a unique phrase. As explained in Chapter 1, it used to be an engineering term to think about every level and every element when solving problems from the highest level, and it gradually become a political term in the Chinese context. The term, used in this context, indicates that the central government does not play a role that controls every thing from the highest level.

5.1.2 The Future Expectations of Local Government

According to local governments' documents and materials from the fieldwork, the future expectations of local governments focus on infrastructure development, and are therefore consistent with the sociotechnical imaginary of the central government. However, the sociotechnical imaginary of the central government is vague, while local governments ideas are more specific to their unique environmental and geographical areas. For example, considering the case study cities of this thesis: Beijing aims to develop their ETC and smart traffic light systems;

Shanghai aims to upgrade their testing devices, such as traffic cameras, sensors and GPS; and Chengdu focuses on the smart traffic light system. Zhejiang Province and Hangzhou also concentrate on the development of infrastructure; however, they focus on the rural roads, which does not seem have much to do with "smart" or Big Data. All of these future expectations of the local government have one thing in common: that future expectation should be evaluated in a quantitative way. For example, Beijing would like to measure the number of ETC systems, while Hangzhou would like to measure how many miles of rural roads there are.

As local governments have various future expectations for their Smart Transportation System, these expectations are found in local government documents. The following provincial-level administrative divisions exist in China: 23 "provinces (省)", four "municipalities (直辖市)", five "Autonomous Regions (自治区)", and two "Special Administrative Regions (特别行政区)", followed by sub-provincial divisions, such as the capitals of the provinces. The fieldwork was conducted in seven different locations. Therefore, the relevant local government policies would also be searched from these cities and the provinces (see Figures 1 and 2 for provincial and sub-provincial divisions of the transport system). In order to clearly explain the future expectations of the local governments, I will discuss the documents of the municipalities, the provinces and their capitals.

5.1.2.1 In Municipalities

In the fieldwork, although there are four municipalities I selected two of them as examples in this subsection. The first one is Beijing – the capital of China. Another is Shanghai, a city famous for finance, technology and transportation.

Comparing Beijing's goals to the MOT's "four goals" (summarized in Section 5.1.1), Beijing reduced the MOT's four areas to three: construction, management and service. Officials indicated that they would have specific goals for each year when, in 2017, the Beijing Municipal Commission of Transport participated in a TV interview [53] to explain their "The Plan for the Development of the Smart Transportation System in Beijing in the period of Thirteenth Five-Year (北京市"十三五"时期智慧交通发展规划)". This plan was based on the "Action Plan to Promote the Smart Transportation System (2017–2020)" released by the MOT. In the TV interview, officials proposed their goals for the next five years: (1) construct a new generation of Smart Transportation Service system; (2) realize overall improvements of the regional transportation system; (3) improve the level of recognition of traffic dynamics; (4) improve the modernization of transportation governance; and (5) improve the quality of transportation services. As we can see, these goals are quite vague.

[53] http://jtw.beijing.gov.cn/xxgk/dtxx/201707/t20170712_347849.html

It is possible to uncover more specific future expectation of Beijing from government reports presenting results to the public. For example, "Beijing Develops the Smart Transportation System (北京大力发展智慧交通)"[54] says: "the ETC system, as the main content of the Smart Transportation System, is also an important point for the development of the Smart Transportation System in Beijing." (p.1). This report summarizes the development of the ETC system in Beijing; for example, 544 ETC lanes have been built. Also, another report called "Beijing CBD has established the city's first Smart Transportation System (北京CBD 打造全市首个智慧交通体系)"[55] refers to the smart traffic light system. Thus, these documents indicate that the future of the Smart Transportation System in Beijing is anticipated to be the ETC system and the smart traffic light system.

In 2017, Shanghai Municipal Commission of Transport also participated in a TV interview[56] to explain their plan for developing the Smart Transportation System. The officials presented their plan for the next five years. Unlike Beijing's plan, Shanghai limited its goal to one area – transportation services. In the interview, to explain the issues related to transportation services, the officials showed the development of transportation services in Shanghai, such as transportation apps, information boards, etc. Additionally, they proposed three specific goals: (1) to improve traffic cameras; (2) to upgrade sensors and testing technology; and (3)

[54] http://jtw.beijing.gov.cn/xxgk/xwfbh/201912/t20191209_1007491.html
[55] http://jtw.beijing.gov.cn/hyfc/jtjs/201906/t20190603_311004.html
[56] http://jtw.sh.gov.cn/zcjd/20181205/0010-27345.html

GPS installation for hazardous chemical transport vehicles. For Shanghai, then, their focus is on traffic cameras, sensors, other testing devices and GPS.

5.1.2.2 In Provinces and their Capitals

As discussed in the background, the Western Region and the Eastern Region of China differ in their geographical conditions as well as their economic development. In this subsection, I compare two provinces and their capitals as examples. First, Sichuan Province and its capital – Chengdu – as an example of the Western Region. Second, Zhejiang Province and Hangzhou in the Eastern Region.

Sichuan Province is an underdeveloped area in the Western Region of China. The development of the transportation system lags behind other areas. In 2019, the Department of Transportation of Sichuan Province held an TV interview[57] to express their goals for the Smart Transportation System. In the interview, on the one hand, the officials gave a quite broad definition of the Smart Transportation System: recognition, interconnection, collaboration, people-oriented service, autonomous management, green and low-carbon. On the other hand, they also pointed out that the Smart Transportation System should be application-oriented, and "the application of Smart Transportation System requires a large number of foundations, especially the infrastructure". Chengdu is the capital of the Sichuan

[57] http://jtt.sc.gov.cn//jtt/c103118/2019/11/6/5cff2e3b580e48c9a935e67dd26c8830.shtml

Province. It is a sub-provincial division. Although the Chengdu Transportation Bureau did not hold a TV interview to present their goals, it released a newspaper report called "constructing the Smart Transportation System, a new driving force for managing congestion scientifically (构建智慧交通 为科学治堵注入全新动力)".[58] This news report summarizes the efforts made by Chengdu in the Smart Transportation System. For example, in 2018, Chengdu completed the upgrading of 226 intersections with a smart traffic light system, and delays at piloted intersections decreased by 11.2%.

Zhejiang Province is in the Eastern Region of China. Unlike Sichuan Province, Zhejiang Province is a developed area. Ranking fourth among 31 provincial-level administrative divisions of GDP in 2020.[59] The Department of Transportation of Zhejiang Province did not hold TV interviews to express their plan on the Smart Transportation System which is not the main focus of their work. For example, a report,[60] summarizing the work of the department in 2019, shows that the development of the Smart Transportation System is one of the 13 annual achievements. Hangzhou is the capital of Zhejiang Province. It is also a sub-provincial division. In 2019, Hangzhou Transportation Bureau released a document called "The Thirteenth Five-Year Plan (2016-2020) for the Development of Transportation System in Hangzhou (杭州市综合交通发展十三

[58] http://jtys.chengdu.gov.cn/cdjt/c108493/2018-10/30/content_ccdb0945fca849d3a54c900c93da9c71.shtml
[59] https://www.sohu.com/a/451368479_166075
[60] http://jtyst.zj.gov.cn/art/2020/1/8/art_1676891_41518614.html

五规划)”.[61] This document sets several goals for the development of the Smart Transportation System: “The use of mobile payment in public transportation needs to reach 80%. The use of the ETC system needs to exceed 50%. And the coverage of public information service platforms needs to reach 90%.” However, following in the footsteps of the Department of Transportation of Zhejiang Province, the Smart Transportation System is not Hangzhou’s focus. Every year, the Hangzhou Transportation Bureau releases its work plan for the next year, listing the main goals. Comparing the work plans of Hangzhou Transportation Bureau from 2018 to 2020,[62] reveals what its focuses are.

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[61] http://tb.hangzhou.gov.cn/art/2019/5/15/art_1229355018_3557035.html

[62] http://tb.hangzhou.gov.cn/art/2018/3/5/art_1229355019_3557069.html
http://tb.hangzhou.gov.cn/art/2019/5/13/art_1229355019_3557086.html
http://tb.hangzhou.gov.cn/art/2020/6/15/art_1229355019_3557088.html

Table 5 – The work plans of the Hangzhou Transportation Bureau (2018–2020)

2018 Work Plan	2019 Work Plan	2020 Work Plan
1) To build "Four Good" Rural Roads	1) To promote the construction of key transportation projects	1) To improve the transportation infrastructure
2) To build the transportation infrastructure	2) To realize the integration of transportation systems in the Yangtze River Delta	2) To improve transportation services
3) To improve transportation services	3) To improve transportation services	3) To improve traffic governance
4) To build e-government	4) To build "Four Good" Rural Roads	4) To build green transportation
5) To improve traffic governance	5) To improve traffic governance	5) To build e-government
6) To build green and Smart Transportation	6) To ensure traffic safety	6) To encourage science and technology innovation

According to the "2019 Work Plan", the key transportation projects include 1000km highways and 835km provincial highways, which could be seen as a part of trasportation infrastructure in the "2018 Work Plan" and "2020 Work Plan". Also, in the "2020 Work Plan", the project called "Four Good" Rural Roads is included in the part of improving transportation infrastructure (Table 6). Therefore, it could be concluded that there are four goals that Hangzhou has set over three years: (1) to build "Four Good" Rural Roads; (2) to build the transportation infrastructure; (3) to improve transportation services; (4) to improve traffic governance.

Table 6 – The four common goals from 2018 to 2020

2018 Work Plan	2019 Work Plan	2020 Work Plan
1) To build "Four Good" Rural Roads	1) To promote the construction of key transportation projects (infrastructure)	1) To improve the transportation infrastructure（"Four Good" Rural Roads）
2) To build the transportation infrastructure	3) To improve transportation services	2) To improve transportation services
3) To improve transportation services	4) To build "Four Good" Rural Roads	3) To improve traffic governance
5) To improve traffic governance	5) To improve traffic governance	

Hangzhou concentrates on one key infrastructure project: "Four Good" Rural

Roads. This project is unusual during the period 2018 to 2020, so it needs to be analyzed in a more detailed way. While from 2018 to 2020, most Chinese cities proposed their plan for developing the Smart Transportation System, Hangzhou proposed its transportation plan called "'Four Good' Rural Roads (四好农村路三年行动计划)".[63] "Four Good" means to build, manage, maintain and operate rural roads well. More specifically, the plan shows that its specific goals are to improve 3202 kilometres of rural roads, to construct 3079 kilometres of "economic corridors", build 136 service stations, and repair 2050 kilometres of rural roads. From these examples, it is clear that the plan is an infrastructure project. However, it differs from other projects, because it focuses on rural roads.

To summarize, according to local governments' documents the future expectation of the Smart Transportation System is about infrastructure construction. Different local government have different concerns. For example, Beijing aims to develop the ETC system and the smart traffic light system, while Shanghai prefers to upgrade testing devices. Cities in the Western Region of China are developing slower, as they started to develop the Smart Transportation System in 2019, instead of 2018. Chengdu also focuses on the smart traffic light system. Zhejiang Province and Hangzhou also concentrate on the development of infrastructure. However, they focus on rural roads, which does not seem have much to do with "smart" or Big Data.

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[63] https://www.hzarchives.gov.cn/info/9633.jspx

5.1.2.3 In the Fieldwork

In the fieldwork, interviewees argue that local governments prefer to construct large amounts of infrastructure. Local governments want to invest in the construction of facilities. For example, Mr Wan, a senior expert who works in a research institution for transportation system design, sees it as a common situation in China. He says:

> *Now people don't focus on the software and they focus on the infrastructure. We now have a lot of equipment. However, how to use them effectively and how to use the data collected from the equipment, still needs to improve. When we look at the investment ratio of software and hardware, it differs greatly. The investment of software only accounts for a small proportion. On the more developed stage of the Smart Transportation System, the investment of software will not be lower than the investment of hardware. I think it should be much higher than the hardware. We just get the data from the hardware construction while our goal is not just to get the data but to use the data. (Mr Wan, Chongqing)*

Big Data centers play an important part in Big Data's applications. For example, Big Data centers are significant in the Big Data paradigm: "The data center not only is a platform for concentrated storage of data, but also undertakes more responsibilities, such as acquiring data, managing data, organizing data, and leveraging the data values and functions."(Chen *et al*., 2014, p.178). Big Data centers could provide strong support for data analysis, and this support would in turn help the development of Big Data centers (Chen *et al*., 2014). Big Data centers is an important component of the Smart City.

Big Data platforms usually refer to the platforms that collect traffic information from different places. In other words, Big Data centers are among any other infrastructure in a city, such as a train station. And become an object that can be quantitatively examined under "the pressure system (压力型体制)" (Yang, 2012) (Section 1.2). For example, we can examine whether the city has established a Big Data center and whether the data is well equipped. Big Data platforms are present in major cities in the form of Big Data centers, and, therefore, the number of centers could be counted. Also, the level and the number of the facilities in Big Data centers could be evaluated. For example, Prof. An, who focuses on the use of Big Data in the transportation system, says:

> *Basically, every city has such a platform, but the functions performed by the platform may be differentiated. The worst*

situation is that this platform is just a showcase for the leaders, which delivers the information that I already built such a platform. While I haven't really used this platform to do anything specific yet, it may be useful to show the leaders when they come to visit. (Prof. An, Nanjing)

These Big Data platforms are available as a showcase, because they do not only collect and store virtual data, but they also have physical forms. Their physical forms are Traffic Information Centers or Traffic Data Centers, and different cities may have their own name for it. These data centers can also present data in a visual way. Therefore, when you enter one of these data centers the first thing which catches your eye is the big screen located in the center of the room (Figure 13).

Figure 13. 14. From left to right: **Figure 13.** An overview of Big Data Center; **Figure 14.** In the data center I visited, they conduct "Floating Car Data" technology, and data is collected from GPSs on buses. The red icons represent road congestion, and the green ones represent a clear road. The figures on the left side are a comprehensive evaluation of traffic conditions throughout the city. The rating scale is from 1 to 10. One means that the road is clear, while 10 means that it is extremely congested. The number shown on the photo is 5.8, rated as light congestion.

These big screens show us real-time traffic information from all over the city. The information comes from sensors positioned at main streets, intersections and important transportation facilities, such as train stations, coach stations, etc. (Figure 13). Other information comes from GPSs carried by cabs and buses. For example, Prof. Ci, focusing on the testing technologies used in the Smart Transportation System, describes how to use GPSs to understand road congestion:

> *We started to use GPSs carried by cabs for data analysis. This technology is called "Floating Car Data" [浮动车技术] or "Probe Car" [探测车]. A cab's GPS will report its location regularly. The trajectory of cabs driving on the roads is recorded. Once there are many cabs, we will have a fairly large sample. We will have their driving speed. We then use statistical analysis to understand the traffic conditions of the road. (Prof. Ci, Chengdu)*

Figure 15. 16. 17. From left to right: **Figure 15.** In the Big Data center, we can also see the situation of cabs; **Figure 16.** the situation of public bicycles; **Figure 17.** the situation of the airport and flights. Thus, in the Big Data center, we can see the operation of buses, cabs, public bicycles, etc., the traffic flow on the main streets, and the traffic hubs such as train stations and airports.

According to Prof. An, above, focusing on the use of Big Data in the transportation system, in a worst-case scenario Big Data centers would serve only as a showcase, while a better scenario is that they could provide early warnings and rapid responses to the accidents. He adds:

> *Now, we are able to monitor traffic conditions. And then, after something happens, the data centers could send us an alert, which is possible now, and this is usually called a response [响应] [...] A little further ahead, the department of traffic management could use the data to do some analysis. Then the results of the analysis might guide traffic management in the future. (Prof. An, Nanjing)*

To summarize, according to local governments' documents and fieldwork, the future expectations of local governments are about infrastructure development. This development is consistent with the sociotechnical imaginary of the central government. Yet, the sociotechnical imaginary of the central government is vague and sociotechnical imaginary of infrastructure could be understood in various ways. So local governments develop their own future expectations. For example, Beijing would like to develop the ETC system and the smart traffic light system. Shanghai prefers to upgrade testing devices. Chengdu also focuses on the smart traffic light system. Zhejiang Province and Hangzhou also concentrate on the development of infrastructure. And the future expectations of these local government have one thing in common: the future expectation could be evaluated in a quantitative way. For example, Beijing would like to measure the number of ETC system, while Hangzhou would like to measure the miles of rural roads.

5.1.3 Discussion

The sociotechnical imaginary of the central government is partly ambiguous. Their "Four Goals" (*Smart Infrastructure, Smart Production Organization, Smart Transportation Services, Smart Decision-making*.) which could be seen as four distinct areas (construction, management, service and decision-making) are quite vague. On the one hand, for the future of Smart Transportation System, the central government proposes to develop infrastructure without pointing out specific projects. On the other hand, half of the goals proposed by central government are broad. As the interviewees said, there is no clear direction given. Instead, there are three general directions: management, service and decision-making. Thus, they thought the goal of the Smart Transportation System is unclear, and they do not know which direction to go. The interviewees talked about the lack of "Designed at The Top Level (顶层设计)". This lack of "Designed at The Top Level" indicates the missing role of the central government in the new technology. The central government does not play a role that controls every thing. It differs from the previous impression in Section 1.2 that the Chinese central government will control every aspect of the country's R&D policies.

