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Benchmarking International High-Speed Railways from
the Sustainability Perspective

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A thesis submitted to
the University of Birmingham
for the degree of
DOCTOR OF PHILOSOPHY

Birmingham Centre for Rail Research and Education
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The University of Birmingham
January 2020

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“What is Well Measured is Well Managed”.

ABSTRACT

HSR are capable of meeting many of the mobility needs of individuals and societies in a safe, clean, and reliable manner. There is no unified reporting framework that gathers HSR sustainability topics and issues under the three pillars of sustainability. Also, no previous research has inspected the overall sustainability reporting practices of HSR operators.

To fill these research gaps, this study formulates a sustainability reporting and benchmarking framework which comprises key economic, social, and environmental factors that are representative of the sustainability performance of HSR. A combination of quantitative and qualitative research methods is used. Primary data are obtained from visual observation, surveys, and face-to-face interviews with railway experts, while secondary data are extracted from a wide range of sources.

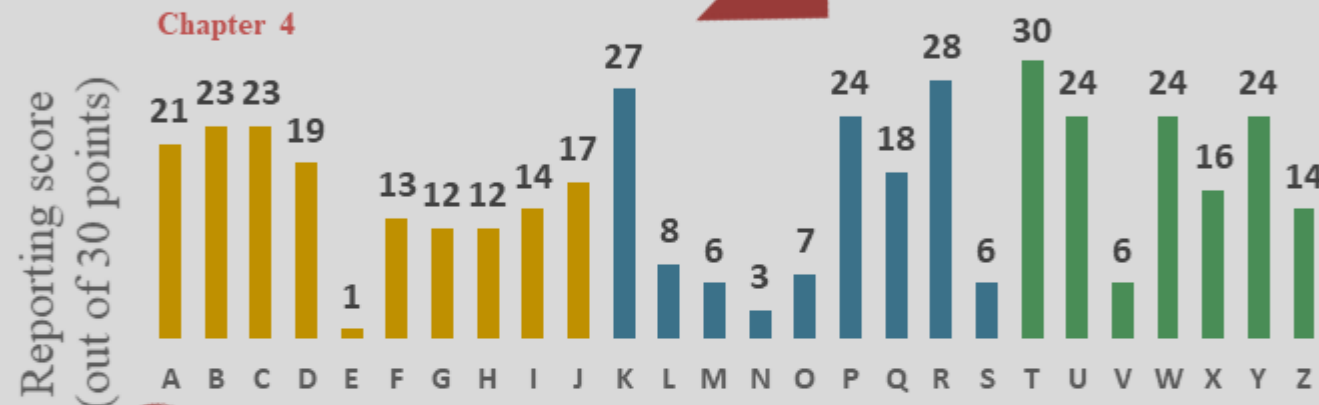
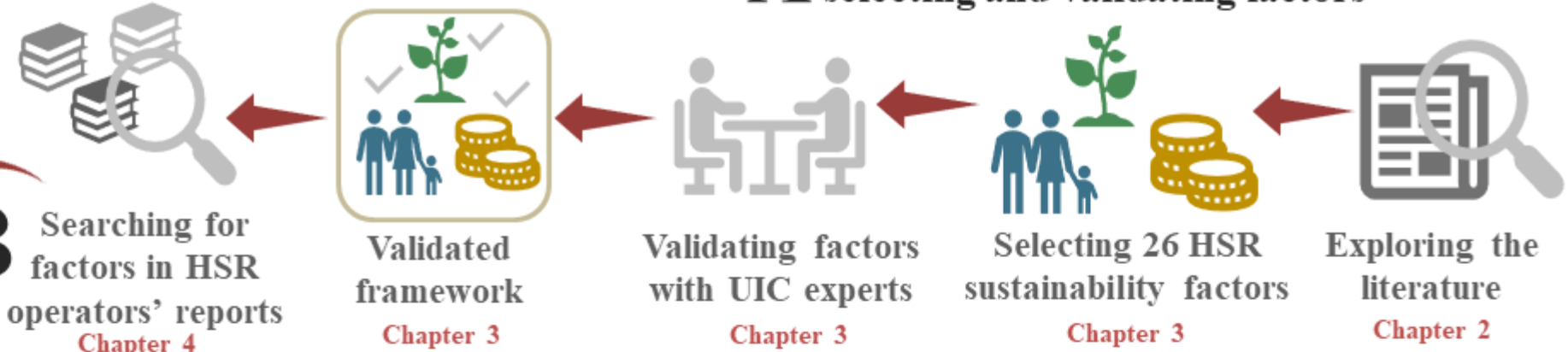
The study created a 26-factor sustainability framework that could be used for reporting and benchmarking purposes. Sustainability factors were selected with the help of experts from the International Union of Railways (UIC). Then, the study examined the availability of the selected factors in HSR operators' publications. Reporting variations were detected and revealed at the levels of sustainability pillars, factors, operators, and indicators. After that, the study proposed a variety of quantitative parameters and qualitative indicators for expressing the 26 selected sustainability factors. The applicability, usability, and availability of data for the proposed indicators were tested with benchmarking exercises which compared both operators and corridors. Benchmarking exercises provided insights into the actual sustainability performance of the benchmarked entities. Finally, in a special case study, the project looked at obstacles that exclude specific groups from using HSR services in China. The study offers

recommendations and points towards areas of improvement which could facilitate a more accurate measurement of the sustainability performance of HSR.

A=Punctuality and reliability **B**=Costs
C=Revenues **D**=Efficiency **E**=Cost-benefit ratio
F=Wider economic impacts **G**=Effects on tourism
H=Competition with air **I**=Integration with other modes
J=International involvement **K**=Safety
L= door-to-door travel time
M=Social segregation
N=Rapid expropriation **O**=Social exclusion
P=Engaging with local communities
Q=Customer satisfaction **R**=Employment
S=Affordability **T**=Carbon emissions
U=Energy consumption **V**=Land use
W=Resources and materials **X**=Biodiversity
Y=Recycling **Z**=Noise

GRAPHICAL ABSTRACT

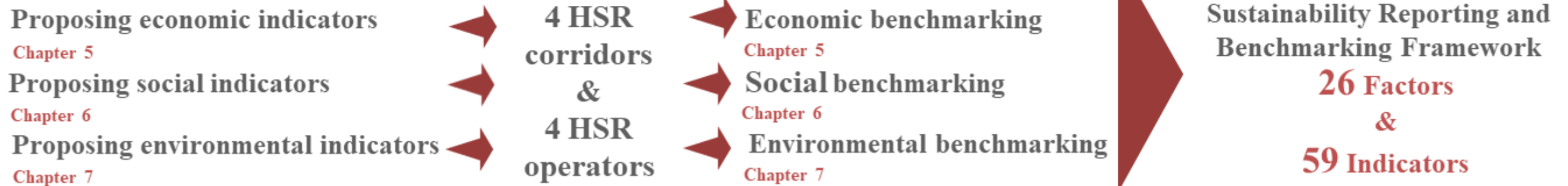
A selecting and validating factors



Selected and Validated Sustainability Factors



C proposing and testing indicators



ACKNOWLEDGMENTS

First and foremost, all praise is due to Allah, the most beneficent, and the most merciful. Peace and blessings be upon the final messenger, Muhammed, his family, and his noble companions.

No words can truly express how thankful I am for being supervised by Prof. Anson Jack. His knowledge, immense expertise, encouragement, and patience have guided me throughout this project and have given me the power and motivation to excel. Anson; the supervisor, the father, and the friend has been always there for me when I needed him. Also, I would like to thank my second supervisor; Prof. Felix Schmid. He often engaged me with him in valuable academic experiences like the Singapore Teaching Program.

I will not forget to express my gratitude to the BCRRE team: Prof. Clive, Dr. Jenny, Dr. Holly, Heather, Mary, and Nadeen. Their support has played a major role in enhancing my academic skills. They have truly been my second family and have made me feel home in the UK.

The University of Birmingham and the Council for At-Risk Academics are acknowledged for offering me the opportunity to continue my academic development, through the provision of the 4-year Postgraduate Research Scholarship.

A big thank you to the International Union of Railways for their wonderful collaboration. I would particularly like to thank Carole, Dr. Paolo, Marc, Stefanos, Marie-Luz, Pinar and Isabelle. Their assistance was essential for conducting this research. Similarly, many thanks to Prof. Hu Hao of Shanghai Jiao Tong University for hosting me as an exchange student.

To my father who was often in my thoughts and dreams – you left early, and you are missed. May your soul rest in peace and we will meet in a better life. Mom, you are the shiny star of life, thank you for all your support and prayers. My siblings: Rabea, Loay, and Maya, I know that the last 7 years were very tough for you, so thank you for being strong and supportive.

Maggie, you have been tightly bound to my soul in each step of this journey. Thanks for being the Moon of all my nights. Finally, I would like to thank my friends in Syria, the UK, Germany, China, and all over the world.

Labib Azzouz

January 2020

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List of Abbreviations

AVE	Alta Velocidad Espanola
BCR	Benefits-to-Costs Ratio
CBA	Cost–Benefit Analysis
CHSR	California High-Speed Rail
CO ₂	Carbon Dioxide
CO ₂ e	Equivalent Carbon Dioxide
CoMET	Community of Metros
CR	China Railways
CRBBG	China Railways Beijing Bureau Group
CRSBG	China Railways Shanghai Bureau Group
CSR	Corporate Social Responsibility
DB	Deutsche Bahn
DfT	Department for Transport
DTD	Door-to-Door
EAR	European Union Agency for Railways
EBITDA	Earnings Before Interests, Taxes, Depreciation, and Amortisation
EC	European Commission
EEC	Eastern Economic Corridor of Thailand
EMUs	Electric Multiple Units
EU	European Union
FS	Ferrovie dello Stato Italiane
FWI	Fatality Weighted Index/Injuries
GHGs	Greenhouse Gases
GRI	Global Reporting Initiative
HSR	High-Speed Railways

HSS	High-Speed Railway Station
HST	High-Speed Trains
IEA	International Energy Agency
KORAIL	Korea Railroad Corporation
KPIs	Key Performance Indicators
LCC	Low-Cost Carrier
MPI	Market Performance Indicator
NHSRC	National High-Speed Rail Corporation Limited
NO _x	Nitrogen Oxide
OECD	Organisation for Economic Co-operation and Development
ORR	Office of Rail and Road
RP	Revealed Preference
RSSB	Rail Safety and Standards Board
SDGs	Sustainable Development Goals
SNCF	Société Nationale des Chemins de Fer Francais
SO _x	Sulphur Oxide
SP	Stated Preference
TACs	Track Access Charges
TGV	France's High-Speed Rail Service
THSRC	Taiwan High-Speed Rail Company
UIC	International Union of Railways
UITP	International Association of Public Transport
VTT	Value of Travel Time
WEIs	Wider Economic Impacts

CHAPTER 1

INTRODUCTION

1.1 Overview

High-speed railways (HSR) began their development in October 1964 in Japan, with the opening of the Tokaido Shinkansen, the first HSR service that connects Central Tokyo with Shin Osaka at a speed of 210 km/h (Leboeuf, 2018). The Tokaido Shinkansen was successful especially in gaining a significant market share from air transport (Nash, 2017). This success was closely watched by European countries, and in 1981 France launched the TGV, the first HSR in Europe that connects Paris with Lyon at a speed of 260 km/h (Leboeuf, 2018). Later, in 1992 Spain opened its AVE, the HSR service that connects Madrid with Seville (Leboeuf, 2018). In 2008, China introduced its first HSR service between Beijing and Tianjin, with a maximum speed of 350 km/h. Since then until today, the scale of the HSR network has radically changed. In 2018, the length of the Chinese network reached 29,000 km, accounting for more than half the global network (Lawrence et al., 2019), see Figure 1-1.

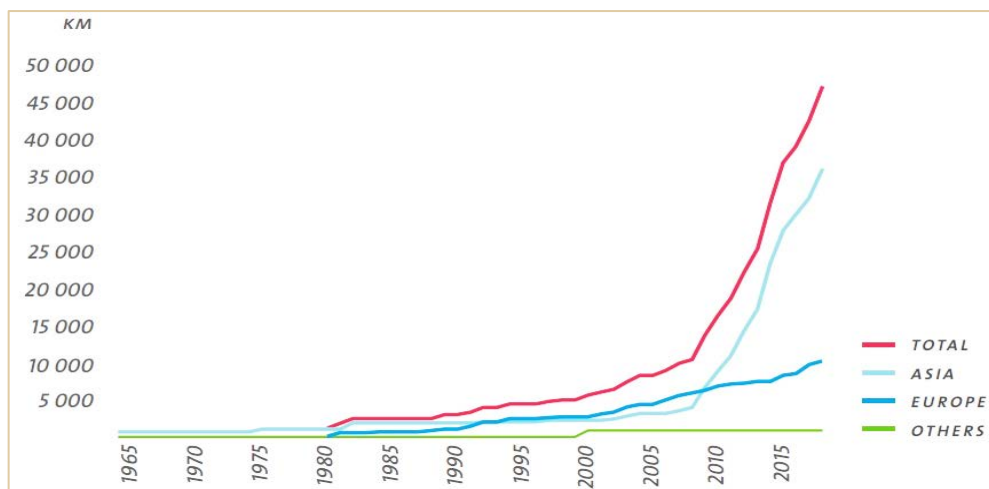


Figure 1-1: High-speed rail network length

Source: Leboeuf (2018)

Today, the popularity of HSR is booming, and several new HSR lines are being developed in the Middle East, North America, Asia, and Africa (Henríquez and Deakin, 2017). HSR are often described as the transportation mode of the future, offering our modern societies a flexible system that can be deployed in different contexts and cultures and under a variety of circumstances (Leboeuf, 2018). HSR are closely tied to the notion of sustainability; they are capable of meeting individuals' and societies' mobility needs in a safe, reliable, and efficient manner, while boosting the economic growth of regions and minimising negative impacts on the environment (Henríquez and Deakin, 2017; Leboeuf, 2018).