However, this ambiguous sociotechnical imaginary could also be a kind of "Designed at The Top Level (顶层设计)" approach. The sociotechnical imaginary of the central government is not about setting a clear goal to achieve in the future, rather it is about recruiting more participants and exploring more possibilities for the development of new technology. Alternatively, the future expectations of local government, according to their documents and my fieldwork materials, focus on the development of infrastructure. As the sociotechnical imaginary of infrastructure could be understood in various ways, local governments develop their own future expectations. For example, Beijing is working on the ETC and smart traffic light systems. Shanghai is upgrading testing devices, such as the traffic cameras, sensors, and GPS. Chengdu is focusing on the smart traffic light system. Zhejiang Province and Hangzhou are concentrating on the development of infrastructure by focusing on rural roads. These future expectations of local governments have one thing in common: that future expectation could be evaluated in a quantitative way. For example, Beijing would like to measure the number of ETC system, while Hangzhou would like to measure miles of rural roads.

5.2 A Positive Imaginary and Negative Expectations: The Dynamic between Central Government and Local Government

Documents and interviews reveal that the sociotechnical imaginary of the central government is positive. The central government believe that the Smart Transportation System will be an important factor for the future of the country's transportation system. However, as the following three subsections outline, the future expectations of the local governments quickly become subtle and complicated, which means that the tensions between a positive attitude and negative expectations lead to realistic decision-making.

5.2.1 Central Government: A Positive Sociotechnical Imaginary and the Influence of The Third Wave

According to the document "Suggestions on accelerating the construction of the Smart Transportation System (关于加快推进智慧交通建设的建议)"[64] released by the central government, the Smart Transportation System is one of its most important national strategies:

As the IT revolution is developing rapidly, the Party and the State

[64] https://xxgk.mot.gov.cn/2020/jigou/zhghs/202006/t20200630_3319717.html

have deployed a series of task in order to take the lead in the IT revolution. The Party and the State take the idea of "Internet Plus" and Big Data as a national strategy [...] The Internet is becoming a critical infrastructure of the transportation system.

The interviewees generally agree that the Chinese government's attitude towards new technologies is positive, especially towards the Smart Transportation System. For example, Mr Cai, a senior expert on the construction of transportation system in a state-owned enterprise, has *"confidence"* in the Chinese government from a macro level. Mr Cai says:

The road system is probably still more of a government driven issue. But, on this matter, I have confidence in our country. As long as it has good market prospects and the public has the demand, the government will definitely promote the development of this technology. It is likely that our country will be ahead of others in the Smart Transportation System. We may not be the first to invent and test it. But largescale applications are likely to be ahead of others. The Chinese people and the government are very open to this new technology. And the Chinese government has a strong executive power. Once the *government thinks it is favourable, it will promote the development of new technologies. We should have confidence. (Mr Cai, Beijing)*

Some participants suggest that China is a good place for new technologies such as the Smart Transportation System to develop because China has *"late-developing advantage"*. Prof. An, a professor in the transportation system field focusing on the use of Big Data in the transportation system, says:

> *The development of the Smart Transportation System in China has not been particularly early, unlike Europe and the United States, but its investment is huge. Because of its late development, things are relatively new: the hardware and equipment are relatively new, and the software is actually keeping up with the world. So a lot of the experimentation and a lot of the application of new technology are actually appropriate in China. (Prof. An, Nanjing)*

Prof. An elaborated with a specific example:

> *I had a conversation with a Canadian company that makes the products of the Smart Transportation System. They came to visit us and they were amazed. He has been to many places before.*

He once told us that if you want to engage in the Smart Transportation System, you must at least be like London. Why should it be like London? He said that he saw that every intersection has a camera, which is a high-definition camera in London. And then you're able to capture the changes in traffic flow and passenger flow through the cameras. Only then can you do things such as regional coordination and control. In fact, many cities, including many in Canada, don't have a lot of cameras so it is hard to achieve. However, when he came to visit some of our stuff, he was very shocked. In fact, in China – not only the metropolises like Beijing, Shanghai and Guangzhou, but also second-tier and even third-tier cities – this kind of hardware has been fully installed. So there is a very good basis to practice the Smart Transportation System [...] So China has the late-developing advantage. (Prof. An, Nanjing)

Some participants also mentioned that the political environment in China is well suited to the development of new technologies. Ms Sheng is a senior expert in the field of driverless vehicles. She works in a research institution under the MOT in Beijing. She said:

Frankly speaking, our country is a society ruled by men. It has not yet reached the society that is ruled by law. So many laws are missing at the moment. In such a society, it has both advantages and disadvantages. Then, when the new technology emerges, innovation is easily achieved in this kind of governance structure with no or very blurred boundaries, because it has no resistance. While in Europe and the United States, it has a well-developed legal system. So when you're trying to make an innovation, you might run into legal barriers. Of course, the ideal state of new technology is that we have everything figured out before we make it. However, we still have an old saying that "failure is the mother of success". So you have to allow new technology to keep making mistakes. Just don't have a serious ethical problem, right? This is where a higher level of fault tolerance is needed. (Ms Sheng, Beijing)

In fact, Chinese people are obsessed with new technology. Prof. Yun is a professor in the transportation system field, focusing on the Smart Railway. He uses a new technique (BIM) to illustrate the enthusiasm for the application of new technology in the Chinese scientific community:

In fact, the Chinese do not reject the world at all. BIM, the *advanced forecast system, and other related equipment that you find in any other country in the world, you can also find them in China. So what do I mean by this? There is a wealth of research on BIM. However, the designing institutes are using it and others are just writing papers (Prof. Yun, Beijing)*

In fact, since the "Reform and Opening", the government has been very supportive of innovation and new technologies. This enthusiasm for new technology, especially Big Data and IT, can probably be attributed to the influence of Toffler's idea "The Third Wave" (1980). Toffler argues, from a technological perspective, that the First Wave is when mankind began agricultural production, and that the Second Wave refers to the Industrial Revolution, which shaped modern civilization. Alternatively, the Third Wave refers to the IT revolution, which Toffler believes will reshape our society and give developing countries a chance. Since the 1980s, senior Chinese government officials such as Zhao Ziyang and Deng Xiaoping have been heavily influenced by Toffler's ideas, even Wang Huning, a senior advisor to Xi Jinping as well as his predecessors, Jiang Zemin and Hu Jintao were also influenced by Toffler's idea (Gewirtz, 2019).

5.2.2 Local Government: A Positive Attitude. A Negative Expectation, and A Realistic Choice

However, when looking at the future expectations of the local governments, a positive attitude towards new technologies balanced with a negative expectation of developing the Smart Transportation System because of the complicated local situation and tight budget of the local government, which leads to a realistic choice.

5.2.2.1 A Positive Attitude

Prof. Huan, a professor in the transportation system field, focusing on data analysis in the transportation system, further noted that the local governments everywhere in China also hold positive, *"open-minded"* attitude towards new technologies. Prof. Huan says:

> *I have confidence in the development of the Smart Transportation System over the next few years. At least the environment is still very open at the moment, and people are still quite open-minded [...] I don't think this kind of atmosphere is only in Shanghai, and it is probably everywhere in the country. For example, I went to Guizhou Province and Yunnan Province, and I think we're all on the same page, including the Ministry of Transport [...] I think it reflects a current social consensus: it is an atmosphere that wants to support such an emerging technology.*

(Prof. Huan, Shanghai)

In other words, all new technology is appealing partly because the mayors and governors are not experts and this new technology is welcomed by the public. As Prof. Ci also says:

> *[These companies] can't answer to, for example, the algorithmic precision of the data processing. And they have no incentive to do it. They pack [their technology] brightly. They are going to scam money [...] Because the government wants to innovate, he cares about using Big Data to do something but doesn't care how much Big Data is actually supported. (Prof. Ci, Chengdu)*

We can also see the influence of The Third Wave in the local governments in China, especially in the Central and Western Regions. Guiyang (贵阳) is the capital of Guizhou (贵州) Province. Guizhou Province is mountainous and the transportation infrastructure is less developed. Prof. Ci, focusing on testing technologies for the Smart Transportation System, highly praises the work of Guiyang in the Smart Transportation System in recent years. The local government of Guiyang wants to overtake the other cities in the Western Regions and catch up with the Eastern Coastal cities.

I think it has nothing to do with the topography. It is almost guided by the local governments. There is a new [Party] Secretary [市委书记] in Guiyang. And Big Data is now an international trend. In order to achieve good performance, the government is thinking about overtaking. Guiyang may lack an industrial base. Relatively speaking, the Big Data industry may help it to catch up with other cities and become a highlight in its performance. So Guiyang will promote Big Data and make it a strategy for its development. And many government sectors will be centerd on Big Data. The Smart Transportation System will also use Big Data. So the Smart Transportation System is also to cater to its Big Data plan. Therefore, the projects in Guiyang will get more support from the government. (Prof. Ci, Chengdu)

The Eastern Coastal cities are also willing to embrace new technologies. For Shanghai, one of China's most developed cities, its goal is to be consistent with the world's most advanced level in the development of the Smart Transportation System. Prof. Ti, for instance, says:

Now Shanghai is constructing the system [...] But many other *cities in China have not yet achieved this level [...] The project is led by the Shanghai Municipal Transportation Commission [上海市交通委] There are still some technical difficulties but we are gradually forming some consensus [...] I think that the whole world is at the same research level now, including the USA, the UK, and China. In fact, we feel that our technology is quite advanced. (Prof. Ti, Shanghai)*

From the above findings, we can see that the developing areas of China want to use the Smart Transportation System to catch up with other cities. While the developed provinces and cities, such as Shanghai, view it as a good chance for their economy on a global level. Thus, we can see that the idea of The Third Wave not only influences central government but also local government. Prof Ti notes a *"consensus"* on the use of new technologies for economic development. In general, local governments in China are extremely welcoming of new technologies such as the Smart Transportation System.

5.2.2.2 A Negative Expectation

However, Mr Zhu, an official working on the transportation system in Hangzhou, provides a differing answer from the other interviewees. On the one hand, he thinks that the leaders also welcome the new technology. On the other hand, he implicitly mentions his concerns about the future of Smart Transportation System. For example, Mr Zhu thinks that local governments are welcoming new technology and innovations: *"Now the [local] government wants to do things well. They are all involved in innovation. Now our country is promoting innovation".* First, he repeatedly mentions *"As a government department, it is a very difficult thing"* mainly *"because it is a very large system".* And he also provides some specific examples:

> *If I want to build a Smart Transportation System, how should I use the testing technology? So, how many kinds of testing equipment are needed? After installing the testing equipment, how do I guide the traffic? These questions, I will put it bluntly, are still in the air. (Mr Zhu, Hangzhou)*

Again, he illustrates that the real transportation system is complicated, so it is hard to develop the Smart Transportation System. He says:

> *the driverless vehicle is simple, but the transportation system is complicated. Every road is different [...] it is difficult to do these things on the streets in the cities. (Mr Zhu, Hangzhou)*

Second, from the local government's point of view, Mr Zhu says that the possibility of implementing a Smart Transportation System is very low due to its cost and size. He says:

> *The theory says that the Smart Transportation System could improve efficiency. I think it is right. However, the possibility of implementation is very low. First, the transportation system is too large. Second, the cost is too high. I think it is crucial for the city to make up its mind to do or not to do. Because when you make a Smart Transportation System, you need to tell the control center from the beginning to the end so that the control center can control it [...] We need to do this at such a great cost. So, how is the local government going to make this decision? (Mr Zhu, Hangzhou)*

5.2.2.3 A Realistic Choice

As discussed above, the local government is the main investor of transportation projects, scientific communities are facing fierce competition, the cost and scale of these projects is also huge, and therefore the local governments are the ones making the final decision. The interviewees reveal that some projects are picked by the local government while others fail. For example, Prof. An introduces his cooperation project with the local government of Kunshan (昆山):

> *We are working on a project called Green Wave. It means that when a car passes the first green traffic light, it will not stop at the second intersection. Cars will pass intersections with all green lights. It was impossible before, with possible red lights all the way [...] We are now working on the project in Kunshan [Jiangsu Province] You can see a good effect. It is also recognized by the traffic police of Kunshan. It is much better than the way that they adjusted by themselves. (Prof. An, Nanjing)*

We can see that this example has been a successful cooperation. While some other projects are not favoured by the local governments. For example, Prof. Ci, focusing on the testing technologies used in the Smart Transportation System, is working on using data collected from mobile-phone masts to understand traffic conditions. He talks about the different acceptance of this technology in different places:

> *After six years of promotion, we still don't have many projects in the Central and Western Regions. In the coastal areas such as Zhejiang Province [浙江], we have used it on the highways and*

factories. And it has also been used in Beijing and Shanghai. I have to say that the research on data from mobile phones is still backward. We have promoted the technology many times and the cities in the Central and Western Regions don't choose it, including Chengdu. (Prof. Ci, Chengdu)

Prof. Ci also informs us above, that his technology is not the only source to collect and analyze data. So we could find that the local governments will *"choose"* different technologies in the Smart Transportation System field. And their choice will decide the direction the Smart Transportation System takes. Prof. Ci also raises a difference between developed and developing regions.

However, it is hard to divide the provinces using the standards "developed" and "developing" as local governments show different concerns. Generally speaking, scientists and scientific communities provide many alternative plans for the local governments. Some of these plans are comparable to the plan designed by Prof. Ci, which is to use existing equipment. And some projects propose, like the project in Kunshan, to set up new facilities, such as new traffic lights. The final choice is made by the local government.

Furthermore, we could find that local governments' choices vary from province to province. So, what are the factors that influence these choices? Local governments must find a balance between favouring new technology and their complicated contextual situations when investing in such projects. Prof. Ci thinks that developing new technologies such as the Smart Transportation System should be seen as part of the government's performance. He says:

> *This has little to do with the terrain and environment, but with the government's orientation [...] Now Big Data is the international trend, so the government will support the development of Big Data for good performance. In order to gain good performance, local governments need to complement dislocation development. While if the local government wants to develop the industry, it may not have the foundation. Relatively speaking, the development of Big Data may enable it to catch up with other cities, or be a highlight of its performance. That's why local governments are taking Big Data as a strategic direction for its development (Prof. Ci, Chengdu)*

However, government officials are not professionals in new technology, such as the Smart Transportation System, but they need to make decisions about which projects to support:

The metro company is in charge of the metro, and National Development and Reform Commission (发改委) follows up on key projects. So our system creates a situation where we don't have a single person who can understand the whole transportation system. Unless the mayor cares about it. So what kind of transportation system in a city is really reasonable? Not many people in Hangzhou understand. I basically learned a little bit about the whole process. I'm the only one in Hangzhou. The professors at Zhejiang University are not involved in many of Hangzhou's projects at all [...] The project is left to the mayor to decide, but the mayor is not an expert. (Mr Zhu, Hangzhou)

On the one hand, local governments don't understand how the Smart Transportation System works. On the other hand, with the cultural enthusiasm to support new technologies throughout China, they still have to invest in the Smart Transportation System. Thus, a situation develops as described by Prof. Ci. At first, government officials support the new technology, but then question the accuracy of its conclusions and are subsequently afraid to invest much money on similar projects. He says:

The report is very nice and the officials also feel good. Because it *has never been seen before. In fact, the officials at first think it is nice, while after seeing a few more, they begin to doubt whether it is accurate or not. How dare I use something that is inaccurate? (Prof. Ci, Chengdu)*

Thus, local governments hold initial enthusiasm for the new technology, the tight budget and lack of expertise to assess their investment lead to the final decision of local government that is to interpret the Smart Transportation System as a set of infrastructures, which include sensors, cameras, roads, GPS, etc. For example, Mr Shan – a senior engineer in the Smart Transportation System, working for a state-owned company in highway construction in Chongqing – provides an example:

I will give you an example. If we build a road, that may have to invest 100 million Yuan, while if I build a Smart Transportation System, I may only have to invest 5 million Yuan. However, the local governments all feel that the 5 million Yuan is not worth spending. They will feel that spending the 5 million Yuan wouldn't see any results. (Mr Shan, Chongqing)

Big Data platforms are also a kind of infrastructure. Prof. An, focusing on the use of Big Data in the transportation system, says:

> *The worst situation we can say is that the platform (of the Smart Transportation System) is just a showcase for the officials. I've built the platform, but I'm not doing anything concrete with it yet. I'm just showing it to the government officials when they come over to visit. (Prof. An, Nanjing)*

Additionally, from the interviews, I find that these experts had doubts about whether the Smart Transportation System was really an advance in content or just "a show". Mayors and governors could not tell the differences because of their lack of expertise. For example, Mr Zhu, the official of Hangzhou, describes the dilemma that the leaders of local governments are facing. Different parts of the transportation system are led by different departments while all final decisions are made by the mayor or the provincial governor. However, the mayor or the provincial governor is not an expert.