HSR operators report on their economic, environmental, and social performance through a variety of publications such as sustainability, corporate social responsibility (CSR), and annual reports. Several benefits can be derived from sustainability disclosure, and firms report on their sustainability performance for different reasons (Del Mar Alonso Almeida et al., 2014). These include backing the decision-making process by providing essential data, justifying a specific project or initiative, attracting additional funding, tracking performance and encouraging continuous progress, and monitoring compliance with environmental policies and regulations (Burritt and Schaltegger, 2010; Del Mar Alonso Almeida et al., 2014).

Sustainability reporting varies across sectors, industries, and firms and, equally, among HSR operators (Del Mar Alonso Almeida et al., 2014). Some studies such as those of Roca and Searcy (2012) and Steurer et al. (2005) point to the lack of standardisation in sustainability disclosure practices. Van Marrewijk (2003) stressed that sustainability reporting should be genuine and tailored to suit a firm's specific visions and conditions. It might be understandable that sustainability reporting should vary among different organisations; however, if stakeholders are to be able to compare firms or industries to identify best practice and areas of improvement, a minimum level of standardisation is required.

1.2 Research gaps

The first research gap to be tackled in this study is that there is no unified reporting framework that gathers HSR sustainability topics and issues under the cover of the three pillars of sustainability. Instead, HSR sustainability topics have been tackled separately by independent researchers in a variety of publications. On the one hand, emissions, energy consumption, safety, employment, and other traditional topics are partly covered in HSR operators' publications (JR-Central, 2018; SNCF, 2017a). On the other hand, newly discussed issues that link HSR with sustainability like social exclusion, land use, and competition with air transport are independently addressed, and in some cases they rarely exist in companies' reports (DB, 2017; Renfe, 2015).

The second research gap is that despite the large volume of literature that links HSR and sustainability, no previous research has exclusively inspected the sustainability reporting practices of HSR operators. Of the previous work reviewed, the closest to this goal are the rare studies that examine the disclosure practices of firms across several industries together. For example, the studies of G&AI (2014) and Andreas et al. (2012) checked the adoption of international reporting guidelines within firms' publications, such as those offered by the Global Reporting Initiative (GRI), without necessarily focusing on a specific industry. Also, Kolk (2008) examined the extent to which corporate governance aspects exist in the sustainability reporting practices of Fortune Global 250 firms. Moreover, Daub (2007) looked at the adoption of GRI reporting guidelines in the disclosure practices of some Swiss organisations, without focusing on a specific industry.

The third research gap is that HSR systems are rarely benchmarked against each other, and there is a scarcity of HSR benchmarking exercises in the literature. Most recent studies

focus on comparing HSR with other transport modes like air transport (Su et al., 2019). Similarly, the publications of the International Union of Railways (UIC) highlight the competitive advantage of HSR against other modes of transport for the aspects of emissions and energy consumption (Leboeuf, 2018). However, much less attention is paid to comparing HSR of specific countries with peers in other countries, and hence little is known about indicators that can be used for facilitating benchmarking exercises within the HSR sector.

The fourth research gap is related to a special case study. The current literature offers a very limited number of studies that examine the relationship between HSR and social exclusion. Different groups in society could be excluded from using HSR services for different reasons. There are currently some limited studies that looked at the link between HSR and social exclusion in Italy, Spain, and the UK (Pagliara and Biggiero, 2017; Pagliara et al., 2016; Pagliara et al., 2017b). However, no similar studies have been conducted to explore the link between HSR and social exclusion in China.

1.3 Research questions, aims, and objectives

Reflecting on the four gaps mentioned above, this study sets out to answer the following four research questions:

1. What are the key economic, social, and environmental factors that are representative of the sustainability performance of HSR and can formulate a reporting framework?
2. To what extent are these sustainability factors covered in HSR operators' sustainability publications?
3. What type of quantitative and qualitative indicators can express the selected sustainability factors and can be used for reporting and benchmarking purposes?
4. What are the main obstacles that exclude specific groups from using HSR in China?

This study aims to formulate a sustainability reporting and benchmarking framework which comprises key economic, social, and environmental factors that are representative of the sustainability performance of HSR. The objectives of this study can divide the research into four main parts as follows, see Figure 1-2:

1. Selecting economic, social, and environmental factors that are representative of the sustainable performance of HSR;
2. Examining the availability of the selected factors in HSR operators' sustainability publications;
3. Proposing a set of quantitative and qualitative indicators that express the selected factors and can be used for reporting and benchmarking purposes;
4. Finally, in a special case study, examining the relationship between HSR and social exclusion in China.



Figure 1-2: The four main parts of the research

It is worth mentioning that the study is concerned with developing a reporting framework that comprises indicators to assess the sustainability performance of HSR operators rather than

to determine whether governments or policymakers should support or invest in HSR as a component of a sustainable mobility system. In other words, the main purpose of the framework is to offer a reporting, benchmarking, and sustainability performance tracking and assessment tool. There are many differences between HSR and conventional railways which justify having a separate set of indicators, for instance, there are different attitudes among users to operational delays, and HSRs can have a significant differential impact on economic development between regions

1.4 Novelty, originality of the topic and its importance

The following points summarise the novelty of the study and its importance:

- **Selecting HSR sustainability factors**

Selecting sustainability factors will result in the creation of the first HSR sustainability reporting framework, which could constitute the backbone of operators' future reporting practices. The framework will encompass traditional topics that hold significant importance for operators such as costs, revenues, and emissions plus issues, topics, and emerging sustainability challenges that are discussed in recent studies. Also, the framework will help reporting and railway agencies to update their publications, by including topics and factors that are currently under-represented in their guidelines and possibly outside their focus.

- **Examining the availability of sustainability factors in operators' publications**

Examining the extent to which the selected factors are covered in operators' publications will reveal variations and gaps in current sustainability disclosure practices. Revealing poorly covered factors will notify international reporting and railway organisations to develop appropriate parameters for enhancing disclosure practices on these factors. Also, detecting

reporting variations among HSR operators can reveal weaknesses and areas of required and potential improvements and hence help to update HSR disclosure practices.

- **Proposing indicators for reporting and benchmarking purposes**

This study will propose and test some quantitative and qualitative indicators that can express the selected sustainability factors. These indicators will offer a minimum level of standardisation and normalisation which is required for conducting benchmarking exercises among HSR operators and corridors. Also, these indicators will help railway and reporting agencies to update their guidelines by including some new HSR-specific parameters. Moreover, some proposed indicators will enhance the reporting practices of independent studies. Some proposed indicators will be tested through benchmarking exercises, which will highlight some lessons and key points to take away.

- **Examining the relationship between HSR and social exclusion in China**

Exploring reasons that exclude specific groups from using HSR in China will serve two purposes: allowing a comparison with Spain, Italy, and the UK; and pointing towards areas of improvement required to allow more passengers to access the HSR service.

1.5 Research scope

This research is built on international comparisons, looking at HSR systems in different countries. Chapter 4 examines sustainability publications of major HSR operators in France, Spain, Germany, Japan, Italy, and China. Also, publications of developing HSR systems in the UK and USA are considered. The benchmarking exercises presented in Chapter 5, Chapter 6, and Chapter 7 focus on four HSR corridors in Japan, France, Spain, and China. However, some

exercises consider the HSR systems of other countries such as Thailand and India. The special case study of Chapter 9 explores the relationship between HSR and social exclusion in China.

1.6 Thesis structure

This study is divided into ten chapters and a summary of their content follows below:

Chapter 2: Literature Review

This chapter starts with basic definitions of sustainable development, sustainable transportation, and HSR. Also, the chapter defines sustainability reporting and its benefits, reflecting on the current reporting situation in the HSR sector. Then, the chapter defines benchmarking, its benefits, and obstacles. After that, a comprehensive collection of economic, social, and environmental topics and issues that relate to the sustainability performance of HSR is presented. HSR operators and corridors are identified in this chapter. Finally, a summary is provided, reflecting on essential points to take away from the literature.

Chapter 3: Methodology

This chapter explains a step-by-step process for conducting the research. The methodology starts with selecting the 26 sustainability factors that constitute the proposed reporting and benchmarking framework. The selection process explains the criteria for selecting factors and how factors are selected through consultation with the UIC's experts.

Also, this chapter presents the scoring criteria that are used for documenting the availability of selected factors in operators' reports, and the criteria for selecting operators, corridors, and indicators for benchmarking exercises. Sources of primary and secondary data are listed in this chapter.

Chapter 4: Examining the Availability of Sustainability Factors in HSR Operators' Reports

This chapter presents numerical results from examining the availability of the selected sustainability factors in operators' publications. Also, it reveals variations in sustainability reporting at the levels of sustainability pillars, sustainability factors, companies, and types of indicators. The chapter discusses the current reporting situation, currently used indicators, and areas of potential and required improvements. Then, the chapter presents a general discussion, key findings, and conclusion.

Chapter 5: Reporting on and Benchmarking the Economic Sustainability of HSR

This chapter proposes some quantitative and qualitative indicators for reporting on the selected economic factors. Also, it offers a variety of benchmarking exercises that look at the economic performance of operators and corridors.

Chapter 6: Reporting on and Benchmarking the Social Sustainability of HSR

For reporting on the selected social factors, the sixth chapter suggests some quantitative and qualitative social parameters. Also, benchmarking exercises that examine the social performance of operators and corridors are presented in this chapter.

Chapter 7: Reporting on and Benchmarking the Environmental Sustainability of HSR

This chapter proposes indicators for reporting on the identified environmental factors and looks at the environmental performance of HSR operators and corridors through environmental benchmarking exercises.

Chapter 8: Twofold Discussion

The eighth chapter provides a twofold discussion that is divided into two parts. The first part discusses the economic, social, and environmental sustainability performances that are revealed through benchmarking operators and corridors, referring to causes that drive such performance and reasons behind variations.

The second part offers a general discussion reflecting on the importance of the sustainability framework and its proposed indicators, plus testing the robustness and effectiveness of the suggested parameters. Also, the second part presents some obstacles to benchmarking and limitations, besides referring to improvement areas and topics of further research.

Chapter 9: Case Study: The Relationship between HSR and Social Exclusion in China

This chapter analyses the reasons and obstacles that exclude specific groups from using the HSR service in China. The chapter starts by explaining methods used for collecting data, reflecting on the stated and revealed preference survey. Then it discusses results and points towards possible solutions and areas requiring improvements.

Chapter 10: Conclusion

The final chapter presents the core findings of this research, showing how these answer the research questions that have been identified by the author. Also, it offers general recommendations and explains pathways to impact.

CHAPTER 2

LITERATURE REVIEW

2.1 HSR and sustainability: definitions and context

This section presents notions of sustainable development and sustainable transportation, and then discusses HSR in the context of sustainability.

2.1.1 Sustainable development and sustainable transportation

First, it is important to distinguish between the two notions of sustainability and sustainable development. Sustainability is often thought of as a long-term aim, while sustainable development refers to a set of actions, processes, and cumulative efforts to achieve it (UNESCO, 2019). The United-Nations (2019) defines sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. To achieve sustainable development, it is vital to balance and harmonise three core components: social inclusion, economic growth, and environmental protection. These components are intertwined and not separate, and all are necessary for the prosperity and well-being of individuals and societies (UNESCO, 2019; United-Nations, 2019). Figure 2-1 illustrates the three pillars of sustainable development.

The United Nations' 2030 Agenda has identified 17 key sustainable development goals (SDGs), which were adopted by countries and world leaders at the UN's summit in September 2015 in New York. These goals reflect on the three pillars of sustainability, comprising topics such as good health and well-being, economic growth, climate action, reduced inequalities, and life on land (United-Nations, 2019). For instance, the life on land goal promotes the protection

and restoration of terrestrial ecosystems, halting biodiversity loss and protecting natural habitats.

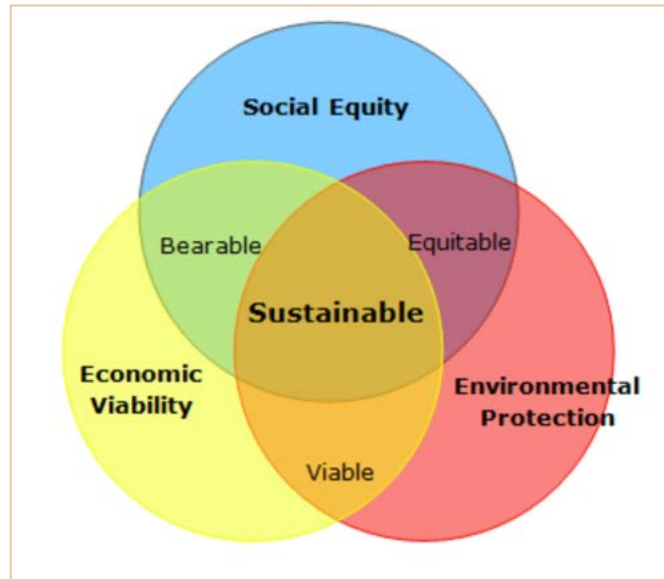


Figure 2-1: The three pillars of sustainability

Source: Future-Learn (2018)

The literature on sustainable transportation is vast and diverse, and several definitions could be used in this regard (Richardson, 2005). Reflecting on the work of Schiller and Kenworthy (2017) and Banister (2018), a sustainable transportation system is one that meets the essential needs and expectations of individuals and societies in a reliable, efficient, and safe manner, considering the safety of travellers, employees, and others. Moreover, sustainable transportation boosts both local and regional economies by enhancing connectivity and accessibility to the job market, plus promoting local businesses, tourism, and other activities. Also, it considers the social equity among and between regions and generations, and so it is affordable, offers seamless journeys, and several mobility options that suit different social groups. Sustainable transportation recycles and reuses its components and limits its waste, emissions, noise, and other adverse environmental effects, alongside protecting biodiversity. Finally, sustainable transport curbs its dependency on non-renewable energies plus decreasing

the consumption of energy that comes from any source to levels that are required for mitigating climate change and for meeting emission reduction targets globally.

The sustainable development goals (SDGs) include eliminating poverty and creating economic growth (United-Nations, 2019). Railways bring significant economic impacts like creating new employment opportunities, enhancing the accessibility to job markets in big cities, increasing land prices, and reducing costs through agglomeration effects (Loo and Comtois, 2015). The SDGs promote sustainable cities and communities, and railways represent a potentially sustainable alternative transport mode when compared with private mobility and aircraft. Finally, the SDGs encourage using clean energy, and HSRs use electricity which can be generated from renewable and sustainable sources including solar, wind, hydro, and tidal (Leboeuf, 2018).