> *I have to say that there are few people who could really understand the entire urban transportation system in a city. Why did I say that? The Department of Transportation is responsible for highway traffic. The Department of Urban Construction is responsible for parking and city roads. The subway company is*

responsible for subways. The National Development and Reform Commission takes care of the key projects [...] None of us could understand the entire transportation system unless the mayor cares about the transportation system and takes the lead [...] However, the mayor is not an expert in this area. (Mr Zhu, Hangzhou)

Because of their lack of expertise, decisions are easily influenced by new elements. Dr. Yi expresses that some Big Data companies are not experts in the field of transportation, but they provide new methods of data collection and analysis:

For example, the judgment of the flow of people or the construction of OD, they are very professional tasks. More than ten years of working experience is required in the area. A person needs to do it for several years without stopping and then he could accumulate some experience. However, these Big Data companies also release the traffic index. Many of them, it is not polite to say, may not have the expertise in the field. While they have a strong brand endorsement to release the index because they have the ability to collect data and analyze data. So people easily believe in them. But its shortcoming is that it is *unprofessional in the field. (Dr. Yi, Hangzhou)*

This fast-paced IT evolution could also be seen as the expression of the idea of The Third Wave. Because the public thinks "new" means something more advanced, the public will force the local governments to make a choice, and the Big Data companies will take advantage of this idea. As a result, the local governments choose to invest in infrastructure and are reluctant to invest in software, like algorithms and so on. For example, Prof. Ci says:

> *Chengdu, relatively speaking, does not pay much attention to it [the software]. It still takes an extensive path of development. It likes to construct new facilities. This kind of governance of transportation is actually outdated. But the government's philosophy tends to lag, although we have called for some changes. Chongqing is doing better. And Guiyang is also taking it seriously. (Prof. Ci, Chengdu)*

According to the interviewees, the local government chooses to invest in the infrastructure partly because of budget. However, some interviewees argue that it is not because of the money. According to Prof. Ci, one benefit of his research is to save money: *"It is cost-effective and it does not require additional investment"*

(Prof. Ci, Chengdu). His method is to collect data through existing mobile-phone masts. However, his method is not welcomed by the local government although it is cost-effective as they still prefer to *"buy equipment" (Prof. Ci, Chengdu)*. Even if the cost of software is much lower, the local governments will still choose to construct infrastructure at a higher cost rather than "unseen" software. The same situation is also faced by Mr Shan:

> *Let me give you an example. We may need to invest 100 million [Chinese Yuan] to build a road. However, if I build a Smart Transportation System or some information system, we may only need to invest 5 million [Chinese Yuan]. We only spend 5 million but the leaders may feel that 5 million is not worth the money [...] Because they feel that the effect of the investment cannot be seen and the rewards will not be visible. (Mr Shan, Chongqing)*

Thus, following on from the above information, I will elaborate on what the other reasons that local governments choose to invest in infrastructure are.

5.3 To Create a Future Expectation of Infrastructure: Budget, Evaluation System and Empirical Knowledge

For the local governments, their future expectation is specific and they choose to invest in infrastructure and hardware facilities such as Big Data centers, sensors, cameras, and big traffic condition screens. The reasons for these choices are: (1) budget, as these local governments took more responsibility in public services after fiscal decentralization, so the local government needs to consider the return on investment in their budgeting; (2) an evaluation system that quantifies such infrastructure and hardware facilities, so they fit well into the pressure system; (3) empirical knowledge as these infrastructure and hardware facilities make the local governments feel in control of data because they turn this “invisible” data into physical entities that can be “seen”. In Big Data centers, people rely on their experience to judge the traffic conditions and develop solutions but all final decisions are still made by government officials.

As outlined, below, the future expectations of local government are influenced by economic factors, such as their budget, political factors, such as the evaluation system, and the epistemological factor such as the epistemological/evaluation basis for making choices.

5.3.1 Budget

As discussed in the background, after fiscal decentralization the local governments gained more autonomy in the economy. Such as taking more responsibility in public services which has led to tight local government budgets. While the local governments enjoy more autonomy, many investments and programs are affected by local government preferences. Transportation infrastructures are deeply influenced by local government investments and preferences as local governments in China are major investors in the local transportation infrastructure.

As laid out in Section 3.1, the "Reform and Opening-up (改革开放)" has contributed towards rapid development of the transportation system, and changed the main investors of transportation projects from central to local government through three fiscal decentralizations, improved average land travel time, and the expenditure on transportation has increased yearly. Similarly, investment in the Smart Transportation System is closely related to the economic status of local governments. For example, Mr Shan is a senior engineer in the Smart Transportation System, working for a state-owned company for highway construction in Chongqing. He says:

> *As a city's GDP or economic level reaches a certain stage, it will naturally invest more in the Smart Transportation System. However, largescale investment into the construction of the Smart Transportation System requires a large amount of financial support. For example, the economic development of Beijing and*

Shanghai will be far ahead of Chongqing. (Mr Shan, Chongqing)

Consequently, local governments began to face tight budgets, because they were made responsible for investing in local transportation projects. At the same time, the share of local government tax becomes smaller than before (Subsection 3.1.1). Due to their limited budget, the local governments have become more cautious in investing in local transportation projects. Mr Zhu, a local official in charge of transport, argues that the lack of significant achievements in the Smart Transportation System is the reason why the government is hesitant to invest in the projects. He says:

> *Our country is good at building high-speed railways, and even airplanes. Another example is medicine. A new drug is invented, and a new surgical device is manufactured. A farmer can figure out how much benefit a seed has [...] I want the mayor to spend 30 billion Yuan a year investing in the Smart Transportation System, but I can't tell him/her what the effect of spending 30 billion Yuan is. If I were the mayor, I wouldn't be able to make up my mind. This is our biggest problem now.*

Mr Li, a senior expert in the metro system, argues that the government's investment on the transportation system must have results. Transportation investment differs from investment on rocket projects, where you can ignore the cost and the results. He says:

> *The point is that it's not quite the same as it used to be, and all the fundings have to be used in a planned and justifiable way. If you invest so much money but don't have any results, you are accountable. People all want results from their investment, right? This is a current situation in our country. It's not like those projects on rockets that the state will invest regardless of cost.*

Thus, such investments target the commercial potential of space, which may not see an immediate return.

5.3.2 Evaluation System

As discussed previously, the evaluation system for the local governments known as "the pressure system (压力型体制)" helps the central government to manage local government, and to ensure local governments can achieve the goals that central government has set. This evaluation system includes a quantitative task, a problem-solving mechanism, and a materialized, multi-level evaluation system. Thus, the interaction between central and local government can be described as a top-down system in which local governments are under pressure from the central government. However, this system might no longer fully describe the current situation in China, especially in the case of Smart Transportation System.

First, clear goals are not presented for the Smart Transportation System by the central government. For example, according to the MOT's "Action Plan to Promote Smart Transportation System (2017–2020)", the four goals of the Smart Transportation System are: 1) Smart Infrastructure, 2) Smart Production Organization, 3) Smart Transportation Services, and 4) Smart Decision-making. These four goals are quite broad. None of them leads to solving a specific problem. Instead, they are more akin to indicating possible directions for the Smart Transportation System. Moreover, the latter two are difficult to measure by quantitative criteria. In addition, the central government has also adopted a focus shift in the evaluation system from economic to ideological issues since 2017 (Qi and Lin, 2018), in the Smart Transportation System. For example, the "2019 Zhejiang Transportation Annual Achievement (2019 年浙江交通年度成就盘点)" [65] document released by the Department of Transportation of Zhejiang Province, lists 13 achievements. Among them, four relate to ideological issues, such as number 1 the effective advancement of institutional reform; number 2 launching a campaign called "Remain true to our original aspiration and keep our mission firmly in mind (不忘初心， 牢记使命)"; number 7 developing a "One-stop

[65] http://jtyst.zj.gov.cn/art/2020/1/8/art_1676891_41518614.html

administrative service (只跑一次)" [66] and advancing law-based administration; and number 13 deepening "full and strict governance over the Party (全面从严治党)". Thus, in this case, the evaluation system is not exactly a top-down system (a "pressure system") because ideological issues cannot always be quantified due to the nature of their social complexity. As discussed above, the sociotechnical imaginary of the central government is ambiguous, and does not present a clear goal nor a quantitative task for the local governments.

Second, instead, local governments use the evaluation system to communicate their achievements upwards, and even their preferences for the future of the Smart Transportation System. For example, Beijing demonstrates in the report "Beijing CBD has established the city's first Smart Transportation System", [67] the development of its ETC system and Smart traffic light system by upgrading 22 intersections. Shanghai prefers to upgrade testing devices, such as the traffic cameras, sensors and GPS, in order to collect traffic information, promoting during a TV interview[68] a total of 1,862 digital bus information boards being installed by the end of 2017 –expressing the present development of the Smart Transportation System. Also, the "2019 Zhejiang Transportation Annual Achievement" report[69]

[66] It means to stream powers, and the things requiring presence in person get done in one place and without the need for a second trip.
[67] "Beijing CBD has established the city's first Smart Transportation System" (北京 CBD 打造全市首个智慧交通体系): http://jtw.beijing.gov.cn/hyfc/jtjs/201906/t20190603_311004.html
[68] http://jtw.sh.gov.cn/zcjd/20181205/0010-27345.html
[69] http://jtyst.zj.gov.cn/art/2020/1/8/art_1676891_41518614.html

indicates how many quantitative tasks were completed in 2019 by Zhejiang Province's Department of Transportation:

> *11 special service teams were set up to go to the front line of more than 110 major projects such as Hangzhou Beltway Western Bypass [杭州绕城西复线], Linjin Highway [临金高速] and Zhoushan Green Petrochemical Base [舟山绿色石化基地], visit more than 50 enterprises and grassroots such as Zhejiang Communications Investment Group CO. LTD. [CICO, 浙江省交通投资集团], Zhejiang Provincial Airport Group [浙江省机场集团], Zhejiang Seaport [浙江省海港集团] and Cao Cao [曹操出行], follow up and serve 26 counties such as Qingyuan [庆元], Chun'an [淳安] and Taishun [泰顺], collect and sort out a list of 270 problems in 6 categories, coordinate and solve 131 problems on site, and continuously follow up 139 issues.*

Thus, through the examples above, the impact of "the pressure system" in the local governments' choices becomes visible. The evaluation system concentrates on quantitative and material factors, so that the local governments prefer quantifiable and visible criteria for project selection. For instance, how many roads are built per year, or how many sensors and cameras have been put in the streets.

Here, the evaluation system does not work from the top to bottom, but inversely as local officials use the evaluation system to present political performance upwards, which also chooses the direction of the Smart Transportation System's development as the local government invests in quantifiable projects. Thus, in this case, the role of the evaluation system is similar to that described by Heberer and Trappel (2013): a means of communication that conveys policy goals and expectations to local government, on the one hand, with the opportunity for local government to pass on its own performance for superiors to "see", on the other hand.

Third, the central government sets the tone in the Smart Transportation System that is quantifiable and measurable, which is another reason for local governments choose to construct hardware facilities. For example, according to the "Action Plan to Promote Smart Transportation System (2017–2020)", MOT proposes 12 tasks, and five of them are presentable in a quantitative way, such as 1) Smart Logistics Parks, 2) Smart Passenger Terminals, 3) Smart Ports, 4) Smart Enterprises and 5) Smart Sensors, information boards, and experiment sites.

Forth, another reason the pressure system might no longer fully describe the current situation in China is that quantitative criteria, such as facilities and quantitative standards, have always been the focus of any evaluation system in China. The preference for quantitative standards is not only in the evaluation system but also in the academic community. For example, Prof. Ci is a professor in the field of transportation system, focusing on testing technologies in the Smart Transportation System. He works at a university in Chengdu. He talked about how he thought that the lack of powerful voices in the field of transportation was due to its inability to meet quantitative standards:

> *There are no Academicians [院士] [70] in the field of transportation. Now, what does China look for in the selection of Academicians? Great academic achievements, big hardware facilities, including the number of SCI papers [..] In the field of transportation, it is about solving problems with a craftsman's spirit [...] For example, we have managed the city's traffic well, but it does not value the selection of Academicians [...] So I would say that we lack a high-level voice in this area. (Prof. Ci, Chengdu)*

Therefore, we might say that quantitative standards are the preference of Chinese society in science and technology, not just that of the government or officials.

Heilmann and Melton (2013) point out that the core of China's policy-making

[70] Academicians (院士): Member of the Chinese Academy of Sciences (中国科学院), the highest academic title in science and technology in the People's Republic of China, a lifetime honor. The Department of the Chinese Academy of Sciences, composed of members of the Chinese Academy of Sciences, has been the highest national advisory body on science and technology since its establishment in 1955.

process lies in "planning" (规划 Guihua), which is not limited to a text or a closed-policy process but is a dynamic process that could be called a “planning cycle”. In this dynamic process, the central government and local governments and other stakeholders are constantly interacting. This explanatory model can also be used to characterize the implementation process of the Smart Transportation System. We can also think of the Smart Transportation System as a dynamic process of the R&D policy. Heilmann and Melton (2013) argue that the key to this dynamic process is the evaluation processes for officials: an individualized, cadre-based, ideological and promotion control mechanism. In other words, the evaluation process is a top-down system designed to "satisfy" superiors. However, Heilmann and Melton do not reveal how it is possible to achieve the "satisfaction" of superiors in the dynamic process.

Thus, in the Smart Transportation System, the sociotechnical imaginary of the central government and the future expectations of the local governments could not be understood as a top-down, pressure system. As discussed above, we can now understand that the central government's imaginary of the Smart Transportation System is “ambiguity in implementation” (Korsnes, 2016, p.50), since its content and implementation will gradually fill in the interaction between the central government and local governments with the use of the evaluation system. Therefore, it should be seen as a dynamic communication process. For the central government, the imaginary is vague. It does not present a clear goal that need to be achieved. It is an open question to be answered. The choice between a more aggressive or more conservative future expectation depends on the local governments. The local government's choice is influenced by the evaluation system. And the local governments use this evaluation system to communicate their performance upwards as well as their preferences to central government. Thus, the imaginary and expectation of the "Smart Transportation System" is a two-way and dynamic process with an interaction between the central government and local governments. The evaluation system, which plays a central role in this dynamic process, should also be a two-way, dynamic system, rather than an entirely top-down "pressure system".

5.3.3 Empirical Knowledge

As discussed above, for local government, the future expectation of the Smart Transportation System is negative, because they do not believe that a large amount of data (e.g. Big Data) could solve traffic problems, mainly because the transportation system is too complicated. Therefore, they rely on their management experience which is a form of empirical knowledge. For example, Big Data centers offer local governments an illusion of being in control. Thus, local government is willing to invest in hardware, such as roads and sensors, because hardware is tangible, yet is unwilling to invest in intangible objects. For example, Mr Wan is a senior expert who works in a research institution for transportation system design in Chongqing. He provides details about the local government's perspective:

Mr Wan: [...] tangible things, it [the local government] feels that they are real. While intangible things, it feels that they aren't real.

Q: So, things like data are not real?

Mr Wan: Yes. Data is something that we can say [emphasis] it is real, however, when it comes to asking for funding and investment, it is not real.

Data cannot be seen or touched, so Mr Wan explains that data is not "real" to the local government. The meaning of "real" in this context refers to the idea that data cannot be grasped in their hands. In other words, it is out of control.

Yet Big Data centers provide an opportunity to turn this invisible data into that which is visible, such as real-time traffic conditions on their big screens. In this sense, Big Data centers have become "real" in the context of local governments. Through these big screens, we can see what is happening in all corners of the city. Invisible data is displayed as presentable charts; therefore, data becomes controllable. Consequently, from the local government's perspective, Big Data centers are worth investing in. However, real-time traffic conditions, display charts and the GPS system (Subsection 3.2.1), only give the illusion that what can be seen can be controlled. For example, Dr Liang studies the transportation of hazardous chemicals in cities. He describes that the department of transportation management uses GPS to track vehicles carrying hazardous chemicals.

> *In terms of supervision, the transportation of hazardous chemicals must be able to be tracked, so every vehicle must be equipped with GPS. I've seen their GPS system during my field trip [...] the Department of Management thinks that I can monitor the vehicles all the time. For example, the vehicle took the wrong route and there was an accident. After the introduction of GPS, it is clear who will take responsibility for such an accident. In this case, the vehicle will definitely take more responsibility for the accident, which is entirely the fault of the transporting companies. Using the GPS system, you can also detect the accident in time. Because there will be someone who keeps an eye on the screens to see if the vehicle takes the wrong way or not.*[71] *However, when the GPS system actually runs, there are problems. A city, for example, has 200 vehicles, and their travel routes are distributed*

[71] The routes for the transportation of hazardous chemicals are carefully selected in China. According to Dr. Liang, the conditions for selecting routes are very strict. For example, these routes are required to stay away from city centers, kindergartens, primary and secondary schools. Therefore, these routes are usually fixed. In this sense, deviations from the fixed routes imply the possibility of accidents.

over three screens. Actually, we cannot tell whether the 200 vehicles are taking the wrong way or not. This system has a feature: if the vehicle deviates from where it should be, a warning sign will appear on the screen so you will know that the vehicle is not following the fixed route. Then it comes back to the problem I mentioned before, the accuracy of GPS. Sometimes it sends an alert, but actually the driver is following the regular route, so it will have certain bugs. If it happens, we need someone to correct this mistake. (Dr Liang, Chengdu)

As we can see the system has inaccuracies despite its use of GPS technology. Thus more data does not necessarily provide more control. I ask Dr Laing how the department of management knows whether vehicle movement is a system error or a driver fault. He says:

Experience. And even though the vehicle deviated from its route, it did not have an accident [...] If it deviates substantially from its regular route, the department will check with other authorities, which is the right way to handle it. (Dr Liang,Chengdu)

Firstly, it is clear from Dr Liang's interview that the local government or its administration uses GPS to determine whose responsibility it is when an accident happens. It is suitable for the top-down pressure system because it is much easier to allocate responsibility for an accident with GPS evidence that can be reported to the higher levels. Secondly, according to Dr Liang, through GPS, people can track the trajectory of vehicles with hazardous chemicals; however, administration relies on their working experience to judge whether the vehicles take the wrong route or not. So on one hand, GPS data is trusted and on the other hand, it is not due to potential system errors. Instead, they trust their working experience.