2.1.2 HSR: definition

The UIC (2019d) explained that HSR are not merely technical systems; rather, they comprise a combination of technical components such as locomotives, infrastructure, and energy alongside cross-sectional aspects like training, marketing, financial, and managerial issues. HSR combine all these different components in a relatively advanced technology, constituting whole integrated systems. According to the UIC (2019d), the following conditions define the border of what is considered as an HSR:

- Infrastructure: new lines designed for speeds of 250 km/h or above;
- Infrastructure: existing lines upgraded for speeds of 200–220 km/h;
- Locomotives: specially designed train sets which can operate at a minimum speed of 250 km/h on newly built lines, with the ability to reach speeds above 300 km/h;

- Locomotives: specially designed train sets which can operate at a speed of 200–220 km/h on upgraded existing lines.

2.1.3 HSR in the context of sustainability

Railways are usually bracketed with sustainability in the transportation literature (Schiller and Kenworthy, 2017). Recently, HSR have often been described as the future's transport mode for several reasons. As a modern mode of transport, HSR are capable of meeting the different mobility needs of individuals, groups and societies, in an efficient, reliable, clean, and safe manner (Leboeuf, 2018). At the individual level, HSR are a reliable transportation mode that feature comfort and travel time savings (Leboeuf, 2018). Moreover, HSR enhance accessibility, allowing more people to access economic opportunities in job markets plus the social, cultural, and political activities of society (Albalade et al., 2012).

The impacts of HSR spread far beyond meeting the transport needs of individuals. At the societal level, HSR reinforce economic development by boosting local economies and the wealth of some regions, alongside supporting sustainable urban growth (Henríquez and Deakin, 2017). In addition, HSR promote the liveability of local communities (Cornet et al., 2018), mainly due to less road congestion and associated reductions in accidents, emissions, and noise levels (Loo and Comtois, 2015). HSR's environmental efficiency is remarkable especially when compared with cars and air transport, offering great potential for reducing energy consumption and CO₂ emissions (IEA, 2017).

HSR are proven to be flexible and attractive transport options which can be deployed in a variety of contexts and cultures and under different circumstances and conditions (Leboeuf, 2018). From China to the USA, HSR as megastructures can change humans' perception about time and distance, connecting places and shrinking spaces (Banister et al., 2013). Seeking a

modern, clean, and efficient transport network, many countries around the world such as China, Japan, Spain, Italy, France, and Germany have deployed their own HSR systems. Other countries are planning and building new HSR lines in the Middle East, USA, India, and Thailand (Leboeuf, 2018; UIC, 2018a).

However, despite their thriving popularity, HSR are often subject to criticism and continuous debate, mainly due to their high capital costs and some associated adverse social and environmental impacts (Albalade et al., 2012; Henríquez and Deakin, 2017). While the economic, social, and environmental benefits have often been used to further justify HSR, arguments and debates have focused on the credibility and validity of these gains (Loo and Comtois, 2015; Henríquez and Deakin, 2017). Criticism of HSR can involve many different factors, including for example; destroying natural habitats, historical forests, and parks along newly-built lines; excessive levels of noise from trains passing near residential areas; social equity and exclusion issues like excluding specific groups from using the service; land acquisition and rapid expropriation issues like displacing rural residents and radically changing their lifestyle; and, encouraging businesses to relocate from small urban centres to big cities.

2.2 Sustainability reporting in the railway sector: benefits and the current situation

Sustainability reports are defined as publications that comprise a combination of quantitative indicators and qualitative explanation through which companies report on their sustainability management practices (Del Mar Alonso Almeida et al., 2014). Companies use sustainability reports as tools for disseminating information and communicating with internal and external stakeholders (GRI, 2018a). Reporting on sustainability factors and challenges which relate to the social, environmental, and economic performance of HSR provide HSR companies with several benefits (Del Mar Alonso Almeida et al., 2014; GRI, 2018a).

The internal benefits of sustainability reporting include:

- Inspiring operators' long-term plans and visions (Sprinkle and Maines, 2010);
- Confirming the linkage between financial and non-financial performance (Del Mar Alonso Almeida et al., 2014);
- Enhancing economic and environmental efficiency, regulating processes, and decreasing costs (Chong and Tan, 2010);
- Recognising potential risks and challenges plus taking advantage of opportunities (Sprinkle and Maines, 2010);
- Revealing early warnings about future mismanagement (Andreas et al., 2012);
- Avoiding unnecessary engagement in publicised environmental and economic failures (Del Mar Alonso Almeida et al., 2014);
- Benchmarking sustainability internally and with other HSR companies (GRI, 2018a).

While the external benefits of sustainability reporting comprise:

- Boosting the reputation of the company and customers' loyalty (Andreas et al., 2012);
- Spreading the HSR culture as a safe and environmentally friendly mode (JR-East, 2018b);
- Showing operators' commitment to the notion of sustainable development, which could influence regional and international collaboration plus attracting potential funds and aid (Andreas et al., 2012; GRI, 2018a);
- Informing stakeholders about the value of the company and its tangible and intangible possessions (Chong and Tan, 2010);
- Strengthening the relationship with local communities by disseminating information about operators' efforts and contribution towards these communities (GRI, 2018a);
- Alleviating negative social-environmental impacts (Del Mar Alonso Almeida et al., 2014).

The GRI is an independent standards organisation that offers reporting guidelines to help businesses and firms to report on their sustainability performance (GRI, 2018a). Del Mar Alonso Almeida et al. (2014) explained that the financial, water, oil, and energy sectors take the lead in sustainability reporting within the GRI community. In contrast, the railway sector is poorly represented, occupying – with the tobacco and toy industries – the bottom of GRI reporting ranking.

Exploring the GRI sustainability report database shows that out of 13450 companies and firms, only 38 are related to the railway sector, and of these 10 companies are responsible for managing HSR activities (Table 2-1). Three of these HSR operators are from Japan, and there is one from each of Russia, Taiwan, Spain, France, China, Italy, and South Korea. These operators are responsible for operating around 20 per cent of the HSR activity around the world, measured by track km, while the other 80 per cent of activity is not reported through GRI. So, there might be a great potential for improving the sustainability reporting of HSR operators. Developing a rail-specific reporting framework which comprises key sustainability issues and topics could be beneficial for facilitating reporting improvements.

Table 2-1: Representation of the rail sector in the GRI reporting database

	Total in the GRI community	Rail sector	Rail sector (% of total)	Rail sector operating HSR services	Rail sector operating HSR services (% of total)	Rail sector operating HSR services (% of rail sector)	Percentage of total HSR lines that are operated by HSR organisations under the GRI banner
Organisations	13454	38	0.28%	10	0.075%	26.32%	20%
Reports	53058	170	0.32%	60	0.011%	35.3%	

Source: author's elaboration of GRI (2019)

2.3 Benchmarking in the railway sector

2.3.1 Definition and benefits

Benchmarking is defined as a structured process of identifying actions that lead to superior performance (CoMET-and-Nova, 2019). Railway benchmarking compares the statistics and performance figures of one company to the same statistics of other companies. Benchmarking might consider financial measures such as revenue per passenger.km and productivity measures such as traffic units per employee. Railways are data-driven systems which produce remarkable amounts of quantitative information so there is great potential for conducting benchmarking exercises with different purposes (World-Bank, 2017b). Internal benchmarking – against other railway companies – is usually useful for operational issues. External benchmarking – against both railway and other sectors – can also be beneficial (World-Bank, 2017b). For instance, benchmarking HSR against air transport and cars can reveal how competitive HSR are on the topics of emissions, energy consumption, and door-to-door travel time.

There are several benefits of benchmarking in the railway sector, and some of these are close to the previously presented benefits of reporting. Benefits of benchmarking include:

- Monitoring performance and setting targets (Hirsch et al., 2003);
- Revealing areas of problems and weaknesses and opportunities for improvements and, as a result, improving overall performance (World-Bank, 2017b);
- Prioritising areas of improvements and supporting the decision-making process for different stakeholders (CoMET-and-Nova, 2019);
- Justifying a reasonable level of financing from governments and other financing organisations (Hirsch et al., 2003);

- Stimulating productive enquiries and questions for deeper research and analysis (World-Bank, 2017b);
- Providing a better understanding of the performance and explaining the situation to internal and external stakeholders (Hirsch et al., 2003);
- Justifying a reasonable level of track access charge from the infrastructure manager (Hirsch et al., 2003);
- Finally, sharing knowledge and lessons and identifying best practice.

2.3.2 Key performance indicators (KPIs)

KPIs are the exchange language used for expressing companies' performance. A KPI is a measurable value that can be used for reporting and benchmarking purposes. Companies use KPIs to demonstrate and to evaluate their success in reaching specific targets (World-Bank, 2017b). KPIs are usually selected depending on the objective of the benchmarking objective, which could be a general review of operational performance or a detailed analysis of areas with big performance gaps (Nicholson et al., 2015). Top-level indicators focus on the overall performance of the company, while low-level KPIs look at specific areas (Nicholson et al., 2015; World-Bank, 2017b).

2.3.3 Problems of benchmarking in the railway industry

Different problems and complexities can be encountered when preparing and conducting benchmarking exercises in the railway sector, such as:

- Multiplicity of outputs: the multiple output is a common feature of railway companies. For instance, a company might report on overall costs and revenues, while providing detailed performance data for different services like subways, regional rail, buses, and HSR. This is

a problem since different services and products have remarkably different costs and revenues (Nash and Shires, 2000);

- Complexity of the production procedure: a single track might be used for carrying different services, and a passenger train can contain different classes (Nash and Shires, 2000);
- Data availability: due to the complexity of railway systems and the diversity and multiplicity of outputs, monitoring and data collecting processes can be demanding, requiring remarkable effort. As a result, some data might not be regularly recorded (Nash and Shires, 2000);
- Quality of the available data: the available data might be inaccurate due to errors in measurements and calculations. Also, data could be biased to cover weaknesses in the actual performance or simply to follow the agenda of the publisher (Nash and Shires, 2000; World-Bank, 2017b);
- Privacy and confidentiality issues: some operators prefer to hide actual performance data, which hinders any potential for conducting benchmarking exercises (Nash and Shires, 2000; World-Bank, 2017b).

2.4 Economic pillar

This section presents several topics that govern the economic sustainability of HSR and offers a selection of parameters which could be used for reporting on these factors.

2.4.1 Punctuality, costs, revenues, and the benefits-to-costs ratio

Punctuality and reliability of HSR services are necessary for the operating company to maintain a good reputation. HSR operators constantly aim to provide punctual services, and some companies such as JR Central promote their HSR as a transport mode which stands for

punctuality (Schumann, 2017). Punctual services attract more customers while meeting their expectations and generating improved revenues (DB, 2017; JR-Central, 2018). In contrast, unreliable services reduce customer trust and numbers, and related revenues. Moreover, delays and disruptions impose financial costs on operators, such as monetary and non-monetary compensation provided to clients (Renfe, 2015).

Costs comprise all expenses associated with operating and maintaining HSR services. These include staff salaries and benefits, monetary expenses related to purchasing energy and equipment, investment in new technologies, and spending on human resource development programmes (JR-Central, 2018; Leboeuf, 2018; SNCF, 2017a). In the European context, track access charges impose another expense on HSR operators and using infrastructure can be expensive, especially in some European countries (Leboeuf, 2018). From a lifecycle perspective, costs include the per.km and total cost of planning and constructing HSR lines, plus expenses associated with recycling locomotives, tracks, and other components (World-Bank, 2017b).

Revenues encompass incomes that are generated by selling tickets and other on-board services (World-Bank, 2017b). Some HSR operators diversify their revenue sources, by managing and operating hospitality, commercial, and residential businesses. These include hotels, shopping malls, cinemas, entertainment facilities, and residential buildings (JR-Central, 2018; JR-East, 2018b). While some of these revenues are generated locally, others can be derived from operating businesses in different international locations (SNCF, 2017a). Operating stations and revenues from merchandisers that sell local and international foods, goods, fashions, and souvenirs are also important (van Hagen and van Oort, 2018). Suzuki (2017) pointed out that diversifying income sources is important for guaranteeing the economic sustainability of HSR.

The benefits-to-costs ratio (BCR) is another important economic factor. While costs and revenues are usually discussed from an operators' perspective, the BCR is often presented in economic feasibility studies of governments, research centres, and individual scholars. A typical cost–benefit analysis considers the different costs and benefits associated with deployment of an HSR project (Brinckerhoff, 2014). Costs include the expenses of planning, constructing, operating, maintaining, and recycling the project. Benefits reflect the advantages provided to both individuals and societies. Individuals' advantages include travel time savings, comfort, and reliability (De Rus, 2012; Nash, 2017). Societies' benefits encompass externalities such as less road and rail congestion, and a reduction in emissions due to shifting from private mobility to rail transport (De Rus, 2012; Nash, 2017).

2.4.2 Wider economic impacts, efficiency, and competition with air transport

The wider economic impacts (WEIs) of HSR projects are usually used for supporting the decision-making process, especially when users' benefits alone are not enough to justify the massive lifecycle costs associated with each project (Nash, 2017; Vickerman and Ulid, 2006). The WEIs encompass agglomeration effects and enhancements in the overall productivity of specific businesses, changes in land and property prices, the creation of new job opportunities, and allowing more citizens to access employment markets, due to better connectivity (Albalade et al., 2015; Albalade et al., 2012; Loo and Comtois, 2015; Nash, 2017). It is worth mentioning that while the WEIs can be positive for specific cities and regions, other locations might be economically and socially disadvantaged. Grossman (2013) discussed that introducing new HSR lines might encourage some business and economic activities to relocate from small cities and towns along the HSR line to bigger cities and metropolitan areas. Also, while new HSR lines enhance the overall accessibility levels in the country, there might be uneven distribution

of accessibility values among regions, due to spatial polarisation effects. Monzón et al. (2013) pointed out that in the Spanish case, the presence of HSR lines created areas with high accessibility values mainly around HSR stations, and shadow areas in isolated zones, with lower accessibility values, see Figure 2-2.

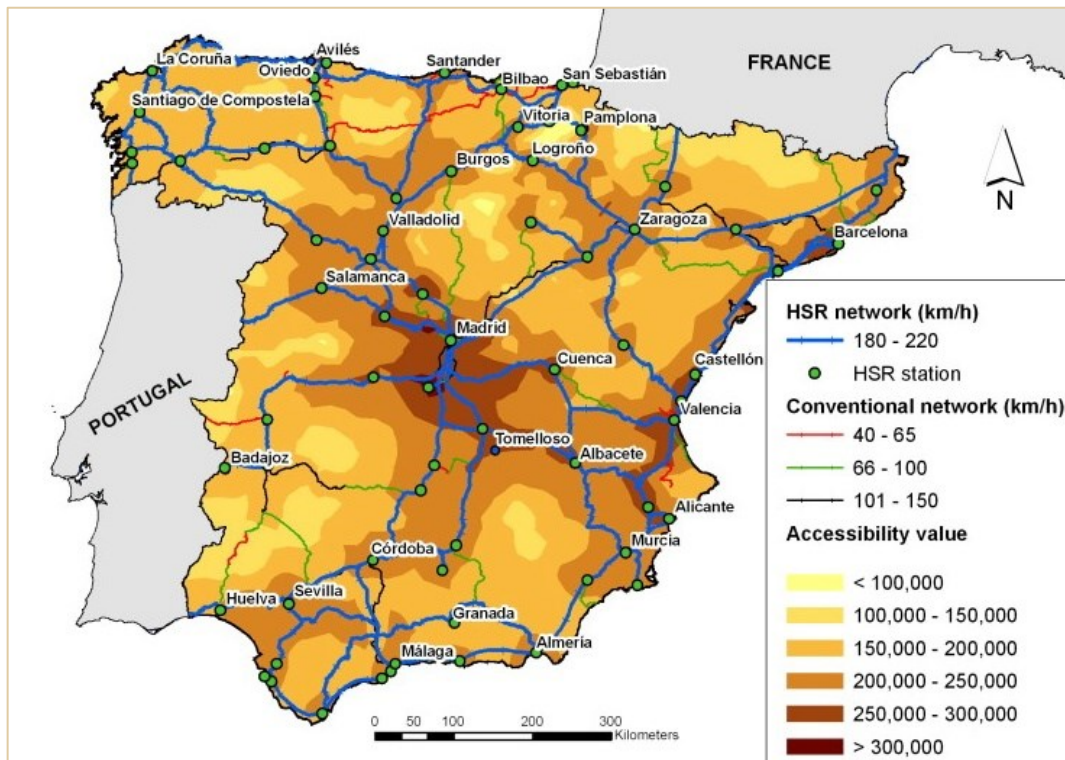


Figure 2-2: Distribution of accessibility values around HSR lines in Spain

Source: Monzón et al. (2013)

Railway efficiency is a very broad term and it can be discussed from different perspectives. Li et al. (2012) discussed energy efficiency while Fukuyama et al. (2011) looked at social efficiency. From an economic perspective, efficiency constitutes an important topic for railway operators, especially considering different financial constraints. Some HSR operators have managed to secure high levels of economic efficiency. Other operators, due to management and/or governmental restrictions, are comparatively less efficient (Beck et al., 2013). Most economic efficiency studies focus on methods to reduce costs associated with

operating railway services, and a wide range of efficiency benchmarking parameters can be used for this purpose (Merkert et al., 2010).

Competition between HSR and air transport is often discussed in the literature, due to its importance for the economic sustainability of both modes (Albalade et al., 2015). Usually, the deployment of new HSR lines and improvements to existing HSR services result in an increase in HSR demand while decreasing the ridership of air transport (Albalade et al., 2015; Clewlow et al., 2014; Givoni and Dobruszkes, 2013; Jiménez and Betancor, 2012). Such changes in demand are accompanied by additional revenues for HSR plus reductions in the total negative environmental effects, due to less air traffic activity (Jiménez and Betancor, 2012). However, the competition between HSR and air transport is governed by different factors such as corridor characteristics, the overall development of the transportation network in cities along HSR lines, and the pricing policies of both modes (Sun et al., 2017). Airlines respond to the competition from HSR in different ways: reducing the frequency of flights; decreasing the number of seats; and, most importantly, promoting the services of low-cost carriers (LCC) which feature discounted fares (Clewlow et al., 2014; Sun et al., 2017).

2.4.3 Effects on tourism, integration with transport modes, and international involvement

Several studies have discussed the relationship between HSR and tourism, suggesting that introducing new HSR lines affects the number of local and international arrivals to specific tourist destinations. However, HSR's effects on tourism are controversial, and while they are prominent in some countries, they are modest in others (Albalade et al., 2017).

Chen and Haynes (2012) pointed out that the Chinese HSR system has significantly boosted tourism, and provinces with HSR have enjoyed 20 per cent increments in the number

of tourist arrivals compared to provinces that are not connected with HSR. Moreover, the French TGV is considered as the catalyst for boosting tourism in small towns around Paris (Pagliara et al., 2015). The Japanese experience shows that connecting cities with the Shinkansen has boosted tourist arrivals in these cities, especially during the first year of opening (Kurihara and Wu, 2016). In Spain, Albalade et al. (2017) clarified that the effects of HSR on tourism are relatively weak and mostly limited to big cities. Some HSR operators promote local and international tourism via online campaigns plus offering integrated tickets and tourist passes (JR-Central, 2018; JR-East, 2018b).

The integration of HSR with other transport modes is important for creating seamless journeys that reduce the hassle of travel, featuring easy transfers between modes plus time savings (Leboeuf, 2018). HSR stations facilitate integration between HSR and other forms of public transport, walking, cycling, and private mobility. The degree to which HSR are well integrated with other modes is decided by several factors such as the appropriate ergonomic design, integrated ticketing, the provision of travel information, the number of metro and bus lines at the station, the availability of taxis, and the availability of parking facilities (Leboeuf, 2018; UIC, 2019a). An HSR appropriately integrated into the transport network can attract more passengers and so generate additional revenues and reduce costs (UK-Parliament, 2011). Other gains comprise social and environmental benefits such as higher access levels and lower emissions (Cheng et al., 2015; Garcia, 2015). Insufficient integration could decrease the overall satisfaction of HSR passengers. Wangshuli (2018) discuss that the Beijing South HST loses its lustre for passengers. In the late evening, several trains arrive at the station, carrying around 10,000 passengers who find themselves having limited mobility options. At night, the station witnesses long queues of passengers who wait for authorised taxis, which are very limited.

Unauthorized taxis overcharge passengers, while most buses stop operating from/to the station, and the overall result is unsatisfied HSR passengers.

International involvement is the final topic that will be discussed within the economic pillar. The international market of HSR is rapidly expanding, with countries such as Thailand, USA, UK, India, Malaysia, and Singapore developing their own systems (Albalade et al., 2012). As a result, China, Japan, France, Germany, and Spain are often involved in competitions for exporting HSR (Grey, 2017; Hu, 2017; Huang, 2017). HSR operators engage in international projects at different levels and for different purposes. These include creating and improving their reputation (Hu, 2017), making their country's HSR a global standard (Albalade et al., 2012), generating additional revenues from international sources as a form of sustainable income (Huang, 2017), exchanging skills and expertise (JR-Central, 2018), and diffusing HSR as a culture of the country (Grey, 2017). Most mutual agreements reflect financing offers, planning assistance, and continuous support. The political atmosphere and international relations can assist or hinder HSR exporting efforts. For instance, despite having the advantage of building HSR at relatively low cost –especially when compared with Japan – China faces serious challenges such as low levels of political trust with ASEAN countries (Hong, 2015). The literature about operators' involvement in international projects is mostly limited to online news and articles. These sources are often biased and influenced by publishers' agendas rather than being the result of systematic research (Xuequan, 2018). In other words, some countries tend to disclose negative information about their competitors' international involvement (Shimbun, 2017). So, it is desirable that HSR operators disclose accurate information about their involvement in projects globally.

2.4.4 Indicators for reporting on economic factors and topics

International agencies like the GRI and UIC offer some reporting guidelines. These comprise different parameters, some of which are railway-specific, while others are applicable to different industries and sectors. Several indicators can be used for reporting on the previously presented economic topics and issues and are applicable in the HSR sector.

Table 2-2 lists some parameters that can be used for reporting on economic factors and topics.

Table 2-2: Indicators for reporting on economic topics and factors

Indicator	Factor which the indicator is used to report	Reference
Aggregate operation costs	Costs	World-Bank (2017b)
Average operation costs (costs/p.km)	Costs	World-Bank (2017b)
The average fare (revenues/p.km)	Revenues	World-Bank (2017b)
Total operating revenues (€ million)	Revenues	World-Bank (2017b)
Infrastructure access charge (€/track km)	Costs	Leboeuf (2018)
Construction costs of HSR line (€ million/route km)	Costs	Leboeuf (2018)
Energy consumption per vehicle activity (MJ/train.km)	Efficiency	UIC-and-IEA (2015)
Operating revenues of HSR per passenger.km (€/p.km)	Efficiency	Beck et al. (2013)
Operating costs of HSR per train.km (€/train.km)	Efficiency	Beck et al. (2013)
Utilisation of rail infrastructure (million train.km/track.km)	Efficiency	Beck et al. (2013)
Benefits-to-costs ratio of the HSR project	Benefits-to-costs ratio	Nash (2017)

Quantitative and qualitative explanation of wider economic impacts associated with HSR projects (new job opportunities, changes in land prices, agglomeration effects)	Wider economic impacts	Nash (2017)
Changes in domestic tourism arrivals after linking a city/town to the HSR network (%)	Effects of HSR on tourism	Albalade et al. (2017)
Changes in international tourism arrivals after linking a city/town to the HSR network (%)	Effects of HSR on tourism	Albalade et al. (2017)
Daily and annual ridership of both HSR and air transport along a particular corridor (thousand passengers daily)	Competition between HSR and airlines	Leboeuf (2018)
CO ₂ emissions of air transport vs HSR (g CO ₂ /p.km)	Competition between HSR and airlines	Leboeuf (2018)
Numbers of bus and underground stations that can be reached directly from the HSR station without transfer	Integration of HSR with other transport modes	Leboeuf (2018)
Number of car parking spaces available at the HSR station (space/1000 daily passengers)	Integration of HSR with other transport modes	Leboeuf (2018)
Number of electric car parking spaces available at the HSR station (space/1000 daily passengers)	Integration of HSR with other transport modes	Leboeuf (2018)
Car parking fee at the HSR station (€/24 hours)	Integration of HSR with other transport modes	Leboeuf (2018)
Number of bus, metro, and commuter lines at the HSR station	Integration of HSR with other transport modes	Leboeuf (2018)

2.5 Social pillar

This section discusses some topics and issues that govern the social sustainability of HSR, plus presenting a selection of indicators that can be used for reporting on them. Also, the section provides an extensive review of the literature about the social exclusion factor, as this topic is the subject of a case study in Chapter 9.

2.5.1 Safety, employment, affordability, and operators' initiative

The safety factor constitutes a top priority for operators, railway agencies, and governments around the world (UIC, 2016b; UIC, 2017; UIC, 2018c). Safe railway services maintain constant passenger numbers and revenues alongside attracting international exporting opportunities. In contrast, unsafe services damage the reputation of the company and impose huge financial burdens on society, due to loss of life and damage to properties (Profillidis, 2014). The safety factor reflects the safety of three main parties: staff in the workplace; passengers in trains, stations, and platforms; and third parties such as drivers and pedestrians at level crossings (ORR, 2018). Moreover, the safety factor discusses the safety culture adopted within railway companies, considering the availability of safety codes, transparency in reporting issues to managers, and the availability of adequate training and skill improvement programmes (Farrington-Darby et al., 2005). Disclosing safety information can promote safe operations and production. For instance, Bingyang (2018) discusses that regulating and updating the safety disclosure procedure in China has significantly reduced accidents and improved safety of railway operations.

The affordability of the HSR service is another socially relevant topic. Basically, the price of the ticket constitutes the most significant factor which influences passengers' choice of mode (Leboeuf, 2018). Reducing HSR ticket prices is assured to be an effective method for

attracting more passengers to use the service. Biggiero et al. (2017) explored the travel preferences of 810 Italian passengers, using stated preference and revealed preference surveys. The results of the study show that reducing the price of a ticket by only 20 per cent is enough to encourage almost 70 per cent of non-HSR users to shift from other modes to HSR.

Delaplace and Dobruszkes (2015) discussed that while the low-cost wave has affected several sectors such as fashion, banking, supermarkets, and air transport, HSR have remained relatively expensive. A hybrid HSR model – between low-cost carriers (LCC) and traditional HSR – has appeared in some countries, offering tickets at discounted and affordable prices (Delaplace and Dobruszkes, 2015). For instance, SNCF has introduced the OUIGO HSR service which offers tickets at competitive prices, especially when compared to traditional HSR and air transport, see Figure 2-3.

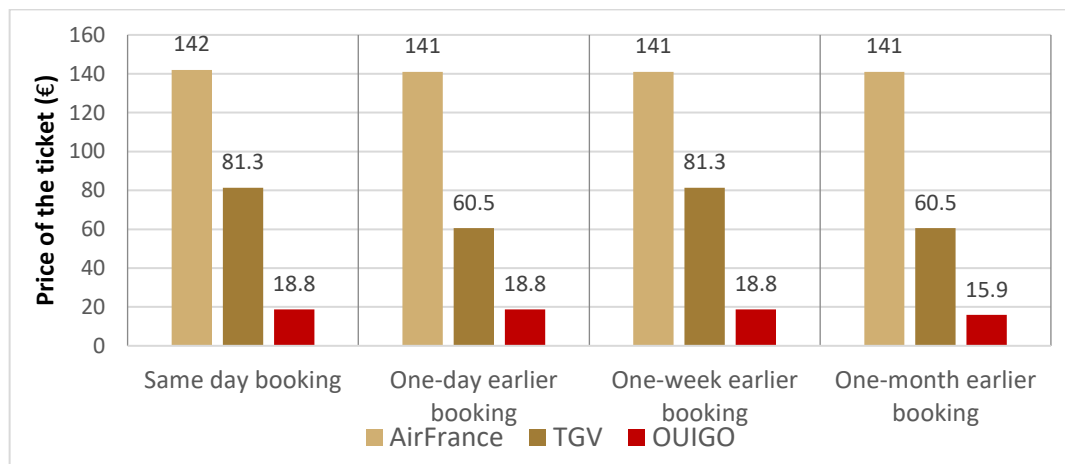


Figure 2-3: OUIGO, TGV and Air France pricing comparison for a Paris–Lyon journey
Source: author’s elaboration on (AirFrance, 2018; SNCF, 2018c; OUIGO, 2018)

Employment is another relevant factor within the social pillar. The employment factor reflects the number of employees hired by the type of contract, position, age, gender, and background plus retention rates (Marimon et al., 2012). Moreover, the employment factor discusses benefits offered to employees such as pensions, parental leave, monetary and non-

monetary bonuses, life insurance, stock ownership, and disability coverage (GRI, 2016d). The provision of such benefits can increase workforce productivity (SNCF, 2017a). Another aspect of employment is skills development programmes and training courses which are offered to staff to improve their theoretical knowledge and practical skills. Such courses and programmes can be offered on a casual or regular basis (GRI, 2016d).