By being able to track vehicles, the local governments and their administrations may feel that they are in control of "invisible" data. The data are, in fact, out of their control and actually in the hands of the Internet companies. If the trajectory of vehicles is turning "invisible" GPS data into a visible form, Big Data centers are turning "invisible" Big Data into physical forms. Big Data centers help transform "out of control" data into what local governments think is "controllable". And in the Big Data centers, judgements are being made by experience of government officials. I will further elaborate on this point in the following sections.

5.4 A New Sociotechnical Imaginary for Next Five Years

In 2021, China started "The Fourteenth Five-Year Plan" (2021–2025). The plan indicates that the sociotechnical imaginary of the central government has changed to become more specific. It focuses on the development of infrastructure instead of the development of the Smart Transportation System. Prior to this, in August 2020, MOT released a document called "Guidance from the Ministry of Transport on Promoting the Constructure of New Infrastructure in the Transportation System (交通运输部关于推动交通运输领域新型基础设施建设的指导意见)"[72]. It aimed to develop an effective new infrastructure in the transportation system by 2035. The first task of which was to construct an integrated and efficient Smart Transportation Infrastructure via some specific goals that have already been seen in Section 5.1.2. For example, the document suggests developing the ETC system on highways, also seen in the future expectations of Beijing. Plus, the document suggests developing testing technology and networks which could be related to the future expectations of Shanghai. Moreover, the construction of rural roads is also one of the goals of the new Smart Transportation Infrastructure, and Zhejiang and Hangzhou concentrated on the development of rural roads from 2018 to 2020.

The development of rural roads does not appear to be related to smart or Big Data. However, in this more recent plan the central government has confirmed that the construction of rural roads is part of the Smart Transportation Infrastructure. Thus, this new sociotechnical imaginary of the central government is a combination of different future expectations of local governments. Moreover,

[72] https://xxgk.mot.gov.cn/2020/jigou/zhghs/202008/t20200806_3448021.html

by summarizing the future expectations of local government, the sociotechnical imaginary of the central government is narrowed from a general area of the Smart Transportation System to a specific focus on the Smart Transportation Infrastructure.

Conclusion

Chapter 4 discussed the ambiguous sociotechnical imaginary of the central government and the future expectations of local governments through government documents and fieldwork materials. I argued in Section 5.1 that the ambiguous sociotechnical imaginary of the central government is a “Designed at The Top Level (顶层设计)” approach. Also, that this finding resonates with “the ambiguity of the government targets on technology projects” (Korsnes (2016), “intentional ambiguity” (Gohli and Fischer (2019), and central government’s orders to “local government to implement policy without clear direction” (Liang et al. (2020),

In Section 5.2, I identified that the central government avoids a clear goal to instead recruit more participants and explore more possibilities for the development of the new technology. Subsection 5.5.1 focused on how the sociotechnical imaginary of the central government is positive; in that they believe that the Smart Transportation System will be an important economic factor for the future. Central government was influenced by “The Third Wave”, which saw technological revolution as a driving force of product development and a boost to the economy. Section 5.5.2 explored in detail how the local governments’ future expectation is specific, related to realistic funding choices in infrastructure and hardware facilities, such as Big Data centers, sensors, cameras, and big traffic condition screens.

In a three-fold manner Section 5.3 outlined that the local governments must consider, first, the return on investment for the Smart Transportation System, because the local governments were made responsible for public services after fiscal decentralization, and on a tight budget. Second, infrastructure and hardware facilities must be quantified, so they fit well into the pressure system. Third, infrastructure and hardware facilities generate a feeling of data control because “invisible” data is shaped into physical entities that can be “seen” for government officials.

Section 5.4 showed how the above context enables a new sociotechnical imaginary to emerge in central government: one that is a combination of the different future expectations of local governments. Moreover, through their "feedback" the sociotechnical imaginary of the central government is narrowed from a general focus on the Smart Transportation System to its infrastructure.

Therefore, a two-way, dynamic process arises between the sociotechnical imaginary of central government and future expectations of local governments. Through this process, the new sociotechnical imaginary of China's central government is narrowed down to play an important role in guiding the country's next five-year development phase.

Chapter 6. Understand Big Data Through the Metaphor that Emerges in the Smart Transportation System

This chapter considers the metaphors for Big Data that were proposed by the interviewees. Guided by these metaphors, in Section 6.1 I propose that the analogy between Big Data and TCM reflects the participants' perception of Big Data, which helps us to understand the nature and characteristics of Big Data in a Chinese context. Through the similarities between Big Data and TCM, I argue in Sections 6.2 and 6.3 that Big Data goes one more step further than TCM: after collecting empirical data from the real world, it uses empirical data to construct a digital world simulating the real world, and people's knowledge of Big Data is generated in this digital world. Finally, in Section 6.4, by reviewing the history of the development of AI I suggest that the new AI model represented by Big Data could be constructed by the idea of Chinese philosophy.

6.1 Big Data and its Metaphors

In this section, I will discuss the metaphors that emerged in the fieldwork. Metaphors are suitable to analyze the nature and characteristics of Big Data because metaphors make abstract concepts easier to understand. Moreover, the use of metaphors is closely related to the different cultural backgrounds and contexts of the users.

6.1.1 Three Metaphors that Emerged from the Fieldwork

Three kinds of metaphors emerged in the fieldwork: (1) to compare the transportation system to the human body, while comparing Big Data centers to the human brain; (2) to relate Big Data to Taoism, arguing that the operation of Big Data is similar to the idea of "non-action by the ruler (无为而治)" in Taoism; (3) to draw an analogy between Big Data and TCM. However, not all of these metaphors help us to analyze the nature and characteristics of Big Data.

The first metaphor compares the transportation system to the human body, while comparing Big Data centers to the human brain. For example, in the interviews, the participants argue that Big Data centers play a role similar to that of a *"brain"*. For example, Ms Bu – conducting research on the Smart Transportation System, focusing on the design of the Smart Transportation System, and participating in several related projects – believes that future development should emphasize the analytical capacity of the *"brain"* which refers to the data centers:

> *Ms Bu: In the past ten years, we have been building the Smart*

Transportation System throughout cities, with increasing emphasis on the analysis and computational decision-making capabilities of its "brain", so that is the "Smart" Transportation System. However, the current is still far from being really smart. It doesn't have that much, that is to say, like a person or like a commander, who can judge the whole traffic situation and then make some more optimized solutions [...] I think in the future there might be a brain that can solve all the problems, but right now the brain is not developed enough. Maybe it only has the IQ of a few years old and it's not enough.

Q: Do we have such a brain built up now?

Ms Bu: The brain, such a brain is the information center of each city, for example. However, the information center does not have a specific business now. That is to say, it is not based on practical applications, which means that it has a lot of data, but it does not solve the problems.

Q: What do you think will be the possible development of the Smart Transportation System in the future?

Ms Bu: I think it's going to enrich its brain. Now outfield equipment has basically matured, while the new equipment has not come out yet. Currently the largest scope is a city. In other words, I can see a city in an information center. Then I need this center to analyze the data. Analytical capacity is actually an invisible skill. It is this invisible skill that should be improved in the future. Now we see through the "eyes", and the data goes into the brain, but it cannot direct the movement of the hands and feet. The future should be to become an overall coordinated person.

Mr Bai also compared the information center to the human brain, and the transportation system to the human body. He is a senior expert in traffic operations and has participated in many urban construction projects. He now works in a research institute in cooperation with the local government in Beijing. In his interview, he describes the issue in terms of data and traffic and technology:

There should be a lot of data on traffic. The traffic light is supposed to serve the evaluation system and the traffic light is a feedback measure. As soon as congestion occurs, I should change the traffic light immediately. However, the current traffic light is fixed. For example, it is now fixed for the time the red light *lasts and the green light lasts. (Mr Bai, Beijing)*

Then, he describes traffic jams as an *"intestinal obstruction"* and argues that the current method of traffic management is to divide the road into sections, and manage them in different sections. However, if one section of the road is congested, the whole road will become more and more blocked by managing the system as a series of parts. Mr Bai says:

> *So what should it be like? There is a brain on top of them. Once the brain realizes that there is now a traffic jam, it will adjust the traffic light. One of the reasons for the current traffic jam is that the different sections don't communicate with each other. The communication between different sections will also depend on the brain. (Mr Bai, Beijing)*

Therefore, he argues that the road should be considered as a whole. The ultimate goal of the Big Data Center is to create a center that is as smart and autonomous as the human brain. And then the Big Data Center could manage the road system as whole.

Moreover, we can also find this correspondence in the Smart Transportation

System that is currently being implemented. For example, Alibaba[73] proposed "The Traffic Brain" program in Hangzhou and in Suzhou. And this program has been experimented on, on a small scale in Hangzhou.

The second metaphor relates Big Data to Taoism, arguing that the operation of Big Data is similar to the idea of "non-action by the ruler (无为而治)". For example, Mr Wan, a senior expert in the Smart Transportation System field, has been studying the intelligence of the transportation system for more than 20 years since his doctorate. He says:

> *Taoism speaks of wu-wei [无为, non-purposive action].[74] I will call it wu [无]. We all know the phrase "non-action by the ruler" [无为而治]. Then the same goes for the development of the*

[73] **Alibaba Group Holding Limited** is a Chinese technology company in Hangzhou (杭州) focusing on e-commerce, Internet and retail, and famous for the electronic payment service Alipay, online shopping search engine Taobao, and cloud computing services Aliyun.

[74] wu-wei (无为)：is Laozi's most famous slogan, and it is also one of the central themes in Taoism. *Wu* is simply "does not exist." In this phrase, however, interpreters treat it as a negative prescription: "avoid *wei*." The harder problem is to understand *wei*. In modern Mandarin, the character has two different tones. The fourth tone reading is usually translated as "for the sake of." In the second tone reading, the character would normally be translated as "to act". Textbook interpretations say *wei* means "purpose" as well as "action", so the slogan means "non-purposive action". The second tone reading, however, has another important use. Some grammar textbooks call it the *putative* sense – "to deem, regard or interpret." *Wei* functions in this sense in literary Chinese belief ascriptions which focus on the predicate. So a belief that S is P takes the de re form [believer] takes *S to be* P (*wei*). *Wei* also figures in a related way in knowledge contexts with nominal predicates – "know to deem as (*wei*) [noun]" (see Stanford Encyclopedia of Philosophy https://plato.stanford.edu/entries/daoism/#Wuwei) Here, I will choose the first interpretation of wu-wei that the phrase means "non-purposive action". First of all, the participant used this phrase in the second tone reading in the interview, and the interview was conducted in modern Mandarin. Second, the interpretation of wu-wei as "non-purposive action" is the most common explanation in China. Third, according to the participant's elaboration later in the interview, the phrase is closer to the meaning of "flexible".

transportation system. For example, after the 1960s and 1970s, probably due to the development of computers, we mainly studied the problems of traffic signalling. And a series of systems emerged at that time. In terms of the scope of the study, they focused on just one aspect or one point, right? By the end of the 1980s, Europe proposed the "drive" program, and the US proposed the MHS, which should probably be considered as the early stage of the Smart Transportation System. By 1994, the unification was completed. The scope of the study of traffic issues at this time was no longer limited to signals and intersections, but encompassed all aspects such as the highways. China has also proposed "Four Transportations" [四个交通, see Section 2.1, The Four Traffic Proposal], and mentioned the seamless integration of the transportation system and so on. The emphasis at this time is on the overall improvement of safety, environmental protection, and efficiency of transportation, not just one aspect.

The most important feature of the Smart Transportation System, as I just said, is that it is analogous to the wu-wei in the Taoism, "non-action by the ruler" [无为而治]. The most important feature [of the Smart Transportation System] is that it is intelligent. While *we can see the feature of "non-action by the ruler" it can adapt to changes. In the case of the Smart Transportation System, this means that I have the ability to provide a good solution that is most close to your target, no matter what scenario or problem I encounter. (Mr Wan, Chongqing)*

Thus, in the opinion of the experts there is a clear cultural metaphorical link to Taoism in the Smart Transportation System.

The third metaphor is the analogy of Big Data to TCM. For example, Prof. Yuan an expert in signal control of the transportation systems and has been involved in many local projects. He argues that Big Data like TCM experiences a shift in thinking based on the large amount data that has been collected:

Now that we are using data to capture the practice, it is a completely different way of thinking. So, it is definitely going to be a big leap forward from a technical standpoint. Because it does not use the same way of thinking or philosophy than before. For example, we asked if there is a future for TCM. The main problem with TCM today is the lack of information. However, if I had all the information about TCM, such as all its prescriptions and all the pathology of patients, I wouldn't need to know the *mechanism at all, and then I would be able to give you a right prescription. Actually, I am not saying that it is definitely going to work. I am just saying that the way of thinking has changed. It will definitely be a big leap forward. However, will this shift be very effective or not?*

It may be effective from a TCM point of view. Because it is about probability, we're actually looking at what percent of people are effective. However, you can't talk to people about percentages in traffic, because it's hard to express it as a percentage [...] We say that there will be rapid advances because the way of thinking has changed. For example, it is also true for signal control in the transportation system. Now Didi also does signal optimization in the transportation system. What makes it [Didi] capable of doing it? We are not saying it understands [what is the signal optimization] Of course, we don't mean that it does not understand. The reason is that it is more confident. When it works on signal control, it thinks about the fact that I have a large amount of data from the vehicles of its company that I can optimize with the data. So it is a different way of thinking. (Prof. Yuan, Nanjing)

While Prof. Yuan supports that additional data leads to better organization, on the other hand, Dr Yi expresses a different view – that technology cannot replace professional expertise. Dr Yi is a senior engineer working for a state-owned company for transportation system design in Hangzhou. He argues that technologies such as TCM that use empirical models had logical flaws, which are therefore uncredible. For example, Dr Yi says:

> *Artificial Intelligence, I don't know how amazing it is. However, we cannot say that we can do everything without a lot of professional knowledge, as long as we have data. Now there is a tendency in China that as long as there is data, through the integration of the data, we can do everything. I don't think so. Let's say that you have 10 million medical records, will you be able to treat the disease? I don't think so, you still have to go to the hospitals to check. It will form an empirical model, somewhat like the empirical models in TCM. However, I think we still need to be careful [...] I don't mean the method. I think it has logical flaws. The logic of using one piece of data to make a conclusion is flawed. (Dr Yi, Hangzhou)*

Alternatively, to the above interviewees, Prof. Fa who is an expert in the integration of IT and engineering in Chengdu's transportation system also suggested that Big

Data is similar to TCM without labelling it as positive or negative. For example, Prof. Fa says*, "Big Data is like TCM. It is all-inclusive. You can put anything into it"* meaning that Big Data is similar to the way of thinking of TCM, and it is possible to use this way of thinking to consider anything.

6.1.2 The Analogy Between Big Data and Traditional Chinese Medicine (TCM)

As I will discuss below, not all of the three metaphors that emerged from the fieldwork can help us to analyze the nature and characteristics of Big Data. Therefore, the three metaphors need to be analyzed in a more detailed way.

First, comparing the transportation system with the human body, although it was a common metaphor across the interviews, focuses on the transportation system itself, not on Big Data. Thus, this metaphor might not be able to help us analyze the nature and the characteristics of Big Data. For example, when Kwakkel and van der Pas (2011) compare the methods used to evaluate medical treatments with urban infrastructure planning, they conclude that the same methods could be successfully used. By applying the well-established methods of dealing with uncertainty of the human body in medicine to the uncertainties of infrastructure planning. Thus, since the focus of this first metaphor for Big Data is on the transportation system rather than on Big Data, I will not analyze it in the following sections.

Second, the linking of Big Data with Taoism might be an isolated case related to the personal background of the participant. Mr Wan loves traditional Chinese culture, and he knows a lot about it. The interview was conducted in the participant's office where traditional Chinese paintings and calligraphy hang on the wall. Also, his desk displays Chinese tea sets, a traditional paperweight, and other items that have traditional Chinese characteristics. However, I was not able to photograph Mr Wan's office because he informed me that it was a private space and he did not grant permission. Compared to other participants' offices, however, his office has the most unique decorations observed during my fieldwork. Moreover, during small talk before and after his interview, Mr Wan talked about traditional Chinese culture being influential in his family when he was a teenager. Therefore, I argue that linking Big Data to Taoism may be an isolated case influenced by the background of the participant. Also, I will not analyze it in the following sections.