2.5.2 Rapid expropriation and social segregation

Rapid urbanisation and the deployment of new transportation modes are often accompanied by a variety of social inequalities among diverse social groups in society. These include changes in lifestyle and occupation, resettlement, and less access to job opportunities in big urban centres (Ortuño-Padilla et al., 2017). The development of HSR projects is often associated with social issues such as the acquisition of land along HSR corridors and around newly built HSR stations (Ayten and Çay, 2017; Chen and Wei, 2013). Land acquisition is usually accompanied by the demolition of private and community properties. These properties include houses, farms, factories, small businesses, workshops, schools, clinics, and community centres (Arcadis, 2018; NHSRC, 2017).

Chen and Wei (2013) discussed that HSR stations in China are typically built in suburbs, which increases land prices substantially. Changes in land values create uneven development patterns, converting farmland into high-rise residential, office, and commercial buildings, mainly for generating profits (Ayten and Çay, 2017; Chen and Wei, 2013). As a result, farmers are often displaced from their land to new urban locations. Rapid expropriation is relevant in both developed and developing countries. However, the consequences of the problem can be more severe in developing countries, where farmers who have been displaced cannot easily integrate into the new urban life. This is because those farmers have spent their life working in

farming plus basic local industries, and so they do not have appropriate qualifications to work in urban businesses (Chen and Wei, 2013). In such cases, monetary compensation for those who have lost their properties is not enough, and rehabilitation programmes are required to assist farmers in their new professional life (Arcadis, 2018). Moreover, revenues that are generated from new projects around stations could be partly used for village renewal programmes and poverty alleviation (Zhao and Zhang, 2017).

The social segregation topic is also relevant within the social pillar. Chen and Wei (2013) explained that new HSR stations present the modern face of China, where rich and well-off citizens gather to use the HSR service which of course they can afford. In contrast, conventional railway stations – which are often located in city centres – are generally considered less prestigious; they feature dirty and chaotic places, in which poor immigrant workers gather (Chen and Wei, 2013).

2.5.3 HSR and social exclusion

The relationship between HSR and social exclusion has been explored in the most recent literature. Levitas et al. (2007) defined social exclusion as the lack of services, goods, and services, and the inability to participate in social, economic, political, and cultural activities and actions that are enjoyed by different groups and classes in society. Lucas (2012) explained that applying the social exclusion notion in the transportation field has several advantages. It assists planners and policy makers to understand that the problem is i) multi-dimensional and can affect individuals and groups, hence it requires multi-fold solutions and interventions, ii) dynamic and changing over time and space, iii) rational as it can be discovered by comparison. Church et al. (2000) categorised the aspects and reasons which can exclude individuals and/or groups from using transportation services into seven principal categories:

1. Geographical exclusion: where it is hard to reach transportation links and stations due to living in remote areas, suburbs, islands, and other zones that are poorly connected to the transportation network (Bartley, 1998);
2. Economic exclusion: where the monetary costs associated with travelling prevent individuals and groups from using a specific transportation mode. Monetary costs include the ticket costs of both the main transport mode such as HSR and connecting modes such as buses and subways (Bottomley, 1997);
3. Time-based exclusion: where the commitment to different tasks and responsibilities leaves specific groups without free time for travelling. Time poverty affects both genders and different groups such as mothers and employees with very tight schedules (Boulin, 1993);
4. Physical exclusion: where the poor design and inadequate ergonomics of stations and facilities plus other physical barriers prevent certain users from accessing transport services. These users could be children, the elderly, people with disabilities, visually impaired people, and travellers who cannot speak or read the local language (Imrie and Imrie, 1996);
5. Fear-based exclusion: where travellers fear for their personal safety in private and public places such as congested trains, waiting rooms, tickets queues, and stations' main halls. In this regards, people's feelings range from awareness and concern through to worry, fear, and terror. These feelings vary noticeably between males and females (Church et al., 2000);
6. Space exclusion: the management and security arrangements of public spaces such as stations and airports can prevent specific users from accessing transport services. For instance, space exclusion might be associated with a lack of first-class waiting rooms and VIP lounges (Oc and Tiesdell, 1997);

7. Exclusion from facilities: where constraints of time, salary, religion, and social status prevent individuals and groups from accessing hospitals, shopping centres, universities, leisure establishments, and other facilities (Leyshon and Thrift, 1995);
8. Other forms like the digital exclusion: some users might not have adequate skills to access and/or use information and communication technologies such as mobile phones, ticket booking apps and digital schedules and notifiers (Thomas et al., 2016). The digital gap between different users might exclude specific groups from accessing HSR services.

Pagliara et al. (2017a) examined the link between HSR and social exclusion in three countries in Europe, namely, Italy, Spain, and the UK. A revealed preference travel survey was used via online platforms, asking passengers about obstacles that prevent them from accessing the HSR service; 414, 359, and 968 useful responses were collected in Spain, the UK, and Italy respectively. The findings of the study revealed that in all countries, economic exclusion followed by geographical exclusion was the most prevailing among other social exclusion categories, especially among passengers with low salaries. Also, passengers in Italy perceived the strongest level of geographical exclusion among the countries surveyed.

Studies looking at the relationship between HSR and social exclusion are very limited, and no previous studies have explored the link between HSR and social exclusion in China. The Chinese HSR network accounts for more than half the global HSR network (Lawrence et al., 2019) and hence it could be useful to identify obstacles that prevent passengers from using the HSR service in China. This will be the topic of Chapter 9 in this research.

2.5.4 Door-to-door travel time, engaging with local communities, and customer satisfaction

Accessibility expressed by the door-to-door (DTD) travel time is a very relevant social factor in the case of HSR. Givoni and Banister (2011) discussed that travellers are less concerned about station-to-station travel time. Instead, they are more interested in the total DTD travel time, considering the time spent on all legs of the journey, from the origin to the destination. The value of travel time significantly varies between countries and users. For instance, in the UK, rail travel time's values range between £5.91 and £ 21.31 for business travellers (DfT, 2015a). Leboeuf (2018) and Chen and Wei (2013) explained that the DTD travel time reflects two notions, namely, external accessibility and internal accessibility. External accessibility refers to time spent on the train between two cities. Internal accessibility considers the time spent reaching the HSR station from the origin, plus time spent within the station for collecting tickets. Besides that, the internal accessibility considers the time spent reaching the destination after leaving the HSR station in the destination city, see Figure 2-4.

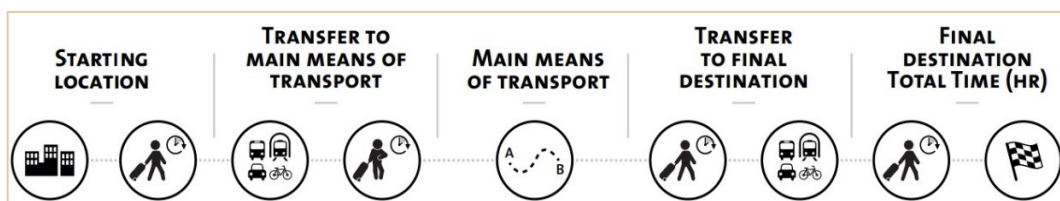


Figure 2-4: Door-to-door travel time components

Source: Leboeuf (2018)

Chen and Wei (2013) pointed out that introducing HSR services along specific lines in China did not bring remarkable benefits in terms of travel time savings. Table 2-3 shows that the internal accessibility time exceeds the in-train travel time by almost 10 minutes in each of the origin and destination cities. This is explained by the fact that most HSR stations in China are located outside city centres, mainly in suburban areas which means it takes a remarkable

amount of time to reach them by other transport modes. Also, Chinese HSR stations are similar to airports in their architectural design, featuring multi-storey megastructures that require considerable time for performing different tasks such as collecting tickets, passing security checks, and finding gates and platforms (Chen et al., 2015; Chen and Wei, 2013). Furthermore, Wang et al. (2016) discussed that planners and decision-makers have focused on intercity transportation while paying less attention to local connections that link HSR stations with their surroundings.

Table 2-3: Door-to-door travel time between Hangzhou and Shanghai

Mode	Origin	Destination	Internal accessibility in origin city (mins)	External accessibility (mins)	Internal accessibility in destination city (mins)	Total travel time (mins)
Conventional rail	Hangzhou Station	Shanghai South	25	108	40	168
HSR	Hangzhou Station	Shanghai Hongqiao	55	45	55	155

Source: Chen and Wei (2013)

Railways are firmly attached to the local communities in and around which they operate, and this attachment is mainly facilitated through stations (Bertolini, 1996). Railway operators engage in a wide range of activities that aim to boost the economic development of local communities while minimising negative environmental footprints and creating extra social benefits. These activities include but are not limited to conducting school visits, planting trees (Renfe, 2015), participating in cultural and art events, hiring local staff (SNCF, 2017a), operating healthcare facilities, supporting local industries, buying from local businesses, and promoting local products on trains and in stations (JR-Central, 2018). Involving the locals in the decision-support and decision-making processes is another essential form of engaging with communities (Cascetta and Pagliara, 2013).

Customer satisfaction is the final factor that will be presented within the social pillar. A positive customer experience motivates travellers to use HSR services constantly and vice versa. In their study, Made and Hagen (2018) found that passengers have three essential needs while travelling by trains:

1. Being in full control of their journeys by being able to access all necessary travel information without necessarily relying on help from others;
2. Having the freedom to spend their travelling time – on trains and in stations – as they wish, such as working, listening to music, and surfing the internet;
3. Being welcomed and appreciated by the railway employees.

Reflecting on these three basic needs, HSR operators conduct travel surveys to measure the extent to which clients are satisfied about the service and to identify potential areas of improvement.

2.5.5 Indicators for reporting on social factors and topics

Table 2-1 presents some parameters that can be used for reporting on the previously discussed social topics. These parameters are offered by international reporting guidelines and other studies and independent scholars who examined social challenges and topics associated with the development and deployment of HSR.

Table 2-4: Indicators for reporting on social topics and factors

Indicator	Factor which the indicator is used to report	Reference
Number and rate of work-related injuries and fatalities caused to railway employees	Safety	GRI (2018b)
Number of minor and serious injuries and fatalities caused to railway passengers	Safety	UIC (2018c)
Number of minor and serious injuries and fatalities caused to third parties	Safety	UIC (2018c)
Total number and rate of new employees hired by age, gender, and contract type	Employment	GRI (2016a)
Quantitative and qualitative explanation of financial and non-financial benefits offered to staff	Employment	GRI (2016a)
Return to work and retention rates (%)	Employment	GRI (2016a)
Door-to-door travel time (minutes)	Door-to-door travel time	Chen and Wei (2013)
Results of a survey that measures the extent to which passengers are satisfied with the HSR service	Customer satisfaction	GRI (2016e)
Percentage of operations with local community involvement implemented (%)	Engaging with local communities	GRI (2016e)
Quantitative and qualitative explanation of positive and negative effects on local communities	Engaging with local communities	GRI (2016e)
Results of a survey that identify reasons behind excluding specific groups from using HSR services	Social exclusion	Pagliara and Biggiero (2017)
Total number of homes, farms, small businesses, and others to be demolished along new HSR lines	Rapid expropriation	Arcadis (2018)
Quantitative and qualitative explanation of compensation provided to owners of land and properties	Rapid expropriation	Arcadis (2018)

2.6 Environmental pillar

2.6.1 Energy consumption, sources, and carbon emissions

Energy consumption is a very relevant environmental factor, especially considering the economic pressure of energy costs and the shortage in non-renewable resources such as hard coal, gas, and oil (Bergendorff et al., 2008; IEA, 2019). The energy consumption of HSR is significantly low when compared with cars and aviation. Figure 2-5 illustrates that the per passenger energy consumption of a 600 km HSR journey is around 87 per cent and 80 per cent lower than the consumption of aviation and cars respectively (Leboeuf, 2018).

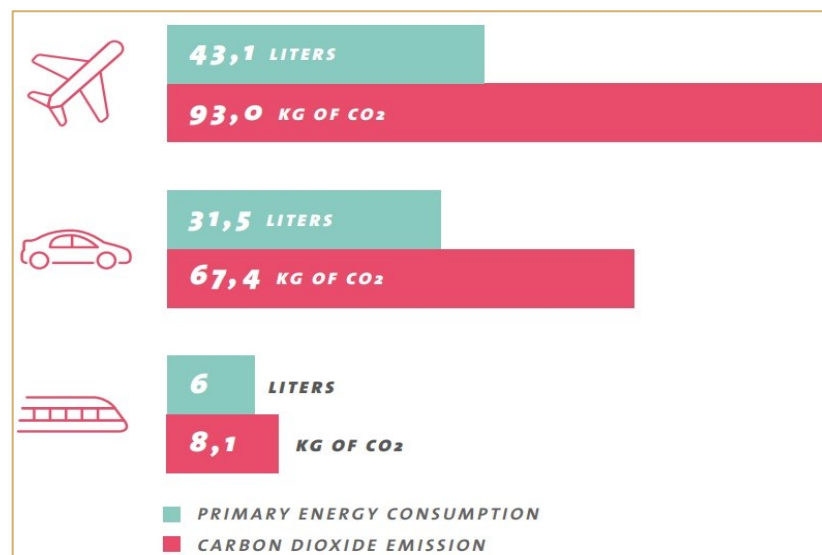


Figure 2-5: Energy consumption and CO₂ emissions of different modes

Source: Leboeuf (2018)

HSR consume energy for different purposes such as traction, on-board and in-station lighting and heating, maintenance, and in-office activities. However, traction constitutes the bulk of energy used, with almost 85 per cent of the total consumption (Bergendorff et al., 2008; IEA, 2019). HSR energy consumption comprise two types: final energy and primary energy. Final energy refers to the energy consumed within the Electric Multiple Units (EMUs). Primary

energy includes – in addition to final energy – the energy required for making the final energy available on board the train. In other words, the primary energy encompasses the energy used for generating the final energy and the energy lost in distribution networks (Bergendorff et al., 2008; Leboeuf, 2018).