Third, drawing an analogy between Big Data and TCM differs from the above idea that relates Big Data with Taoism. Before I start discussing the relationship between Big Data and TCM, I would like to clarify that the analogy between Big Data and TCM is related to the Chinese cultural context in which the participants were embedded, rather than to the specific experiences of the participants and researchers. In other words, the participants used the analogy to explain the nature and characteristics of Big Data. This metaphor is therefore not an isolated case. It is a consensus among the participants. This analogy seems very special as it is not found in other studies (based on my extensive literature review). It was not expected at the beginning of the fieldwork, yet due to the participants' consensus it is not an exception caused by the interview setting, the personal background of the researcher, or the personal background of the participants. This analogy helps us understand the nature and characteristics of Big Data.

This analogy is unrelated to the personal background of the participants. The participants are people with expertise in transportation and Big Data, but a general knowledge of traditional Chinese culture. To be more precise, their general knowledge comes from the Chinese context rather than the result of study traditional Chinese culture or have a family influence of traditional Chinese culture on them. In the fieldwork, I did not observe that the participants had many connections to traditional Chinese culture. For example, interviewees who made this point have very modern offices (see Figures 18 and 19). Dr Yi was interviewed by telephone, so I have no information about his office decor. Yet we can see that the decorations in Prof. Yuan's and Prof. Fa's offices are very different from Mr Wan who presents the idea that Big Data is related to Taoism.

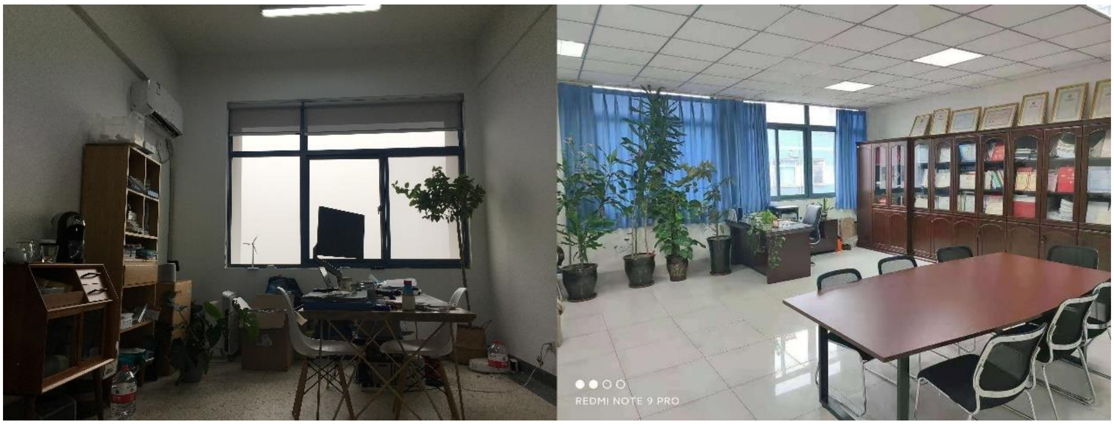


Figure 18. 19. From left to right: **Figure 18.** Prof. Yuan's Office; **Figure 19.** Prof. Fa's Office.

Likewise, during the small talk that proceeded their interviews, the participants they (apart from Mr Wan) did not talk about topics related to traditional Chinese culture. I also searched their CVs online. For example, Prof. Fa studied science in high school. In Chinese high schools, students of art and students of science are taught very differently. Students of science study physics, chemistry, biology, mathematics and civil engineering. Therefore, I do not think that this third analogy connecting Big Data and TCM is related to the personal background of the participants.

Also, this analogy is not related to the personal background of the researcher. In addition to the background of the participants, it is also worth discussing whether the background of the researcher is relevant. I sent my CV to all my participants before the interviews. The CV shows my education background, i.e. an undergraduate major in philosophy, and a master's in the philosophy of science and technology (Figure 20). However, there is no indication on the CV of the courses I have taken.

教育背景

2010.9-2014.7	**南京大学**	**哲学学士**	**南京，中国**
2014.7-2017.6	**南京大学**	**科学技术哲学硕士**	**南京，中国**
2013.1-2013.5	**University of Dayton**		**戴顿，美国**
2015.9-2016.5	**Université Paris 1 Panthéon-Sorbonne** • 交换生 专业方向：科学技术哲学		**巴黎，法国**
2014.6-2014.7	**Université de Nantes**		**南特，法国**
2017.9-	**University of Wariwick** • 博士研究生 专业方向：科学社会学		**考文垂，英国**

Figure 20. CV. Education Background – Major in Philosophy and Philosophy of Science and Technology.

Thus, the participants' understanding of the researcher's education background may be that I hold an understanding of philosophy. Also the participants' perception of philosophy could be the general understanding of "philosophy" rather than the professional one. There is more nuance understanding of philosophy in the professional field. For example, in the department of philosophy, undergraduate courses have different themes, including Chinese Philosophy, Western Philosophy, Marxist Philosophy, Ethics, Aesthetics, Logic and Religion. While in the general understanding of philosophy, the mainstream idea is to equate it with "Marxism". And it is usually questionable whether Chinese philosophy is part of philosophy. For example, people usually ask undergraduates of the Philosophy Department, "Is there philosophy in China?". Thus, from the perspective of the participants, the educational background of the researcher is unrelated to Chinese Philosophy. In conclusion, participants are using this analogy of TCM to explain their own ideas with no influence from the researcher. Otherwise, participants would have used formulations related to Marxism to explain their ideas.

Moreover, the participants used the analogy of *"Traditional Chinese Medicine"*, while they did not use the terminology of Chinese philosophy, such as Taoism, Confucianism, etc. I think that it shows that the participants are referring specifically to TCM rather than extending to Chinese philosophy. In other words, for the participants, they are focusing on the issue of science and technology, not on Chinese philosophy. So, this analogy is what the participants wanted to express. Thus, having ruled out the possibility of this metaphor being an isolated case, in the next section, I will further analyze this analogy.

6.2 Big Data and Traditional Chinese Medicine (TCM)

In the previous section, I described the three metaphors which emerged in the fieldwork. The final one, the metaphor between Big Data and TCM, might be an unusual case which needs to be explored deeply. I argue that the participants try to link Big Data and TCM in order to explain the nature of Big Data, and that they also want to use this analogy to point out possible solutions to the issue of Big Data. In this section, I will analyze this analogy and argue that for the participants "TCM" is the "familiar shape" of ancient Chinese scientific thought, which indicates that Big Data has some characteristics that are not found in modern science and technology. Then, I summarize four similarities between Big Data and TCM.

6.2.1 Big Data is Similar to TCM

Three participants describe the similarity between Big Data and TCM. For example, Prof. Yuan is a professor in signal control of the transportation systems and has been involved in many local projects. He argues that Big Data, like TCM, shifts in thinking/interpretation based on the large amount data that has been collected. Prof. Yuan says, "*it is definitely going to be a big leap forward from a technical standpoint. Because it does not use the same way of thinking or philosophy than before.*" Recall that Prof. Yuan previously mentioned signal control in traffic as an example: when we have data on company vehicles we can optimize how this data is used at that point. On the other hand, recall that Dr Yi – a senior engineer working for a state-owned transportation system company in Hangzhou – argues, in Subsection 6.1.1, that technologies such as TCM that use empirical models have logical flaws, and were therefore not credible. A third example comes from Prof. Fa who is an expert in the integration of IT and engineering in the transportation system. He suggests that Big Data is similar to TCM: *"It is all-inclusive. You can* *put anything into it".*

From the above examples, the participants' analogy between Big Data and TCM could be divided into two parts: (1) Big Data is similar to TCM, and (2) whether Big Data or TCM is credible, the participants try to use TCM to demonstrate its credibility.

6.2.2 Why They Choose Traditional Chinese Medicine (TCM)

In the interviews, this metaphor between Big Data and TCM, relating cutting-edge technology to traditional technology, is rare. First, this comparison actually focuses on the rhetoric, which makes it appealing. For the characteristics and nature of Big Data, Chinese scientists and engineers recognize that it is data-driven and inductive based on observations (See Section 6.2). Similarly, Anderson (2008) proposes "the end of theory", indicating that Big Data is an empiricist epistemology and inductive in nature. Frické (2015) has a more moderate point of view, although he argues that "Inductive algorithms are a central plank of the Big Data venture", he believes that Big Data is "supervised regression" and "supervised classification". Coveney, Dougherty and Highfield (2016) argue that modern science is a combination of "Sir Francis Bacon's insistence on experimental design and Galileo's establishing scientific knowledge on a mathematical basis". Here, the characteristics and nature of Big Data are called "a form of pre-Galilean rationalism" (Coveney, et al, 2016). Therefore, from "a form of pre-Galilean rationalism" to "Traditional Chinese Medicine", the understanding of the characteristics and nature of Big Data is similar, while the way to express them is quite different. In other words, they are different in rhetoric. The study of "the comparison between TCM and Big Data" could also be seen as a study of rhetoric.

Second, more specifically speaking, "the comparison between TCM and Big Data" could be seen as a metaphor. In a narrow sense, a metaphor could refer to the particular use of certain words in a language, for example, to refer to Y by the name of X (Guo, 2004). Moreover, a metaphor is not only a rhetorical technique in a language but also a way of thinking. Lakoff and Johnson (2008) put forward a theory called "Conceptual metaphor", arguing that the nature of metaphor is a systematic mapping across conceptual domains. Thus, the study of metaphor could also be a study of the way that people see the world. In the cross-cultural studies about metaphors, different cultures view the same thing from different perspectives, so they may use different metaphors to describe the same object. For example, Chen (2005) studies the change of our eyes as an expression of anger between different cultures. Chen (2005) points out that the Chinese would talk about the bulging eyes, while the Japanese notice that the eyes would become triangular in shape, when describing anger. The choice of metaphor often reflects the cultural framework that is influenced by traditions, values, the way of thinking, historical background, and so on (Chen, 2005). Therefore, the metaphor chosen by the Chinese scientists and engineers in this study is both unique and worthy of study.

Thus, it needs to be explored more deeply. Although I use words like “analogy” or “metaphor” to describe the participants’ expression, I think the use of the analogy of TCM is very special in this context, since participants use it not as a term but as a way of thinking. In previous studies of Big Data, analogies and metaphors often take the form of object-to-object correspondence. For example, Puschmann and Burgess (2014), find a lot of Big Data metaphors from several websites, referring to natural forces like “floods” and “tsunamis”. People in their study use this metaphor to express that Big Data has the characteristics of a flood, such as being fluid, disruptive, etc. However, my participants use the analogy *“TCM”* not in this sense. *“TCM”* is not an object. It is a system which includes a way of thinking, and several treatments and techniques for Big Data led by this way of thinking.

First, when the participants related Big Data to TCM, they did not mean that Big Data was similar to the medicinal treatments or techniques of TCM. For example, they did not associate Big Data with herbs, acupuncture, or other specific therapies. As mentioned above, the participants only had a general knowledge of TCM, so they did not point out the similarities at a technical level, but in a holistic sense. In fact, the participants pointed out that the way Big Data works is similar to the way TCM works. For example, Mr Jiang is a senior project manager who is in charge of the construction of a Smart Transportation System project. He argues that Big Data comes from the experience of a large number of projects, but such experience makes it difficult to guide projects that don't have previous experience. Mr Jiang says:

> *The use of Big Data has its benefits and its drawbacks. Where does Big Data come from? Big Data definitely comes from data collection from previous projects. [...] What do we do if we don't have the experience that people have had in the past? Using Big Data, it's possible to make more scientific and reliable decisions about the things have been done routinely or have been done before. However, if we are going to do something that has not been done before, there are some new risks that they may not be aware of. When we try to do something unconventional or innovative, Big Data may be the barrier. This over-reliance on, or obsession with Big Data can also be an excuse for so-called experts to oppose innovation. (Mr Jiang,Beijing)*

Second, when participants draw this analogy between Big Data and TCM, they refer to ways of thinking being similar to each other: the way Big Data works is similar to the way TCM works, because they use the similar modes of thinking.

Which might seem strange to a medical Western perspective based on science, but suits the holistic Chinese culture. According to Prof. Ti, Big Data is viewed as an accumulation of experience, and also as an analogy to professionals with a great deal of experience. Prof. Ti is a professor focusing on the transportation infrastructure in one of Shanghai's universities. He argues that data-driven ways of thinking are based on experience. Prof. Ti says:

> *Data-driven, in short, is based on experience. For example, nowadays we often see the traffic lights at intersections, and we need to find out the best distribution of these traffic lights. You might use a model which is based on some kind of theory about the traffic flow, and figure out a best solution. However, an experienced local engineer or traffic police can also provide a solution based on his judgement of the intersection and his general experience. You will find that his solution is also very good. It is also actually a data-driven solution. It is essentially the same thing. He also has an empirical model of his own. (Prof. Ti, Shanghai)*

Therefore, in its current stage, the data-driven model of the Smart Transportation System is similar to the solutions given by experienced professionals.

Third, the TCM mindset refers to the mindset of traditional Chinese science and technology and medicine. The participants use TCM as a representative of this way of thinking. On the one hand, for the participants, TCM is a traditional Chinese science with which they are most familiar. And when using metaphors, people usually choose a “familiar shape”. On the other hand, this mode of thinking has the characteristics of traditional Chinese science and technology which is still used in modern Chinese society. The participants are not experts in traditional Chinese science and technology but choose a familiar shape when making an analogy.

Medicine, agriculture and astronomy are representative of ancient Chinese science and technology, all of which share a common intellectual foundation derived from Chinese philosophy. According to Qian’s (2005) research, the vast majority of scientists in ancient China have been astronomers, agronomists or medical scientists. All three disciplines are closely related to social practice, and have adopted Confucianism with its emphasis on practicality. Nowadays in China, the closest connection of traditional Chinese science and technology within everyday life is TCM. Although traditional astronomy and agronomy were once closely associated with people’s everyday lives, they are now largely withdrawn from Chinese people’s life, and we can usually find them in the museums. However, TCM is still active in the daily lives of Chinese people. There are TCM hospitals in almost every province and every city in China (Subsection 3.3.1). The idea of “focusing on the whole” is also reflected in TCM (Shao & Yan, 2007). Therefore, TCM could be seen as a representative of traditional Chinese science and technology, as well as a mode of thinking. Considered in this light, it is understandable that the participants chose TCM as a metaphor.

In this sense, TCM plays the role of a bridge that brings two abstract thoughts together. For the participants, "TCM" is their "familiar shape" for ancient Chinese scientific thought. TCM is a traditional Chinese technology that they can still find in their daily lives. And TCM has the characteristics of traditional Chinese technology and can be seen as an example of traditional Chinese science and technology.

6.2.3 Similarities Between Big Data and TCM

In the previous section, I explained that the participants' use of "TCM" as an analogy was to link the idea behind Big Data with ancient Chinese technological thought. In this section, I will explore the similarities between the two, from the perspective of the participants. I argue that "ancient Chinese scientific thought" that the participants indicate is not used in the sense of Chinese philosophy, nor the sense of the philosophy of science. As mentioned in the previous sections, the participants do not have a professional background in philosophy and have a general knowledge of traditional Chinese culture.

First, in the sense of Chinese philosophy, ancient Chinese science is a unique and self-consistent system. Ancient Chinese science and technologies share the same theoretical system, based on the Theory of Qi (元气论) and the Theory of Yin and Yang (阴阳理论), while Western science is "objective science" (Liu Shengli, 2011). It also reflects the two main streams of Chinese philosophy: Taoism and Confucianism. Although Confucianism and Taoism disagree on how to unite humanity and nature, they both advocate viewing human and nature as an organic whole. The second feature is "the holistic unity of humanity and nature", which means the laws of the world are similar to the laws of the human body. Since heaven and human, or the nature and human form as an organic whole, the nature and the human body were also understood as a whole in ancient Chinese science and technology.

From the perspective of the philosophy of science, it is a question worth exploring whether there is science in ancient China at all. Joseph Needham is one of the best-known scholars of ancient Chinese science and technology. "The Needham Question",[75] the question of whether there was science in ancient China here becomes a matter to be explained. The answer to this question depends on how researchers define "science". For example, Coveney, Dougherty and Highfield (2016) point out that modern science is based on Bacon's experimental methods

[75] "*Why did modern science, the mathematization of hypotheses about Nature, with all its implications for advanced technology, take its meteoric rise only in the West at the time of Galileo?*", and why it "*had not developed in Chinese civilization*" which in many previous centuries "*was much more efficient than occidental in applying*" natural knowledge to practical needs?

and Galileo's mathematical basis. If we take this as a criterion, there is no doubt that ancient Chinese science was a pre-Galilean product, which means an unfinished product of modern science. However, there is another way to view science; that is, as a valued social institution.

We may find that science takes on different forms. For example, comparing Chinese, Indian and Western medicine, Bivins (2010) shows us that the line between "orthodox medicine" and "alternative medicine" is not entirely clear, and that medical knowledge is always transferred between cultures. In fact, the same is true between modern science and local scientific knowledge. For example, according to Montgomery and Kumar (2015, p.331), "translation has been a major force in the history of science" and translations could help create some new scientific cultures (Section 2.1).