The source of energy is also important, and while some HSR operators rely hugely on electricity generated by burning fossil fuels, others diversify their energy mix by using electricity that comes from renewable sources such as wind, solar, and hydraulic power. HSR are 100 per cent electrified systems, which means they are automatically compatible with renewable energy without the need for technological modifications.

CO₂ emissions constitute a fundamental environmental challenge in the 21st century, as the main human-made greenhouse gas (GHG) that contributes to global warming (Baron et al., 2011). IEA (2017) discussed that HSR are environmentally competitive especially when compared with aviation and private mobility. Moreover, HSR can play a vital role in decreasing transport-related CO₂ emissions, specifically by displacing short-haul aviation. Figure 2-5 shows that the per passenger CO₂ emissions for a 600 km HSR journey are almost 90 per cent lower than for aviation (Leboeuf, 2018).

HSR projects produce CO₂ at all stages of a project's lifecycle including the planning, construction, operation, maintenance, and recycling stages (Leboeuf, 2018). The construction stage is considered as a major contributor, especially in cases where the project requires enormous amounts of earthworks, bridges, and tunnels (Leboeuf, 2018; Lin et al., 2019). However, in most cases, operating HSR is the biggest contributor to the total amount of emissions among all other stages. Lin et al. (2019) explained that the carbon footprint for operating the Beijing–Shanghai HSR corridor accounts for almost 71 per cent of the total

emissions, while the construction and maintenance stages accounts for 20 per cent and 9 per cent of emissions respectively. CO₂ emissions for the operation stage include those created by generating electricity for traction, heating, loading, and other on-board services plus electricity for operating stations, offices, and printing tickets (Bergendorff et al., 2008; Leboeuf, 2018).

CO₂ emissions are directly linked to the consumption of energy, and decarbonisation of the energy mix is a vital driver for diminishing CO₂ emissions. Nuclear and renewable energies emit much lower emissions when compared with fossil fuels such as oil, coal, and natural gas (Bergendorff et al., 2008). Figure 2-6 shows the variation among countries in terms of the per passenger.km CO₂ emissions of HSR, and this variation can be explained by differences in the energy mix used in each country. Besides greenhouse gasses, HSR generate other pollutants that affect air quality including particulates and Nitrous Oxide. However, it is worth mentioning that other pollutants such as SO_x and NO_x are negligible and insignificant in the case of HSR especially when compare to CO₂ emissions (Bergendorff et al., 2008).

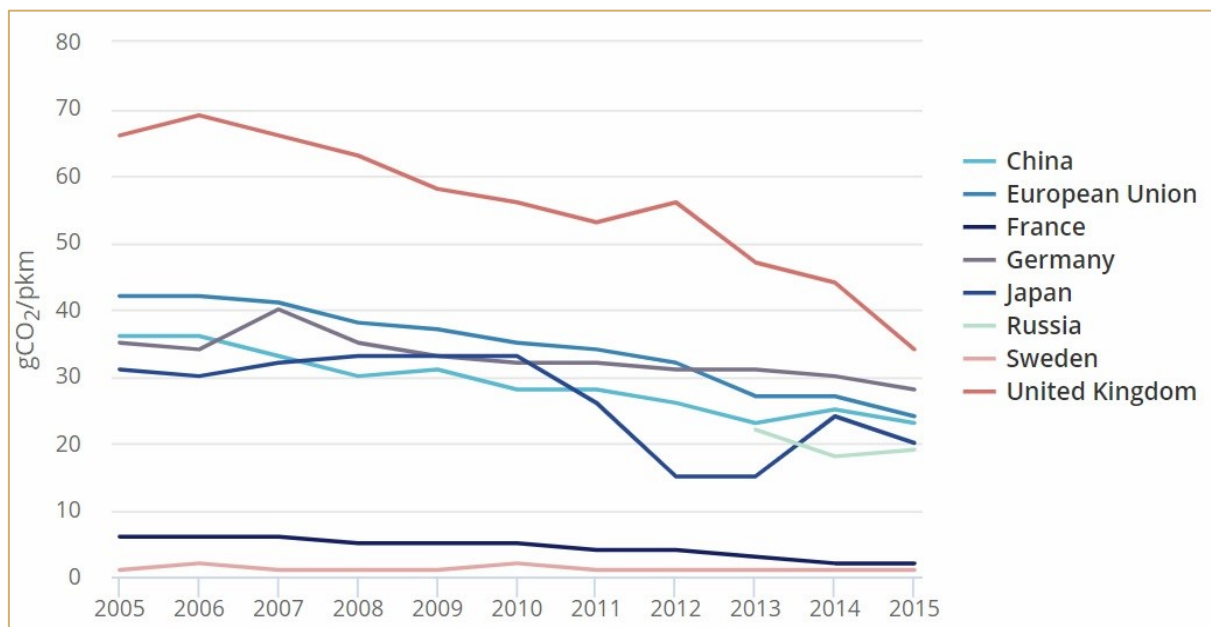


Figure 2-6: CO₂ emissions from HSR by geographic area

Source: UIC-and-IEA (2017)

2.6.2 Land use and biodiversity

The land use factor reflects vegetation management practices adopted by HSR companies. Seeking safe and efficient operations in balance with optimum environmental performance, operators regularly use herbicides and other active substances (Nolte et al., 2018). The application area includes tracks and sealed and unsealed surfaces. Sealed zones encompass platforms, streets, and parking spaces, while unsealed surfaces refer to forests, meadows, and areas around stations. The cost, amount, frequency of use, area of application, and amount of water used vary considerably among operators and countries (Nolte et al., 2018). For instance, the UIC's HERBIE study looked at the vegetation management practices of different European operators. It revealed that while SNCF and DB use almost the same amount of herbicide per track km, SNCF pays almost double (Nolte et al., 2018), see Figure 2-7.

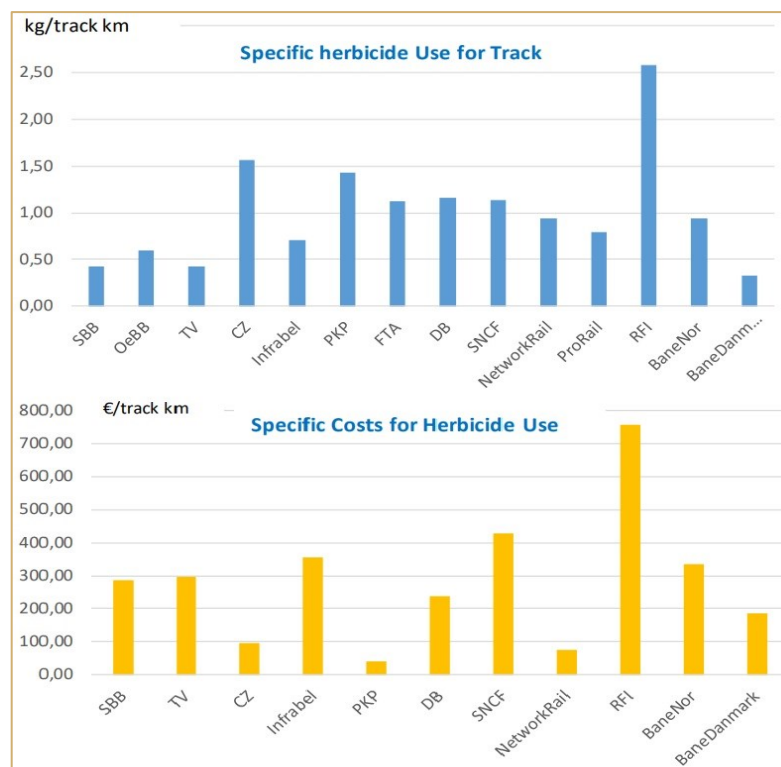


Figure 2-7: Cost and amount of herbicides used in different EU countries

Source: Nolte et al. (2018)

Biodiversity is another important topic within the environmental pillar. HSR activities are often linked with risks that threaten the wildlife forms along railway tracks and around HSR stations and depots. Affected areas typically include national parks, ancient woods, protected areas, and world-listed heritage sites. The most evident impact of HSR on wildlife is direct mortality, which occurs due to different reasons such as rail entrapment, collision with moving trains, wire hits, and electrocution (Borda-de-Água et al., 2017; Carvalho et al., 2017). Secondary effects of linear infrastructures – like HSR – include preventing the natural movement of animals or severing links between populations and building biodiversity bridges above railway tracks is necessary in such cases (Ward et al., 2015). Other impacts might be related to spills and hazardous waste which contaminate the soil around tracks and stations, trees, and plants (Renfe, 2015). Carvalho et al. (2017) explained that the negative impacts of HSR might be more severe than those of conventional rail. This is because HSR operate at higher speeds, with higher noise levels and different fencing methods. Some operators adopt solutions and initiatives for protecting biodiversity and alleviating negative impacts linked to their operation.

2.6.3 Materials, resources, and recycling

HSR operators consume considerable amounts of materials and resources such as fresh water, sand, paper, iron, and copper. These materials can be obtained from sustainable sources and are used for different industrial and non-industrial applications. Different tasks include construction and maintenance works, washing locomotives, printing tickets and vouchers plus performing daily office tasks such as printing (DB, 2017; FS-Italiane, 2017). The consumption of materials results in the generation of refuse, litter, and industrial waste, which might be

hazardous in some cases. Some HSR operators adopt methods for cutting the consumption of renewable materials while minimising reliance on non-renewable resources (Leboeuf, 2018).

HSR systems feature a variety of materials and components, some of which are easier to recycle than others. For instance, recycling paper, aluminium, glass, wood, cloth, and iron is relatively easier than reprocessing concrete (JR-Central, 2018; SNCF, 2017a). Moreover, due to its complex nature and the variety of components, recycling passenger rolling stock can be more challenging than recycling freight locomotives (Silva and Kaewunruen, 2017). Several environmental and economic benefits are associated with recycling. For instance, SNCF generates additional revenue by reselling unrecyclable scrap and components. HSR operators have different methods and attitudes towards recycling, which are reflected in their annual and sustainability report (Grossrieder, 2011).

2.6.4 Noise

Railway noise is the final factor that will be presented within the environmental pillar. HSR operations generate noise which impacts the quality of life in residential buildings and other properties alongside the railway track (Vos, 2016). HSR noise imposes remarkable health risks on humans, which vary in their severity. Effects of noise encompass sleep disturbance, annoyance, stress, increments in blood pressure, and even cardiovascular disease (Vos, 2016). The EU Position Paper on the dose–response relationship for transportation noise explains that HSR’s noise level of 85 dBA highly annoys almost half the residents near the railway track (Vos, 2016), see Figure 2-8. Ivanov et al. (2017) pointed out that a high-speed train (HST) with a speed of 280 km/h generates a sound level of 89.4 dBA, which will highly annoy almost 70 per cent of residents.

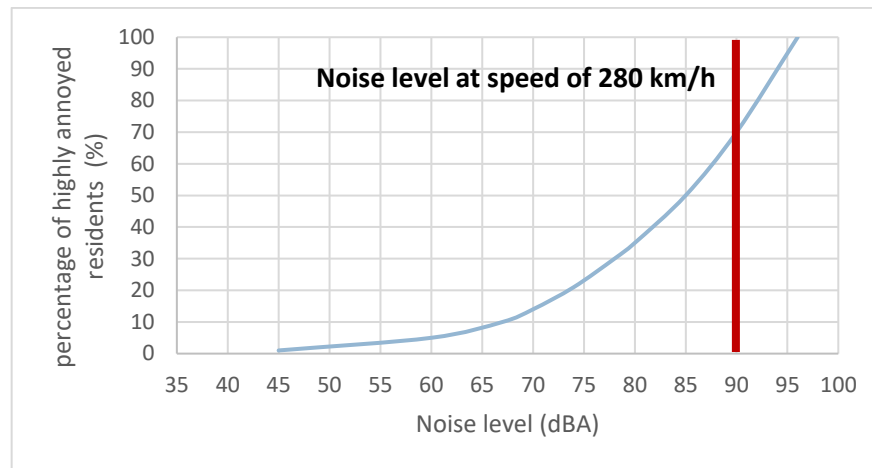


Figure 2-8: Percentage of highly annoyed residents against exposure to railway noise

Source: author's elaboration on Vos (2016) and Ivanov et al. (2017)

Noise levels differ significantly depending on several variables such as the length of the locomotive, the operating speed, the shape of the train and its components, and the distance from the track (Ivanov et al., 2017). Most HSR operations create noise levels that exceed the national and international limits, which vary according to the policies and legislation of each country (Ivanov et al., 2017; Vos, 2016). As a response, some HSR adopt different solutions for controlling noise levels, and most of these solutions focus on either the design of the train and its components or the track and its surroundings (Ivanov et al., 2017; Vos, 2016). Train solutions include on covering the noisiest parts, modifying wheels and brakes, and reshaping the nose of the train for better aerodynamics. Track methods are focused on erecting noise-absorbing walls, especially near residential areas. The cost and effectiveness of these solutions vary considerably. For example, erecting noise-absorbing walls can reduce noise levels by up to 10 dBA, while enclosing noisy parts is proven to be less effective (Vos, 2016).

2.6.5 Indicators for reporting on the environmental factors and topics

Table 2-5 presents some indicators that can be used for reporting the previously discussed environmental topics. These indicators are mostly offered by reporting guidelines.

Table 2-5: Indicators for reporting on environmental topics and factors

Indicator	Factor which the indicator is used to report	Reference
Specific CO ₂ emissions of railway activities (g CO ₂ /p.km)	Emissions	UIC (2016a)
Specific CO ₂ emissions of railway activities (g CO ₂ /seat.km)	Emissions	UIC (2016a)
Well-to-wheel CO ₂ emissions of rail transport (g CO ₂ /p.km)	Emissions	Leboeuf (2018)
Total amount of CO ₂ emissions related to all stages of the lifecycle of the HSR project (tonnes)	Emissions	Leboeuf (2018)
Amounts of NO _x , SO _x , particles, and other pollutants (tonnes)	Emissions	UIC (2016a)
Aggregate energy consumption for all activities of the firm	Energy consumption	UIC (2016a)
Primary energy consumption of HSR (kJ/p.km)	Energy consumption	UIC (2016a)
Final energy consumption of HSR (kJ/p.km)	Energy consumption	UIC (2016a)
Share of renewable energy in the total energy used for generating electricity (%)	Energy consumption	Bergendorff et al. (2008)
Sound levels at a distance of 25 m and a height of 3.5 m above the rail track (dBA)	Noise	Ivanov et al. (2017)
Pass-by sound levels of electric locomotives with a speed of 250 km/h or more (dBA)	Noise	EURLEX (2014)
Amount of herbicides used for controlling vegetation along railway tracks (kg/track km)	Land use	UIC (2018b)
Cost of herbicides used for controlling vegetation along railway tracks (€/track km)	Land use	UIC (2018b)

Quantitative and qualitative explanation of features, values, and specification of biodiversity zones near railway activities	Biodiversity	GRI (2016b)
Quantitative and qualitative explanation of firms' activities effects on biodiversity	Biodiversity	GRI (2016b)
Quantitative and qualitative explanation of firms' efforts in conserving biodiversity	Biodiversity	GRI (2016b)
Amount of renewable/non-renewable materials consumed (tonnes)	Resources and materials	GRI (2016c)
Percentage of input materials recycled (%)	Recycling	GRI (2016c)
Percentage of materials reclaimed (%)	Recycling	GRI (2016c)
Weight of non-hazardous/hazardous refuse produced by type and disposal method (tonnes)	Materials	GRI (2016c)
Quantitative and qualitative explanation of significant spills	Materials	GRI (2016c)
Weight of hazardous refuse transported by type (tonnes)	Materials	GRI (2016c)

2.7 Key HSR operators

This section presents five HSR operators, reflecting on their ownership, responsibilities, businesses in which they are involved, and the location of their activities.

2.7.1 Central Japan Railway Company (JR Central)

JR Central is a private railway company which is responsible for operating Japan's main transportation artery, the Tokaido Shinkansen HSR service between Tokyo, Nagoya, and Osaka. Also, the company is developing the Chuo Shinkansen, which uses a superconducting maglev system, along the Tokyo–Osaka corridor. Besides that, JR Central operates a network of 12 conventional rail lines plus other transportation services (JR-Central, 2018; JR-Central,

2019a). JR Central's operation zone comprises areas of Nagoya and Shizuoka. The activities of JR Central are not limited to operating transportation services; the company has a strong presence in the real estate sector, managing a combination of department stores, hotel, food and beverage chains, retail and wholesale shops, construction and maintenance businesses, and financial service agencies (JR-Central, 2018; JR-Central, 2019a).

2.7.2 Société Nationale des Chemins de Fer Français (SNCF)

SNCF is a state-owned railway company that is responsible for operating France's national rail traffic, including the French high-speed rail network (TGV). SNCF is involved in six key businesses (SNCF, 2017a; SNCF, 2019e):

1. Managing, maintaining, and renovating the rail network plus providing access and setting infrastructure charges;
2. Operating the long-distance rail network including the TGV, OUIGO, Eurostar, and Thalys;
3. Operating commuter mobilities including the transportation network in the Paris region, the regional rail service (TER), and car rental services;
4. Renovating, improving, and managing around 3000 railway stations on the French network;
5. Operating freight transport and logistics services in France and 120 countries worldwide;
6. Managing businesses in the real estate sector, including social housing units.

2.7.3 Renfe Operadora

Renfe is a state-owned railway company that is attached to the Spanish Ministry of Development. Renfe operates the Spanish high-speed rail network (AVE). The company is involved in four main businesses (Renfe, 2015; Renfe, 2019b):

1. Operating the passenger rail network including short-, medium-, and long-distance services, alongside managing tourism activities in Spain and other international locations;
2. Operating a freight rail network as a part of comprehensive logistics chain, at the national and international levels;
3. Manufacturing, renovating, and maintaining locomotives and other railway components, plus providing industrial consultation and managing workshops;
4. Offering rolling stock sales and rental services, to both local and international parries.

2.7.4 China Railway Beijing Bureau Group (CRBBG)

CRBBG is a large railway transportation company directly under the management of the China Railway Corporation, the state-owned parent firm. The company is responsible for operating the Beijing–Shanghai HSR line from the Beijing side. The jurisdiction of CRBBG is Beijing, Tianjin, Hebei, and Shanxi, plus parts of Shandong and Henan provinces (CR, 2019; Tielu, 2019).

The operator has three main responsibilities within its jurisdiction: operating different transportation services, managing railway stations, and managing the rail infrastructure. Transportation services include high-speed and conventional rail for both passengers and freight plus buses. Moreover, the company conducts transformation projects for renovation of locomotives and modernisation of railway stations, alongside carrying out railway research (CR, 2019; Tielu, 2019). The parent company is involved in a variety of businesses in the sectors of tourism, catering, hospitality, engineering, and technology, and integration with other transport modes (CR, 2019).

2.7.5 China Railway Shanghai Bureau Group (CRSBG)

CRSBG is another major public railway company which is directly managed by China Railway Corporation. The company operates the Beijing–Shanghai high-speed line from the Shanghai side. The jurisdiction of the company is Shanghai, Jiangsu, Anhui, and Zhejiang plus small parts of other provinces (CR, 2019; Tielu, 2019).

Like the Beijing Group, CRSBG manages transportation services, stations, and infrastructure within its jurisdiction. Transportation services include passenger and freight conventional railways, HSR, and buses. Finally, the company is hugely involved in construction works which are mainly related to the rail sector and associated businesses (CR, 2019; Tielu, 2019). Table 2-6 presents key data related to the length of the rail network operated by the five HSR companies.

Table 2-6: Rail network length of five HSR operators

Operator	JR Central	SNCF	Renfe	CRBBG	CRSBG
Total network (km)	1970.8	30000	12000	8787	9996.6
HSR network (km)	552.6	2734	3240	1779	3357.4

Source: author's elaboration on (CR, 2019; JR-Central, 2019a; Renfe, 2019b; SNCF, 2019e; Tielu, 2019).

2.8 Key HSR corridors

This section presents key four HSR corridors from around the world. These corridors will be the focus of some benchmarking exercises in Chapter 5, Chapter 6, and Chapter 7.

2.8.1 Tokyo–Osaka HSR corridor

The Tokyo–Osaka corridor accommodates the Tokaido Shinkansen, the first HSR service in the world and the core of the Japanese HSR network. The line is Japan’s main transportation artery that connects the largest metropolitan areas of Tokyo, Osaka, and Nagoya (JR-Central, 2019e). The construction works started in 1959 and the line was opened in 1964. JR Central currently operates the 552.6 km line – see Figure 2-9 – offering around 323 trains per day and transporting almost 145,000 passengers (JR-Central, 2018; JR-Central, 2019c). The corridor has greatly boosted the economy of its region plus the whole Japanese economy, being one of the most successful HSR lines around the world (Albalade et al., 2012; Henríquez and Deakin, 2017).



Figure 2-9: The Tokyo–Osaka HSR line

Source: (JR-Central, 2019a)

2.8.2 Paris–Lyon HSR corridor

The Paris–Lyon corridor hosts the TGV Sud-Est, the renowned and first HSR service between Paris and Lyon, see Figure 2-10. Alstom started building the line in 1978, and it took almost 10 years to finalise it, while SNCF started operation in 1981 (SNCF, 2019c). The line constitutes France’s oldest and most profitable and Europe’s most heavily trafficked high-speed corridor, with around 240 trains/day working on it. Moreover, the 425 km line handles almost a third of the HSR activity in France, and traffic is expected to grow in the coming years. The annual ridership grew by almost 520 per cent between 1982 and 2017 (SNCF, 2019c).



Figure 2-10: The Paris–Lyon HSR line

Source: Co-Corporation (2019)

2.8.3 Madrid–Seville HSR corridor

The Madrid–Seville corridor hosts Spain’s first HSR line, which connects the Spanish capital with the Andalusia region in the South, see Figure 2-11. Construction of the line started in 1989 and lasted for almost 33 months (Adif, 2019a). ADIF owns the line, while Renfe – the operator – started operating the line in 1992. During the first 10 years of its operation, the line transported around 120 million people, and in 1998, the HSR service along the corridor the line won the European Quality Award for quality management and business excellence (Adif, 2019a). Coto-Millán et al. (2007) pointed out that the line is relatively isolated from the rest of the Spanish HSR network, and it is hardly connected to the surrounding economy.



Figure 2-11: The Madrid–Seville HSR line

Source: Adif (2019a)

2.8.4 Beijing–Shanghai HSR corridor

The Beijing–Shanghai HSR corridor connects the two major economic zones of Beijing and Shanghai in China, see Figure 2-12. Construction of the line started in 2008 and the first commercial HSR service was available to the public in 2011. The 1318.3 km line constitutes China’s most profitable HSR corridor, featuring more than \$1 billion in net operational profits in 2015 (Nunno, 2018). Both CRBBG and CRSBG are responsible for operating the line, which transported more than 930 million passengers in 8 years (Guangming, 2019). Cities along the corridor have witnessed remarkable economic benefits, while deployment of the line has improved both the technical standard systems and management levels of China’s HSR (Guangming, 2019).

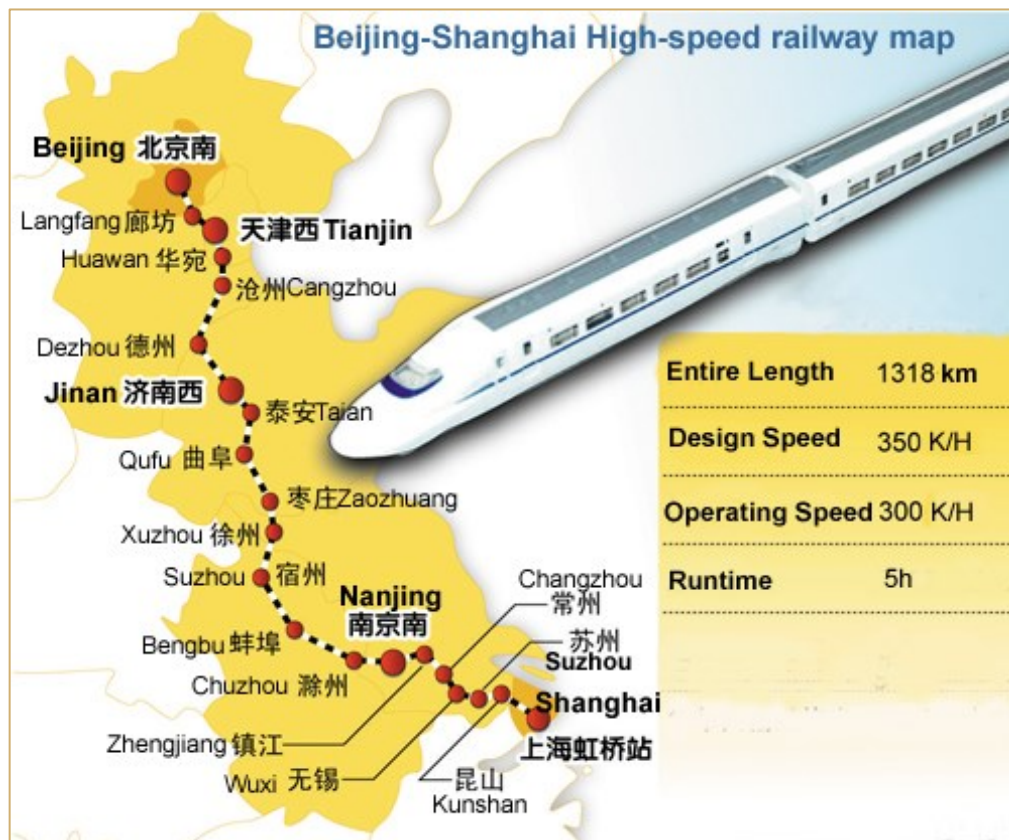


Figure 2-12: The Beijing–Shanghai HSR line

Source: China-Daily (2018)

Table 2-7 exhibits some key information related to the HSR corridors presented above. Other information such as the daily and annual ridership, operating speeds, and durations will be presented in the benchmarking exercises in Chapter 5, Chapter 6, and Chapter 7.

Table 2-7: Background information on the four HSR corridors

HSR corridor	Tokyo–Osaka	Paris–Lyon	Madrid–Seville	Beijing–Shanghai
Length (km)	552.6	425	471	1318.3
Opening year	1964	1981	1992	2011
Number of stations	17	4	5	24
Operator	JR Central	SNCF	Renfe	CRBBG + CRSBG
HSR Service	Tokaido Shinkansen	TGV Sud-Est	AVE Andalusia	CRH
Origin and destination stations	Tokyo Central to Shin Osaka	Paris Gare de Lyon to Lyon Part Dieu	Madrid Atocha to Santa Justa	Beijing South to Shanghai Hongqiao

Source: author's elaboration on (Adif, 2019a; JR-Central, 2019e; JR-Central, 2019c; SNCF, 2019c; UIC, 2018a; UIC, 2019c)

2.9 Summary and closing remarks

This chapter provides basic definitions and reflects on the benefits of sustainability reporting and benchmarking. Also, it introduces key HSR operators and corridors. Most importantly, a variety of economic, social, and environmental topics and issues that relate to the sustainability performance of HSR are discussed. Some of these topics hold significant importance from an operator's perspective while others are discussed in most recent studies by different scholars. This chapter also lists some economic, social, and environmental indicators that can be used for reporting on sustainability topics; most of these parameters are offered by international railway and reporting organisations.