The participants do not view TCM from either of these perspectives above. They make the analogy based on their working experience and the general understanding of ancient Chinese science and technology. They do not imply that Big Data has a close relationship with Chinese philosophy, such as Confucianism or Taoism. Also, they do not try to reveal whether science existed in ancient China. It would be more accurate to say that in their daily work, they have found that Big Data presents some characteristics of TCM. These characteristics differ from the modern science and technology they employ, and are instead similar to traditional

Chinese science and technology. Therefore, they use "TCM" as an analogy to highlight these characteristics. I will summarize these characteristics below which, according to the fieldwork, are: (1) an emphasis on experience, (2) an emphasis on observation, (3) an emphasis on practicality, and (4) an emphasis on the individual.

6.2.3.1 An Emphasis on Experience

The participants argue that Big Data and TCM are both work-based. Because of the idea of "the holistic unity of humanity and nature", ancient Chinese science and technology understood the world through observation and accumulated a great deal of experience. According to the interviewees' responses, Big Data is viewed as an accumulation of experience, as well as TCM professionals with a great deal of experience. For example, Mr Jiang is a senior project manager who is in charge of the construction of a Smart Transportation System project. He argues that Big Data comes from the experience of a large number of projects:

> *Big Data definitely comes from data collection from previous projects. So let's say that since it's data collection from the previous projects, we can understand that since you're using Big Data, you're never going to be able to jump out of the wisdom of previous generations (Mr Jiang,Beijing)*

Also, Prof. Ti who focuses on the Intelligent Transportation Infrastructure, argues that "*Data-driven [methodology], in short, is based on experience*". In its current stage, Prof. Ti says "*an experienced local engineer or traffic police can also provide a solution based on his judgement".*

6.2.3.2 An Emphasis on Observation

The participants indicate that the way to accumulate experience is to observe as in traditional Chinese science and technology. For example, Yang Jinyun (2001) suggests that ancient Chinese scientists believed that through unremitting observation, they could understand and grasp the nature and the laws of the world. Methodology which focuses on observation emphasizes not only the importance of experience, but also the importance of intuition (Qu Xiuquan, 2010).

Knowledge of TCM usually can only be learned and taught through observation in specific contexts. Furthermore, for TCM, the accumulation of experience, or data, is very important. For example, according to Ding and Chen Fan (2007), medical records make up the majority of the ancient Chinese scientific and technical archives, providing access to relevant cases. According to Liu Shengli (2011), ancient Chinese science was learned through lots of practice, examples, and lots of "tacit knowledge", which Liu calls the "material first" method of learning.

Liu argues that when studying Western science, people first learn abstract theories and then use these theories to guide practice, the "form first" approach.

When we turn our attention back to the issue of Big Data, we see that participants consider Big Data, or machine learning, to be a "material first" method. The development of Big Data comes from the accumulation of a great deal of experience. This learning approach makes Big Data resemble an experienced professional, to a certain extent. For example, Prof. An proposes the use of simulation to compare the effects of different traffic management plans. Prof. An says:

> *Which solution is more appropriate and reasonable for urban transportation? It could be compared by simulation. Generally speaking, the simulation is credible [...] The trend now is called the real-time simulation. There are sensors, cameras, and other monitoring devices on the road that we can collect real-time data from. Then, I import real-time data into my simulation system. We can then run the simulation system. Road conditions of my simulation and the real road conditions are basically synchronized. However, there will be a time difference between the two, a time difference of a few minutes. On this basis, I can predict [the situation afterwards]. Because the previous*

conditions all match, I can predict the change in traffic conditions for the next time period, for example, a few minutes later. (Prof. An, Nanjing)

Another example comes from Prof. Fa who informs me about the latest application of Big Data in the transportation system: “digital twin”. “Digital twin” means that people use data collected from the real world, and construct a digital world which simulates the real world on computers. Then, people observe changes in the digital world to predict possible changes in the real world to plan future actions. Thus, whether it is dealing with traffic situation in the next few minutes, few days, or years, these examples rely on observing a digital world which simulates the real world. Then they take actions according to predictions made in the digital world.

6.2.3.3 An Emphasis on Practicality

For modern science and ancient Chinese science, observation is the foundation. However, ancient Chinese science placed emphasis on practice rather than theory; concerned with the effects, while processes in scientific inquiry can be obscure. There are two reasons for this emphasis on practice: the first one is the holistic view, and the second is that there is a strong influence of Chinese philosophy on traditional Chinese science. Chinese philosophy always focuses on practical dimensions.

First, because of the holistic view, ancient Chinese science was more willing to observe things as a whole. As Wu Lin and Tong Ying (2005) point out, ancient Chinese science regarded the object of observation as an impenetrable black box and speculated about the internal structures and mechanisms from the external environment and behaviour. The flaw in this methodology is the lack of in depth study of the details, as Yang (2001) highlights. This holistic view also prevented ancient Chinese scientists from using logical reasoning to obtain precise knowledge, so, according to Qian (2005), China lacks a tradition of using rigorous logical reasoning. A typical example of this is the Theory of Qi. Ancient Chinese scientists considered Qi（气）to be the fundamental element that makes up everything in the universe which has had a direct and profound impact on many disciplines, and is one of the pillars of the ancient Chinese science. However, no scientist has ever elaborated, reasoned, or proved what Qi is and what its nature is. According to Qian's study (2005) on the ancient Chinese book on science and technology called "The Dream Pool Essay (梦溪笔谈)", although the book covers astronomy, geography, physics, chemistry, and other natural knowledge, it only records many important phenomena that people have observed, but it does not provide any explanation of these phenomena. Qian thinks that it is also the same for almost all other scientific works in ancient China.

Second, traditional Chinese science is closely related to Chinese philosophy with its strong sense of social responsibility. For example, as Jin Guantao *et al.* (1982) point out, Confucianism places the understanding of nature at the service of its ethical doctrine. So it does not exclude certain technologies that can serve real life, but technologies that do not serve real life are dismissed as meaningless. Moreover, Confucianism is not concerned with the anomalies of nature. For example, The Analects states: "The subjects on which the Master did not talk, were: extraordinary things, feats of strength, disorder, and spiritual beings."[76] Therefore, Confucianism is not concerned with unusual natural phenomena, nor does it focus on scientific questions that have no direct application. On the other hand, Chen Yan (2009) points out that Taoism shares the same idea that the nature is mysterious and unknowable. For example, Dao De Jing says: "The Dao that can be trodden is not the enduring and unchanging Dao."[77]

Chinese philosophy's emphasis on practicality leads to the same criteria for evaluating science and technology in ancient China. So scientific research is judged by its importance and urgency in practical application. For example, in ancient China, mathematics was treated as a technology rather than a science. According to Cao's (2003) study of the ancient Chinese mathematical classic "The Nine Chapters on the Mathematical Art (九章算术)", although the book contains 264 mathematical problems and their solutions, it does not give sufficient

[76] The Analects. Shu Er (论语.述而)：子不语怪，力，乱，神。
[77] Dao De Jing (道德经): 道可道，非常道.

attention to mathematical theory. For example, it does not form the mathematical paradigm of Euclidean geometry.

In the same vein, this Chinese emphasis on practicality is also reflected in TCM. In the development of TCM, the solution of practical problems usually comes first, while explanations and principles take a back seat, or there is even no explanation at all. For example, Shao Lei and Yan Jianhua (2007) argue that TCM often tries to find and collect all possible methods for solving clinical problems. A typical example is the "Tried and Tested Medical Prescription (验方)", which puts the interpretation of disease and treatment principles on the back. Shao and Yan (2007, p.55) say: "This effort is concerned with its practical utility, which is statistically motivated by the fear of 'rejection of truth'. That is, some useful methods may be missed." Frické (2015) explains "The numbers are provided in advance from elsewhere, then analysis is done on them.", which is a form of statistics.

When we look at the participants' descriptions of their participation in the Smart Transportation System project, we see the same emphasis on practicality, rather than on principles. For example, Prof. An, focusing on the use of Big Data in the transportation system, is interested in the use of data science in the transportation system and has participated in several traffic simulation projects. He argues that the results of traffic simulation are an ideal situation that is difficult to achieve in reality. In fact, we only see a trend of traffic through the traffic simulation at this point. Prof. An says:

> *For example, if I make a simulation of the transportation system, the Scenario 1 may be two minutes or three minutes shorter than the Scenario 2. But this may not fit the reality. Because there are things in reality that you cannot simulate. [...] There will be a time lag between my simulation and real road conditions [...] But if I can predict the change of trend accurately, it is actually possible for the traffic police to deploy it in advance. (Prof. An, Nanjing)*

In fact, we only see traffic trends through a traffic simulation at this technological point in time, but the results provide enough information for people to take actions to solve immediate congestion issues.

6.2.3.4 An Emphasis on the Individual

Both Big Data and TCM deal with individual cases. As we can see, from the perspective of the interviewees, Big Data can be viewed as an experienced TCM doctor, to some extent. In the context of Chinese culture and TCM, an experienced TMC doctor refers to a “good doctor” who can provide effective treatments, although they may not be able to explain the reasoning behind treatments to maintain the body in a balanced state (Subsection 3.3.1). What makes the experienced TMC practitioner a good doctor is their years of experience, typically a more mature doctor, having dealt with a lot of patients in their long career. A wide variety of patient experience enables them to "prescribe the right treatment (对症下药)"; that is, one-on-one, individualized treatment. It is not a universal treatment that can be applied to a wide range of patients. Similarly, the interviewees usually assume that the solutions provided by Big Data are specific and localized, and cannot be generalized. For example, Prof. Yuan – a professor in signal control of the transportation system – has been involved in many local projects. He argues that the solutions provided by Big Data are specific and localized, so they are difficult to replicate elsewhere. Prof. Yuan says:

> *I can customize a great program for you, and I'm sure it can be done. But what is it replicable for? This tailor-made approach. In other words, this approach means that I still need to design [on a case-by-case basis] for the next project. Then its generalizability is extremely limited. Although I have created some techniques, they are still not enough to make the solutions replicable. Some technologies may be somewhat different from case to case [...] I don't want to be a doctor of TCM. We know that TCM has its own philosophy and methods. However, the methods of TCM are not able to be a system which can be*

generalized. I don't think this is the kind of thing I want to achieve in the future. (Prof. Yuan, Nanjing)

The current situation is to provide individualized solutions like TCM, so Prof. Yuan expresses his desire to create a solution to be generalized across the transportation system, rather than individualized solutions like "TCM".

To summarize Subsection 6.2.3, the participants make the analogy between TCM and Big Data based on their working experience and the general understanding of ancient Chinese science and technology. The participants used TCM as an analogy, but they did not refer to specific TCM practices. Instead, the participants pointed out that how Big Data works is similar to the way that TCM works, such as the emphasis on the experience and observations. TCM is their "familiar shape" of ancient Chinese scientific thought. Thus, they indicated a similarity between the thoughts that guide the practices of Big Data and TCM. In this sense, TCM plays the role of a bridge that brings two abstract thoughts together.

The participants use "TCM" as an analogy to highlight similarities between Big Data and TCM. Four similarities arise, emphasize: (1) experience, Big Data and TCM both work based on experience; (2) observation, the way to accumulate experience is to observe; (3) practicality, Big Data and ancient Chinese science place emphasis on practice above theory; and (4) individual cases, over generalizable ones. Moreover, through this analogy, between Big Data and TCM, I conclude that the participants propose three Big Data characteristics connected to the Smart Transportation System: (1) Big Data is an empirical science that works by accumulating a large amount of experience; (2) Big Data is based on observation; and (3) because of the above two points, Big Data is difficult to generalize.

6.3 The Analogy Between Big Data and TCM is to Demonstrate Whether Big Data is Credible or Not

I would like to illuminate that the analogy between Big Data and TCM used by the participants is really a discussion about Big Data's credibility. In Subsection 6.3.1, I will clarify that it is not a "Needham Question" about traditional Chinese science and technology, but a question about the credibility of Big Data. Based on the differences between TCM and Big Data proposed by the participants in the previous section, in Subsection 6.3.2 I argue that observation is significant in TCM and Big Data. Although traditional Chinese science and technology and Big Data use observation as their main method, traditional Chinese science observes the real world, while the observations of Big Data are taken in the digital world.

6.3.1 It is not "The Needham Question", but an Exploration of Big Data's Credibility

In Sections 6.1 to 6.2, I explained the similarities between Big Data and TCM. From these similarities, I summarized three characteristics of Big Data which differ from modern science and technology, and the participants reveal these characteristics by using a TCM analogy. The participants also present a second question: "Is Big Data or TCM credible?" This question is related to the definition of science and whether science has only one form or multiple forms. When the definition of science involves traditional Chinese science and technology, it is probably related to "The Needham Question" – whether there was science in ancient China. However, in this context, the question is about the definition of science, but it is not a "Needham Question". It is about whether empirical science is a science at all, and whether results derived from a great deal of empirical data are credible.

As discussed in Subsection 6.2.2, the participants' ideas were based on their daily working experience and their general knowledge of traditional Chinese science and technology. They did not mention the connection between Chinese philosophy and technology, nor did they investigate whether there was science in ancient China. Moreover, similarities between Big Data and TCM proposed by the participants are at a technical level, not at the level of philosophy or traditional Chinese science. So, the question here would be whether the results of Big Data are credible because it uses observation as a method to collect a large number of empirical data.

In the interviews, the participants gave us three kinds of answers to this question: (1) it is credible, (2) it is not credible, and (3) it is not necessary to discuss whether it is credible or not, and we should focus on the effect. For example, Prof. Yuan – a professor in signal control of the transportation systems in Nanjing – has been involved in many local projects. He argues that for Big Data, like TCM, "*the way of thinking has changed*" based on the "*large amount of data from the vehicles of its company that I can optimize with the data.*" On the other hand, although Dr Yi also uses the TCM analogy, he expresses a different view. Dr Yi argues that technologies, such as AI, that use empirical models have *"logical flaws"*, which are therefore uncredible: "*The logic of using one piece of data to make a conclusion is flawed.*" A third example comes from Prof. Fa who is an expert in the integration of IT and engineering in the transportation system. He suggests that Big Data is similar to TCM but does not indicate an opinion that the similarity between Big Data and TCM is good or bad: "*It is all-inclusive. You can put anything into it* ".

Thus, the participants drew different conclusions about the credibility of Big Data through the same analogy. They argue, respectively, that Big Data is as credible as TCM, that Big Data is as untrustworthy as TCM, and that Big Data is similar to TCM without specifying whether it is credible. In other words, the participants present a second question: "Is Big Data or TCM credible?" In this context, I argue that the question is about the definition of science and whether the results that are derived from a great deal of empirical data is credible. However, the participants did not give a clear answer to this question. The participants also proposed some differences between Big Data and TCM. These differences may help to explain Big Data's credibility.

6.3.2 The Difference Between TCM and Big Data Lies in their Different Means of Observation, Which Affects the Credibility of Big Data

In Subsection 6.1.2, I described that the participants propose three Big Data characteristics: (1) Big Data is an empirical science that works by accumulating a large amount of experience; (2) Big Data is based on observation; and, (3) because of the above two points, Big Data is difficult to generalize. Alternatively, when I studied the analogy between Big Data and TCM in more detail in the research materials, I found some differences between the two. It is these differences that may explain the credibility of Big Data.

Although, both traditional Chinese science and technology and Big Data use observation as their main method, traditional Chinese science observes the real world, while the observation of Big Data is taken in the digital world. For example, Prof. Fa tells me about the latest application of Big Data in transportation systems, which is called "digital twin" (Subsection 6.2.2.1), using data to construct a world which simulates the real world on computers. For it to be useful in terms of modelling and predicting outcomes, the digital world needs to simulate the real world – as similar to the real world as possible. Prof. Fa's team uses sensors, cameras and other devices, to collect data from tunnels under construction, and use the data to create a simulated tunnel on the computer. Then, they will input construction operations on the computer to observe and predict what might happen. Prof. An also proposes the use of simulation to compare the effects of different traffic management plans. Prof. An says:

> *I import the real-time data into my simulation system. We can then run the simulation system. The road conditions of my simulation and the real road conditions are basically synchronized. [...] I can predict the change in traffic conditions for the next time period, for example, a few minutes later. (Prof. An, Nanjing)*

The participants all agree that a "digital twin" cannot achieve an exact simulation as the real world. For example, when I ask Prof. Fa if that was because the sensors or other devices were not accurate enough Prof. Fa states that the devices are part of the reason, also the real world is too complex. Prof. An also argues that the current simulation can only be accurate in a quite small space. While in a larger space, the uncertainty increases. For example, he says:

> *The accuracy of the simulation might be high, when it runs in a relatively small space. Because the road condition is not so complicated [...] However, at larger scales, for example, dozens of intersections or hundreds of intersections, the effect of the simulation will be different from the real one. Because there is more uncertainty. Because the traffic system is actually disturbed by human behaviour. (Prof. An, Nanjing)*

Prof. Fa also pointed out that they also use physical and chemical principles along with devices to simulate the real world. So, sometimes, they only need to get a few key data to construct a simulation to observe and predict what they might face in the future by varying its parameters.

Therefore, according to the participants' responses, it is clear that Big Data uses observation as its main method. Through simulation, people observe and predict what might happen in a world constructed by data, and then take action in the real world. In this sense, the role of theory becomes part of the construction of this digital world, rather than the ultimate goal of increasing science and technological knowledge. Therefore, the operation of Big Data could be divided into four steps: (1) Big Data uses a “medium” to collect a large amount of empirical data from the real world; (2) people use this empirical data with theories to simulate the real world and construct a digital one; (3) people make observations and predictions in the digital world; and, (4) people take actions based on these predictions. The “observation” of Big Data could be divided into two further types: first, constructing the digital world; second, observing the digital world to gain experience. In other words, although Big Data is an empirical science based on observation, it is different from TCM. TCM collects empirical data in the real world, and accumulates experience. It obtains results through induction. While Big Data adds one additional step: after collecting empirical data from the real world, it uses empirical data to construct a digital world, and then people conduct their observations in a simulation. Fisher and Mehozay (2019) propose a similar point of view when studying how algorithms view the audience. Algorithms do not view the audience in an accurate way, but the analysis of algorithms is based on behavioural data left in the digital world, not the real world.

6.4 Big Data Observations in the Digital World – the Medium and the Construction of the Digital World

Given the arguments of the previous sections, it is crucial for the accurate use of Big Data to construct a digital world that simulates the real world accurately. The degree of simulation accuracy effects the accuracy of observation conducted in the digital world. Here, I will analyze the mediums (e.g. human senses, technology) that collect empirical data from the real world to construct a digital world. Also, I would like to explore how the digital world is constructed.

The medium is very important for Big Data to construct a digital world. On the one hand, Big Data collect and uses empirical data from the real world to construct a digital world simulation. On the other hand, in a Chinese context different mediums should also be viewed as extensions of different parts of the human body. According to Center (1969), "Every human is endowed with a variety of senses that may be used to perceive reality (visual, auditory, tactile, kinaesthetic, olfactory, etc.). At any given moment, an individual relies on these senses in different proportions." (p.2) Center (1969) argues that different cultures also rely on different senses to produce different cultural patterns. Thus, when we view the different mediums used by Big Data as extensions of different parts of the human body, these are comparable to different senses, metaphorically speaking. Additionally, the data collected by different medium might have different patterns.

In previous studies, data is classified according to its characteristics. In general, such collected data is classified as structured, semi-structured, and unstructured data. For example, structured data is tabular data found in spreadsheets or relational databases; unstructured data lack the structural organization that needs machines for analysis such as text, images, audio, and video (Gandomi & Haider, 2015); semi-structured data lies between structured and unstructured data. However, data classification might differ if we consider how different mediums may construct different patterns.

Therefore, reclassifying the data according to its different mediums, I would like to divide the data into two types: (1) data collected by human senses (e.g. sight, touch, etc.) and by the extension of people's senses (e.g. cameras as an extension of human vision); (2) data collected by people as a whole by collecting the traces left by people in the digital world. The first type of data is collected by a single sense and can only partially simulate the real world because they depend on body parts (e.g. the eyes) and devices, such as sensors and cameras. The data they collected is incomplete and due to the loss of data during transmission. For example, Ms Zhao, an expert in traffic signals, says:

> *Data may be lost in transit, which is inevitable. [...] Then you extract it and analyze it. You may find that it is missing the most critical part and your analysis may not be right. There are still problems. Also, I believe that it is a process of technological development. Just like the development of automation, which I experienced before. In the beginning, although we thought that it could be implemented, in the end we still made a lot of*

mistakes and there was the problem of the control system for a long time. Of course, now we have a lot of protection measures so there will not be big problems, or the probability of going wrong is very low (Ms Zhao, Chengdu)

Mr Qian is a senior engineer currently involved in a Smart Transportation System project. He provides a detailed answer about the efficiency of the data collection system in the Smart Transportation System:

The speed limit on the highway is 120 km/h, and the speed is usually 100 or 110 km/h. The transmission technology may not be able to send information or receive one at such high speed. For example, we have some technologies which could send and receive information between cars and you could find those apps in the city. However, if you drive to 120 km/h, those technologies may have a higher rate of packet loss, so it may not be so accurate. That is to say, that our new technology still has a lot of difficulties. (Mr Qian, Beijing)

Moreover, the current data system lacks timely updates. Prof. Di, working in the Smart Transportation System field, gives an example:

> *Whether this road is broken or not, we won't know until a year later. For instance, at the end of 2018, I went to Shenzhen [深圳]. At that time, they just finished acceptance of the 2017 data collection in Shenzhen. So you can imagine that the data is actually not that useful, because one year has passed and the whole thing has changed [...] We want to find a quick means of updating. We may not achieve weekly updates, but we want to achieve a monthly update of the state of our roads. (Prof. Di, Beijing)*

As we can see current transport system updates are lagging a year behind. Related to this point, not enough data is being collected. Prof. Di, adds:

> *As long as the accumulation of data occurs, the development of Smart Transportation System will be very fast. What is missing now is the accumulation of data. (Prof. Di, Beijing)*

The reason for this lack of data may be sensors, according to Ms Bu, a senior expert in the Smart Transportation System field, working for a state-owned company of transportation system design. She says:

For example, the data are insufficient currently. There are several reasons. One is that the sensors we use now break down easily. And all the electronic devices are fragile. The sensors have to be updated every five years. The sensors may suddenly break down but you can't pinpoint its location because we don't know where it is [...] We give numbers to the sensors. If we store its number in the database, I could then use the GPS to pinpoint its location. However, I have to convert that GPS information to the coordinate on my map so that I could know where it is. (Ms Bu, Shanghai)

Ms Bu explains above how sensors require maintenance, replacement, and software improvements to sustain their usability. Mr Ri, a senior expert in BIM, also mentions a software problem:

First of all, there is a problem with software. Now some of the popular BIM software, to be honest, they can only run the project of one building [...] The railway project may be thousands of kilometres, which is very common. That is to say, the railway model is loaded into its software but it cannot run or you may not be able to open it after you've built the model on the *software. Now we generally divided into several sections. Even for a section of a few dozen kilometres, it actually doesn't work well. Especially for the sections that involve terrain, the software will stick. However, transportation construction must involve terrain. (Mr Ri, Tianjin)*

These quotations raise issues of data quality, quantity, and software capacity which could be categorized as technical issues, as they mostly involve sensor accuracy, software updates, and the stability and integrity of the transmission equipment. Combined, these issues limit devices from collecting data. Therefore, to construct a digital world (for the first type of data), devices need to combine the theories of physics, chemistry, traffic management, etc. For example, Prof. Fa notes that they also use physical and chemical principles along with the devices to simulate the real world. So, sometimes, they only need a few key data points to construct a simulation. Then they can observe and predict what they might face in the future by varying the parameters.

The second type of data is collected by people as a whole via mobile phones, GPS, and even consumption data. This data does not rely on a single human sense: it collects data on people's activities. I might say that, in this sense, "people" also become a medium. Because people also enter the overlapping boundary between the real world *and* the digital world. We take buses and metros in the real world, and we also leave our travel information in the digital world accordingly. For example, Dr Yi, a senior engineer working for a state-owned company of transportation system design in Hangzhou, talks about using the data of mobile phones to build models. He says:

> *I will give you the simplest example. For instance, I can use the location data from mobile phones to find out how many people are there in this area. Let's say I'm using a model to calculate the results from the raw data: how many people are there in this neighbourhood? (Dr Yi, Hangzhou)*

However, the digital world constructed by this second type of data does not necessarily need the assistance of theories. It is possible to construct a digital world based on the "performative individual" as Fisher (2019) suggests. In other words, the algorithmic episteme may not reflect the real situations. Therefore, I argue that similar situations that we could construct the digital world without theories is the reason why the idea of "the end of theory" (Kitchin, 2014) emerged in several Big Data studies.

The "the end of theory" concept argues that an increase in the amount of data will form more credible results. Thus, theory does not play a role in data analysis which should be objective. This idea is often combined with empiricism and is considered a rebirth of the empiricist epistemology. However, acknowledging that being objective is still underpinned by subjective reasoning, another idea about the operation of Big Data arises which proposes that people will first have a theoretical framework or hypothesis before they analyze the data: analysis becomes "data driven" (Subsection 3.2.2). Internet companies are more likely to have this second type of data. Some studies suggest that these two ideas relate to the different communities to which they belong. For example, Kitchin (2014) argues that "the end of theory" is trusted by the business community such as data brokers, data analytic providers, software vendors, consultancies. While the idea of data-driven is held by academia. He also argues that the business community uses the idea as a kind of rhetoric to convince others.

In conclusion, "data-driven" and "the end of theory" are both involved in Big Data. The difference is that these two epistemologies rely on different types of data. Data can be divided into that collected by (1) the human senses, including devices, or (2) people as a whole by collecting people's digital traces. The first data type needs to combine the theories of physics, chemistry, traffic management, etc. to construct a digital world. While the digital world constructed by the second data type does not necessarily need the assistance of these theories. It is possible to construct a digital world based on the "performative individual".

6.5 A Detailed Discussion of Big Data

The analogy between TCM and Big Data arising from the research is unique, but it is also understandable. Before I start discussing the relationship between Big Data and TCM, I wish to clarify that the analogy between Big Data and TCM is related to the Chinese cultural context in which the participants were embedded, rather than to the specific experience of the participants and the researcher. In other words, the participants used the analogy to explain the nature and characteristics of Big Data. It also shows the influence of Chinese culture on Chinese scientists and engineers.

6.5.1 Big Data: An Empirical Science

The analogy between TCM and Big Data indicates that Big Data is an empirical science from the participants' perspectives. The participants refer to the similarities between the way of thinking of TCM and the way of thinking of Big Data (Subsection 6.2.1). TCM, it is the "familiar shape" of traditional Chinese science and technology (Subsection 6.2.2). Furthermore, the participants use this analogy, as they indicate that Big Data has some characteristics that are not found in the modern science and technology (Subsection 6.2.3). So they turn to traditional Chinese science and technology.

The participants saw four main similarities between the way of thinking of Big Data and that of traditional Chinese science and technology: (1) Big Data, like traditional Chinese technology, is based on a vast amount of experience; (2) Big Data derives a great deal of its experience from observation; (3) Big Data focuses on practice, not theory; and (4) Big Data is worked on a case-by-case basis, so its results are difficult to generalize. Individual cases are important for Big Data because Big Data is an empirical science, and it uses observation as its method. At the same time, it does not pursue abstract theories and conceptual ideas, but focuses more on practice. Thus, according to the participants, Big Data is an empirical science.

6.5.2 The Mediums of Big Data

As discussed above, Big Data requires a lot of experience, and the method to accumulate this experience is observation. The participants used "TCM" as an analogy because the "observation" of Big Data is similar to TCM. TCM accumulates empirical data through people's eyes, hands, etc. The devices used by Big Data to accumulate empirical data such as the sensors, mobile phones, etc., could be seen as a "medium", suggested by McLuhan as "any extension of ourselves" (cited in Federman, 2004, p.1). For McLuhan, the concept of medium could refer to a lot of things. For example, people use a hammer so a hammer could be seen as the extension of people's arms. In the case of this research, abstract objects such as language could also be seen as extensions, which "extends our thoughts from within our mind out to others" (Federman, 2004. p.2). In this case, sensors, cameras, and mobile phones could also be seen as extensions of human body, such as our eyes and hands.

In this sense, the way that Big Data accumulates empirical data is also through the methods of observation, such as the "eyes" and "hands". In other words, Big Data uses "mediums". Although these mediums are cutting-edge technologies in the Smart Transportation System, they could be perceived as extensions of the human body. Furthermore, the "observation" of Big Data could be divided into two types: (1) to construct the digital world, (2) to observe this digital world and gain experience. The first type of data, it needs to combine the theories of physics, chemistry, traffic management, etc. in order to construct a digital world. It is related to the idea of "data-driven" that means that people will first have a theoretical framework or hypothesis before they analyse the data. While the digital world constructed by the second type of data does not necessarily need the assistance of the theories. It is possible to construct a digital world based on the "performative individual". It is related to the idea of "the end of theory" that argues that the increase in the amount of data will make the results more and more credible. Therefore, I argue that the two epistemologies which are "data-driven" and "the end of theory" are both involved in Big Data. The difference is that the two epistemologies rely on different types of data.

6.5.3 The Artificial Intelligence (AI) of Chinese Philosophy

By reviewing the developmental history of Artificial Intelligence (AI), I imply that Big Data might be seen as a new model, yet the philosophical ideas behind this model fit with Chinese philosophy. According to Dreyfus (2007), philosophy and the manufacturing of AI have long been closely related. He argues that researchers try to turn rationalist philosophy into AI projects, for instance:

> *Hobbes' claim that reasoning was calculating, Descartes' mental representations, Leibniz's idea of a 'universal characteristic' (a set of primitives in which all knowledge could be expressed), Kant's claim that concepts were rules, Frege's formalization of such rules, and Wittgenstein's postulation of logical atoms in his Tractatus (Dreyfus, 2007, p.247).*

Dreyfus (2006; 2007), studying the development of AI models, suggests that different models are supported by different philosophies. For example, the AI model created by Marvin Minsky – "a structure of essential features and default assignments" (Dreyfus, 2007, p.248) – is related to Husserl's idea of ''frame'' – ways of thinking about how people organize, interpret and reproduce social life and our understandings of it (Dreyfus, 2006).

However, Minsky's frame model failed, because the model could not tell from the large number of facts stored in the database which are relevant to its recognition framework (Dreyfus, 2006). After the failure of Minsky's frame model, another AI model was created by Rodney Brooks; Dreyfus called it "Heideggerian AI", suggesting that the model is related to the existential phenomenology of Heidegger, Merleau-Ponty, and Todes (Dreyfus, 2006). Brooks's Heideggerian AI takes into account the environment, but it can "respond only to fixed features of the environment, not to context or changing significance" (Dreyfus, 2006, p.250). So Brooks's Heideggerian AI also failed.

Ultimately, Dreyfus argues that these models fail to avoid the issue of how to frame data. Therefore, he suggests that AI models should learn in context, and should in "more and more finely discriminated situations" (Dreyfus, 2007, p.250).

Connecting the above framing issue of AI systems to my data, the participants would agree with Dreyfus that AI models need to learn from context and experience. As discussed throughout this chapter, the participants propose three characteristics of Big Data: (1) Big Data is an empirical science that works by accumulating a large amount of experience; (2) Big Data is based on observation through certain mediums; and (3) because of the above two points, Big Data is difficult to generalize. In other words, Big Data learns from accumulating a large amount of experience (e.g. inputted data) as well as from context through observation of its surroundings.

On the other hand, “observation” plays an important role in Big Data, both in the real world and in the digital world. As discussed above, the “observation” of Big Data could be divided into two types: The first type of observation is to construct the digital world. Big Data uses a “medium” to collect a large amount of empirical data from the real world. The second type is to observe the digital world and gain experience. Moreover, our senses play an important role in the observation of Big Data. In other words, Big Data observes and perceives the world through the senses. For example, I find two types of data: (1) Data collected by human senses. This type of data is collected by a single sense such as sight, touch, etc. Also, this type of data is collected by the extension of people’s sense. For example, the cameras could be seen as an extension of human vision. (2) Data that collected by the people as a whole. This type of data is not collected by a single sense. It treats people as a whole, and collects data on people’s activities. In this sense, “people” also become a medium. Thus, our senses, extensions of our senses, and even the human body as a whole, become the medium of observation and perception. In other words, in Big Data, we use our bodies to observe and perceive the world, both the real world and the digital one.

As Dreyfus suggests, Merleau-Ponty relates the body and the world, making it possible for us to break through the frame problem. The key is the “feedback loop between the embodied agent and the perceptual world”, an ‘‘intentional arc’’ proposed by Merleau-Ponty (Dreyfus, 2007, p.250). However, unlike Dreyfus, the participants suggest that the best way to avoid the frame problem might be to disregard the “frame” entirely. Through the similarities, of Subsection 6.2.3, the participants point out that Big Data places more emphasis on practice than theory, and it focuses more on individual cases rather than conceptual and generalization. In other words, it is difficult to conceptualize the results of Big Data, to form an abstract theory, or have a so-called “frame”. In this sense, the participants have abandoned the “frame”.

The abandonment of “frame” is one of the characteristics of Chinese philosophy, and, thus, as demonstrated in this chapter it also influences the development of science and technology in a Chinese cultural context. In TCM or Chinese philosophy, it is not important whether science and technology can be conceptualized or whether they form an abstract theory. It is the practicality of science and technology that is most important. The “frame” is also one of the features of Western philosophy. Therefore, it is difficult to give up the idea of creating AI through a “frame”. As Dreyfus says, previous AI projects were based on rationalist philosophy, using these forms to guide the material world. Therefore, I suggest that the new AI model represented by Big Data could be constructed around the ideas of Chinese philosophy.

Chapter 7. Conclusion

This thesis has presented an in-depth sociological examination of the Smart Transportation System that is, similar to the ITS, a new form of the transportation system using advanced ICT to improve its efficiency and safety. Around 2005, the Chinese term “Smart Transportation System (智慧交通 Zhihuijiaotong)” replaced ITS, adding its own local understanding and creation to the term. In this sense, the Smart Transportation System is not only a transportation system combining ICT, but also related to smart cities, Big Data, and the IoT. Moreover, it has become a development target for the future transportation system of China. Thus, the Smart Transportation System has been shaped by its Chinese context.

In turn, through examining this system it is possible to gain a better understanding of the political, social and cultural factors involved in constructing its future. Considering the political, social and cultural contexts that deeply impact the development of the Smart Transportation System, this thesis structured its discussions around three specific themes from a Chinese perspective: (1) the constructing of sociotechnical imaginaries and future expectations, (2) the policymaking process involving science and technology, and (3) the nature of Big Data from the Chinese perspective of view.

Regarding these themes, first, in future-oriented representations and anticipatory practices, varied and unclear concepts have hindered STS research, especially the combined use of two important concepts – future expectation and sociotechnical imaginary. Second, the function of these two concepts has not been fully explored in Chinese science and technology policymaking. Also, upon a closer look, a feature called "the lack of Designed at The Top Level" (缺乏顶层设计) emerged in Chinese policymaking process without datailed analysis about what role it plays. At its core, related to the above two themes, this thesis distinguishes sociotechnical imaginary from future expectation (see Chapter 4), and in addition demonstrates the role they play in the communication and coordination between the central government and local government in the science and technology policymaking (see Chapter 5). Third, the notion of technology as "smart" brings Big Data into the transportation system, introducing new changes and new actors into this government-led field. By analyzing the TCM metaphor for Big Data that emerged during the fieldwork, in Chapter 6, this thesis indicates that Big Data is an empirical science in which observation plays a significant role.

7.1 In Relation to the First Research Question of this Thesis

In order to solve the problem of unclear boundaries between the concepts proposed by Berkhout (2006), I have introduced Kuhn's (1970) paradigm, studies of Chinese policymaking, and the algorithmic episteme (Fisher (2020), into this thesis to distinguish between future expectation and sociotechnical imaginary. Drawing on the interview materials and the analysis of research papers, I identify two scientific communities – "Road and Waterway Transportation" and "Computers and Computer Applications", to illuminate a lack of a designated academic field for the Smart Transportation System. These two different scientific communities have different paradigms, but also have different future expectations. With Road and Waterway Transportation aiming to develop a series of infrastructure and hardware facilities, and with Computers and Computer Applications making full use of a large amount data to generate software.

I apply Kuhn's concept of paradigm to understand the future expectations as a series real-time shared beliefs of the future in this case, which are derived from the paradigms of different scientific communities. Adopting a perspective of Chinese policymaking, the future expectations could be construed as "tradable assets" (Brown, Rip, and van Lente, 2003) that represent the the interests of the scientific communities, and could be sell to the local gorvernments. Therefore, the future expectations are derived from the paradigms and the interests of the scientific communities in this case.

Based on the interview materials, besides these different future expectations, a collective sociotechnical imaginary arises in academia that regards the Smart Transportation System as a supplementary tool to improve the efficiency of the transportation system. In other words, it cannot work without human intervention, especially in selecting data and verifying the results, which indicates an emphasis on expertise. Based on the interview materials, I argue that scientists and engineers try to involve themselves in the decision-making process with their expertise. Meanwhile, the participants' emphasis on expertise fights against the algorithmic episteme and digital discourse (Fisher, 2020), both at the epistemological level and at the political level. Thus, this thesis shows that in the Smart Transportation System, future expectation is related to the paradigms and the interests of these two scientific communities, while sociotechnical imaginary links to epistemology and the knowledge used in the decision-making process.

7.2 In Relation to the Second Research Question of this Thesis

I have analyzed the policymaking process of the Smart Transportation System by employing the concepts of future expectations and sociotechnical imaginaries. Inspired by Korsnes (2016), I use "sociotechnical imaginary" to identify the transportation development targets of the central government, and academia as a whole, and use "future expectation" to identify transportation developmental targets at a local level. Drawing on the plans and documents put forward by the central government alongside the interview materials, this thesis echoes the results of several studies on the policymaking of science and technology in China

(Gohli & Fischer, 2019; Korsnes, 2016; Liang *et al.*, 2020), but also provides some new insights within the Chinese context.

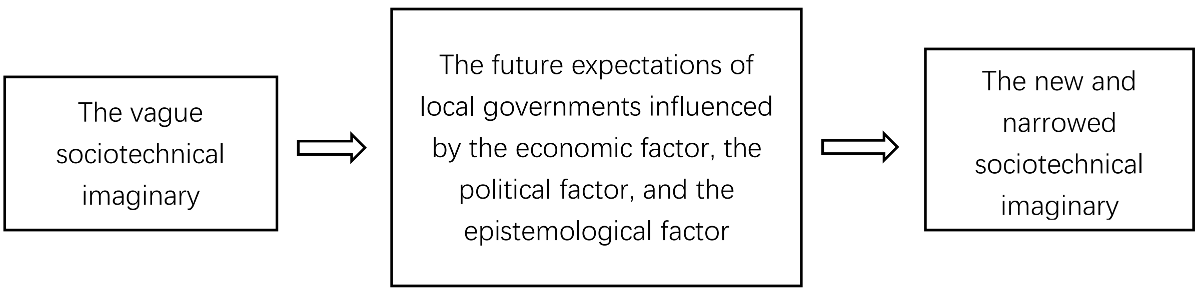
I show that the central government does not provide clear and specific sociotechnical imaginaries – exemplified as future targets and directions – on the Smart Transportation System. This lack of guidance is called "the lack of Designed at The Top Level (缺乏顶层设计)" approach by the participants. However, contrary to the assumption that the central government lacks an influencing role, "the lack of Designed at The Top Level" could be divided into two parts: (1) half of the plans of the central government offer a broad, general direction for the Smart Transportation System – the development of the infrastructure, for instance, without providing specific meanings of the infrastructure they seek; (2) the other half of the plans suggest directions for management, service and decision-making in a more broad way. In other words, this "lack of Designed at The Top Level" strategy does not indicate central government's missing role, rather that the sociotechnical imaginary of the central government is broad but not absent.

Based on the local governments' documents and the fieldwork materials, this thesis shows that the future expectations of local governments focus on the development of infrastructure in different ways, such as the ETC system in Beijing, the Smart testing devices in Shanghai, and the rural roads in Hangzhou. However, instead of different forms of Smart Transportation System projects being raised by the local governments, the future expectations of these local governments all fall into the range of the infrastructure, echoing the sociotechnical imaginary of the central government. This is further supported by the local governments influence on the central government. After four years of development, for instance, a new sociotechnical imaginary of central government arises that is a combination of the different future expectations of local governments. Moreover, by summarizing the future expectations of local government, the sociotechnical imaginary of the central government is narrowed down from the Smart Transportation System to the Smart Transportation Infrastructure.

This thesis updates the dynamic, cross-level system proposed by Heilmann and Melton (2013). A dynamic system of policymaking for the Smart Transportation System is a two-way process between the sociotechnical imaginary of central government and future expectations of local governments. When starting to develop a new technology such as the Smart Transportation System, the central government provides local governments with broad and vague imaginary instead of specific goals. And then local governments take responsibility for implementation by setting their future, specific expectations. These future expectations of local government are influenced by economic factors, such as budget, political factors, such as the evaluation system, and epistemological factors, such as the epistemological basis for making choices. In reporting on their performance, local governments inform the central government of their future expectations for the Smart Transportation System. This enables the central government to analyze and combine different future expectations to create their new sociotechnical imaginary – guiding development for the next five years.

Therefore, this dynamic process is like a cycle. And as technology develops, there will be more than one cycle because each local government repeats this process to the central government. The key to the dynamic process is the vague sociotechnical imaginary of central government and the specific future expectations of the local governments. It is not a purely top-down system, because it leaves room for specific local conditions. However, the local governments remain under supervision by the evaluation system set by the central government. Because of the evaluation system's long-standing preference for quantitative standards, local governments have chosen to construct infrastructure as their achievement.

Figure 21. A two-way, dynamic process between the sociotechnical imaginary of central government and future expectations of local governments



7.3 In Relation to The Third Research Question of this Thesis

Third, I have explored the nature of Big Data through the metaphors which emerged from the fieldwork. In the fieldwork, the participants draw an analogy between TCM and Big Data. The meaning and use of this analogy are unique in the Chinese context, referring to the similarities between ways of thinking about TCM and ways of thinking about Big Data. Considering Puschmann and Burgess (2014), the participants chose TCM as an analogy because it is their "familiar shape" related to traditional Chinese science and technology. These noted similarities indicate that Big Data has some characteristics that are not found in the modern science and technology.

The key point is that Big Data is an empirical science from the participants' point of view. The participants propose four similarities: (1) Big Data, like traditional Chinese technology, is based on a vast amount of experience; (2) Big Data, like traditional Chinese technology, derives a great deal of its experience from observation; (3) Big Data, like traditional Chinese technology, focuses on practice, not theory; and (4) Big Data, like traditional Chinese technology, works on a case-by-case basis, so its results are difficult to generalize.

This comparison reveals that observation is the main method of accumulating experience for Big Data. The analogy of "TCM", which accumulates empirical data through people's eyes, hands, etc., relates to the devices used by Big Data to accumulate empirical data, such as sensors, mobile phones, etc. These devices could be seen as "mediums", suggested by McLuhan. According to McLuhan, "a medium is any extension of ourselves" (Federman, 2004), so these sensors, cameras, and mobile phones, could also be seen as extensions of human body, such as our eyes and hands.

Moreover, traditional Chinese science observes the real world, while observations of Big Data are taken in the digital world. The operation of Big Data could be divided into four steps: (1) Big Data uses a "medium" to collect a large amount of empirical data from the real world; (2) people use the empirical data, as well as the theories to simulate the real world and construct a digital world; (3) people make observations and predictions in the digital world that simulate the real world; and (4) people choose actions based on a simulation's predictions. Thus, Big Data has one more step than TCM because after constructing a digital world people conduct their observations in the digital world. In other words, knowledge of Big Data is generated in the digital world.

The "observation" of Big Data, Step 3 above, could be further divided into two types. First, construction of the digital world. Second, to observe the digital world and gain experience. Considering McLuhan's notion that "a medium is any extension of ourselves" (Federman, 2004), I would like to divide the data into two types: (1) data collected by human senses, by a single sense such as sight, touch, etc., and by the extension of people's senses through devices; and (2) data that is collected by the people as a whole. For instance, that collects the traces left by people in the digital world.

Considering the nature of Big Data in more detail, the first type of data needs to combine the theories of physics, chemistry, traffic management, etc. to construct a digital world. It is related to the idea of "data-driven" that means that people will first have a theoretical framework or hypothesis before they analyze the data. While the digital world constructed by the second type of data does not necessarily need the assistance of such theories. It is possible to construct a digital world based on the "performative individual", for instance. This second idea is related to the idea of "the end of theory" that argues that increases in the amount of available data will make the results more credible. Therefore, I argue that these two epistemologies ("data-driven" and "the end of theory") are both involved in Big Data. The difference is that these two epistemologies rely on different data types.

Big Data also influences sociotechnical imaginary and future expectations. Related to this part of research question three, apart from providing an insight into the newly emerged technology of the Smart Transportation System in China, this thesis makes three important contributions to STS research on future-oriented representations and anticipatory practices, the studies of Chinese science and technology policymaking, and the study of Big Data and AI. First, this thesis advances future-oriented studies by distinguishing between the concepts of future expectation and sociotechnical imaginary. The previous studies do not provide the explaination about the formation of different future expectations, and this thesis provides a possible explaination. Moreover, this thesis extends the concept of sociotechnical imaginary, which moves beyond the current focus of instrumental political action (Jasanoff, 2015) in policy documents, and draws attention to the policymaking process.

These findings will benefit future research on future expectation and sociotechnical imaginary. Yet, this thesis also covers several limitations on studying the two concepts. The participants of this study mostly come from academia and local governments, few interviews have been conducted with people from the Internet companies controlling Big Data, because of the lack of time and gaining access to appropriate gatekeepers. Thus, more empirical studies on the Internet companies involved in the Smart Transportation network needs to be conducted to further test and refine these findings, which is an important direction for my research in the future.

Second, this thesis develops the studies of Chinese science and technology policymaking by outlining a two-way, dynamic circle in which the development goals of technology are formulated based on future expectations and sociotechnical imaginaries. In this circle, the sociotechnical imaginary of the central government could be characterized as an intended institutional void, leaving space for regional disparity; while the local governments cleverly interpret the central government's sociotechnical imaginary. Thus the local governments' future expectations inform that of the central government's sociotechnical imaginary, driving the birth of a new sociotechnical imaginary that leads to the development of the Smart Transportation System for the next five-year plan. These results flesh out the empirical details of the interaction between technology and politics in China. Admittedly, although this thesis has analyzed seven cities in China, limited by time and money, the examples from the South-East of China (e.g. Shenzhen [深圳] and Guangzhou [广州]) have not been covered. More examples could be added in future studies, and even some comparative studies could be conducted based on this thesis.

Third, this thesis importantly furthers our understanding of Big Data and AI, by revisiting the nature of Big Data from the perspective of traditional Chinese culture. In doing so, this thesis brings together two competing epistemologies of Big Data – "data-driven" and "the end of theory" – and argues that these epistemologies rely on different data types that are both derived from the "observation" of Big Data. Big Data's knowledge is generated by observing the digital world that is constructed from a large amount of empirical data from the real world through a “medium”, such as sensors and mobile phones. The linkage between the real world and the digital world is people, which means that people might have a dual identity and a dual life as with increasing technology use in daily life, such as travel apps. The digital world might not only be the simulation to the real world one day, because the digital world could generate its knowledge, and then establish its epistemology and ontology based on the knowledge derived from the digital world. Therefore, further research could join the ongoing discussion about the metaverse (a series of virtual spaces) proposed by Facebook. Moreover, Dreyfus (2007) demonstrates a link between philosophy and the manufacture of AI. The analogy that arose from the fieldwork between Big Data and TCM might indicate that the manufacture of AI, such as Big Data, could be led by Chinese philosophy and its ways of thinking. However, regarding the limitation of probable cultural bias of both the researcher and the participants, more research is needed to apply and investigate the relationship between Chinese philosophy and Big Data.

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Appendix A. List of Interviews

***Table A*. List of interviews**

Interview #	Location	Participant	Field	Gender	Duration	Method
1	Chengdu	Ms Zhao	Traffic Signals	Female	1h45mins	Face-to-Face
2		Prof. Ci	Testing Technology	Male	1h23mins	Face-to-Face
3		Dr Liang	The Transportation of Hazardous Chemicals	Male	53mins	Face-to-Face
4		Prof. Fa	The Integration of IT and Engineering	Male	45mins	Online-Video
5	Beijing	Mr Bai	The Traffic Operations	Male	1h11mins	Face-to-Face

6	Beijing	Prof. Di	Smart Transportation System	Male	1h9mins	Face-to-Face
7		Mr Cai	The Construction of the Transportation System	Male	46mins	Face-to-Face
8		Prof. Yun	Smart Railway	Male	47mins	Face-to-Face
9		Mr Jian	Smart Highway	Male	20mins	Face-to-Face
10		Mr Qian	Smart Highway	Male	30mins	Face-to-Face
11		Mr Li	Smart Metro System	Male	1h20mins	Face-to-Face
12		Mr Jiang	The Construction of Smart	Male	28mins	Face-to-Face

			Transportation System			
13	Beijing	Ms Sheng	Driverless Vehicles	Female	1h	Face-to-Face
14	Tianjin	Mr Ling	The Construction of the Transportation System	Male	30mins	Face-to-Face
15		Mr Wang	Transportation System Design	Male	1h	Face-to-Face
16		Mr Ri	BIM	Male	34mins	Face-to-Face
17	Shanghai	Prof. Huan	Data Analysis of the Transportation System	Male	30mins	Telephone

18		Prof. Ti	Transportation Infrastructure	Male	48mins	Face-to-Face
19	Shanghai	Ms Bu	Transportation System Design	Female	51mins	Face-to-Face
20	Nanjing	Prof. An	The Use of Big Data	Male	57mins	Face-to-Face
21		Prof. Yuan	Transportation System Signal Control	Male	45mins	Face-to-Face
22	Hangzhou	Mr Zhu	An Official Working on the Transportation System	Male	1h5mins	Face-to-Face
23		Ms Qing	An Official Working on the Traffic Operations	Female	45mins	Face-to-Face

24		Mr Zhou	An Official Working on the Traffic Operations	Male	45mins	Face-to-Face
25	Hangzhou	Dr Yi	Transportation System Design	Male	45mins	Telephone
26	Chongqing	Mr Guo	Traffic Management	Male	32mins	Face-to-Face
27		Mr Wan	Smart Transportation System	Male	40mins	Face-to-Face
28		Mr Chong	Smart Highway	Male	35mins	Face-to-Face
29		Mr Shan	Highway Construction	Male	35mins	Face-to-Face