Exploring the literature showed the diversity of sustainability topics that can be linked to the performance of HSR. Designing, planning, implementing, operating, and recycling HSR might bring a variety of social, economic, and environmental benefits. Nevertheless, these might be accompanied by potential negative impacts that could hinder the overall sustainability performance of the system. Considering that ‘what is well measured is well managed’ tracking and measuring both positive and negative impacts of HSR support sustainability management and can help managers to boost benefits while minimising negative effects. The literature shows that HSR’s positive and negative impacts vary according to the context and location and designing a reporting and measurement framework will allow the comparison between different contexts.

The extent to which the previously discussed sustainability topics are covered in operators’ sustainability publications and the nature of their representation are unknown. Some topics might have a stronger presence in company reports than others. Also, some companies might be reporting on more topics than their peers. In other words, sustainability reporting variations might exist on different levels.

HSR operator and corridor performance in terms of the economic, social, and environmental topics discussed might vary. Such variations can be revealed through benchmarking exercises, which require a set of standardised KPIs. The literature lists some indicators; however, the availability of performance data that relate to these indicators might be obscure.

Seeking a minimum level of reporting standardisation, Chapter 3 selects a framework of 26 sustainability factors, all of which relate to the topics and issues discussed in the sustainability literature in Chapter 2. Then, Chapter 4 examines the availability of these factors

in HSR companies' sustainability publications, revealing reporting variations at different levels. Chapter 5, Chapter 6, and Chapter 7 propose a variety of economic, social, and environmental indicators respectively, and show how these can be used in benchmarking exercises.

CHAPTER 3

METHODOLOGY

This chapter explains the overall approach to the research. This study is based on fulfilling four key points:

1. Exploring, selecting, and legitimising HSR sustainability factors;
2. Searching for sustainability factors in operators' publications;
3. Proposing and testing a combination of indicators that express sustainability factors and could be used for reporting and benchmarking purposes;
4. Analysing the relationship between HSR and social exclusion categories in China as a special case study.

To fulfil the above-mentioned points, this study used a combination of quantitative and qualitative research methods. Primary data were obtained from visual observations, surveys, and face-to-face interviews with experts, while secondary data were extracted from a wide range of sources and materials. Also, the logic behind selecting specific sustainability factors, publications, HSR companies, indicators, and corridors is explained and justified in this chapter. Moreover, different criteria were applied to guarantee the validity and robustness of different steps and methods. Figure 3-1 illustrates the step-by-step process for conducting the research.

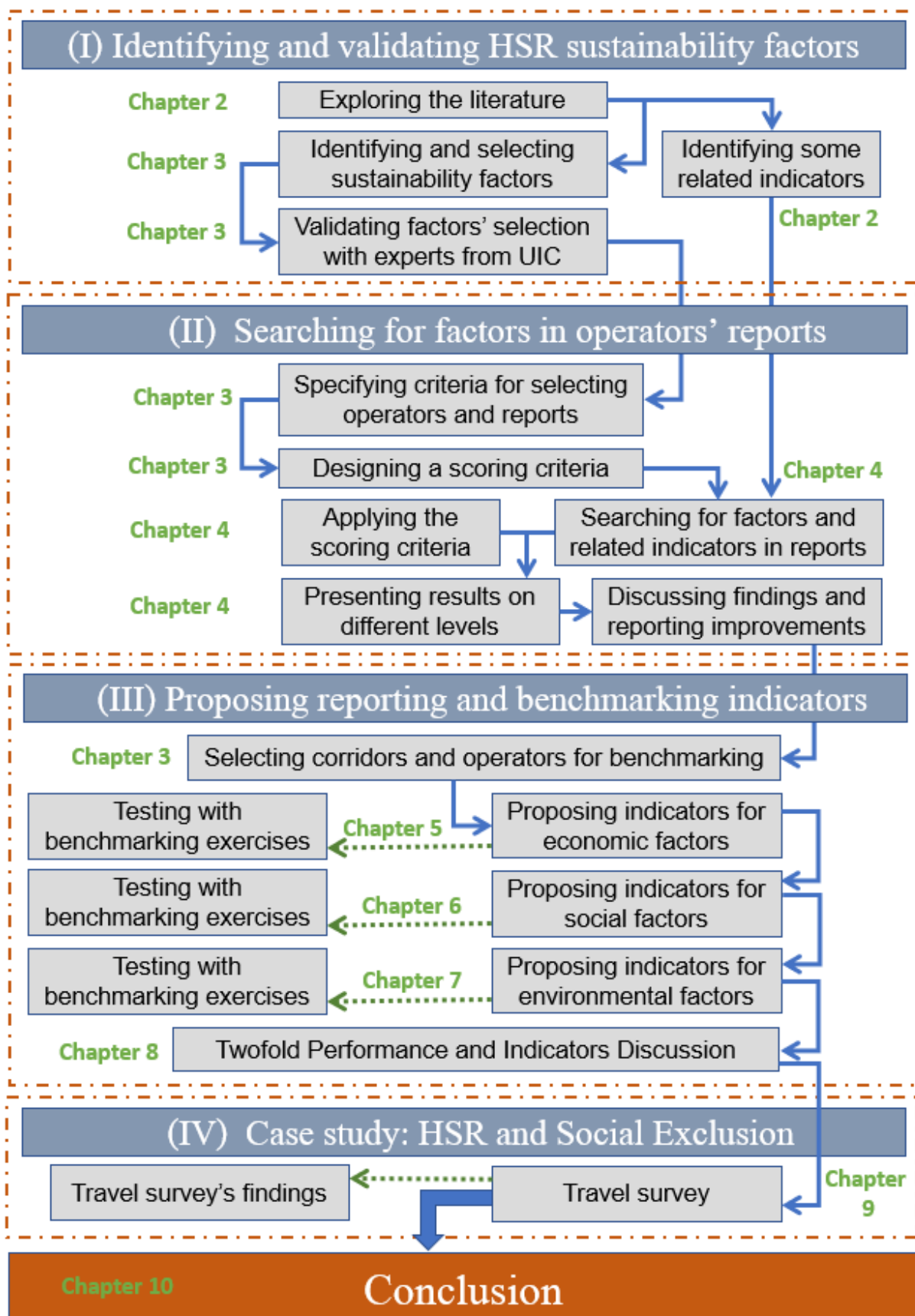


Figure 3-1: Step-by-step process for conducting the research

3.1 Selecting and legitimising HSR sustainability factors

3.1.1 Selecting HSR sustainability factors

Chapter 2 presents a variety of economic, social, and environmental topics, challenges, and issues that relate to the sustainability performance of HSR. Some of these topics hold significant importance for HSR operators while others constitute the interest and focus of recent publications that discuss the correlation between HSR and sustainability, see Figure 3-2.

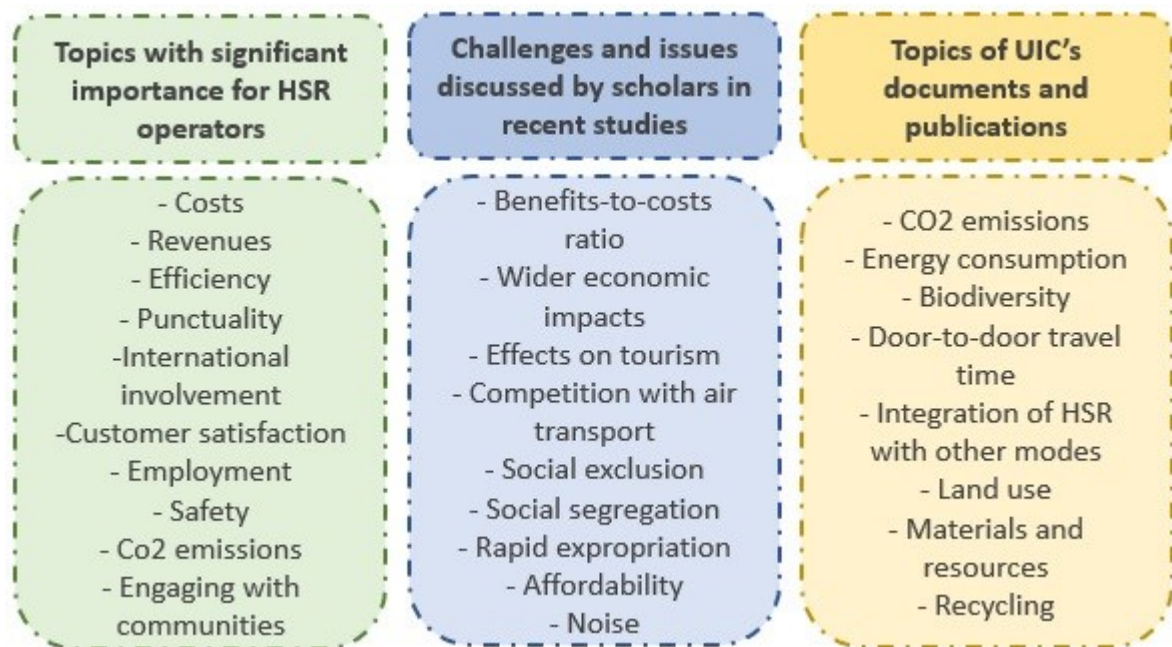


Figure 3-2: Topics that relate to the sustainability performance of HSR

Source: author's elaboration on different sources

The above-mentioned topics are discussed in recently published books, journal papers, online articles, operators' documents, and UIC publications. After a thorough and rigorous exploration of these materials, this study identified a set of 26 factors that are firmly tied to the sustainability performance of HSR. Table 3-1 presents ten economic, nine social, and seven environmental factors that were identified. Also, Table 3-1 refers to the sources in which factors were discussed. The 26 factors selected constitute the HSR sustainability framework.

Table 3-1: The 26 HSR sustainability factors identified

Economic sustainability factors	Related sources
Punctuality and reliability	Schumann (2017), Renfe (2015)
Costs	Ollivier et al. (2014), World-Bank (2017b), SNCF (2017a)
Revenues	World-Bank (2017b), van Hagen and van Oort (2018), Suzuki (2017)
Efficiency	Merkert et al. (2010), Beck et al. (2013), Fukuyama et al. (2011), Li et al. (2012)
Benefits-to-costs ratio	Nash (2017), Tao et al. (2011), Brinckerhoff (2014), De Rus (2012)
Wider economic impacts	Cheng et al. (2015), Vickerman and Uljed (2006), Nash (2017), Albalade and Bel (2012), Albalade et al. (2012), Loo and Comtois (2015)
Effects on tourism	Albalade et al. (2017), Albalade and Fageda (2016), Chen and Haynes (2012), Kurihara and Wu (2016), Pagliara et al. (2015)
Competition with air transport	Fukuyama et al. (2011), Delaplace and Dobruszkes (2015), Sun et al. (2017), Jiménez and Betancor (2012), Clewlow et al. (2014)
Integration with other modes	Leboeuf (2018), UIC (2019a), Garcia (2015), Chen et al. (2015)
International involvement	Huang (2017), Hu (2017), Grey (2017), JR-Central (2018), Hong (2015), Shimbun (2017)
Social sustainability factors	Related sources
Safety	Profillidis (2014), UIC (2018c), ORR (2018), Farrington-Darby et al. (2005)

Door-to-door travel time	Leboeuf (2018), UIC (2019a), Chen and Wei (2013), Wang et al. (2016)
Social segregation	Chen and Wei (2013)
Rapid expropriation	Chen and Wei (2013), Arcadis (2018), Ortuño-Padilla et al. (2017), Zhao and Zhang (2017)
Social exclusion	Pagliara et al. (2017b), Pagliara et al. (2017b), Church et al. (2000), Levitas et al. (2007)
Engaging with local communities	Cascetta and Pagliara (2013), Bertolini (1996)
Customer satisfaction	Sahin Dölarslan (2014), Made and Hagen (2018)
Employment	Marimon et al. (2012), World-Bank (2017b), GRI (2016d)
Affordability and operators' initiatives	Biggiero et al. (2017), Delaplace and Dobruszkes (2015)
Environmental sustainability factors	Related sources
Carbon emissions	Lin et al. (2019), IEA (2017), Wang et al. (2019), Cornet et al. (2018), Bergendorff et al. (2008)
Energy consumption and sources	IEA (2017), Li et al. (2012), Leboeuf (2018), IEA (2019)
Land use	Nolte et al. (2018)
Resources and materials	Renfe (2015), SNCF (2017a), FS-Italiane (2017)
Biodiversity	Carvalho et al. (2017), Borda-de-Água et al. (2017)
Recycling	Silva and Kaewunruen (2017), Grossrieder (2011)
Noise	Ivanov et al. (2017), Vos (2016)

Source: author's elaboration on different sources

The framework features consistency and interaction between its selected factors. On the first hand, good performance on a specific factor will bring co-benefits for other factors. For instance, higher recycling might bring costs down and increase revenues. Similarly, consuming less energy will reduce costs and emissions. Punctual services result in higher customer satisfaction. On the other hand, good performance on a certain factor may create disbenefit to other factors. For example, offering compensation to land and property owners who lost their properties will increase construction costs.

To further justify the author's selection, all identified factors were related and matched against the following five criteria:

1. The common definition of sustainable transportation as presented by Schiller and Kenworthy (2017), see Figure 3-3;
2. Topics presented within the UIC's document 'HSR Fast Track to Sustainable Mobility' (Leboeuf, 2018), see Figure 3-3;
3. The rail sustainable development principles of the Rail Safety and Standards Board (RSSB, 2016), see Figure 3-4;
4. Topics within the book 'High-Speed Rail and Sustainability: Decision-Making and Political Economy of Investment' (Henríquez and Deakin, 2017), see Figure 3-4;
5. The 17 SDGs (United-Nations, 2019), see Figure 3-5.

The matching process illustrated in Figure 3-3, Figure 3-4, and Figure 3-5 shows that each selected sustainability factor relates to at least one topic and SDG from within the selected criteria, a fact that adds more credibility to the 26 factors selected. It is worth mentioning that most of the criteria tackle a specific country or region when discussing a particular sustainability topic, without necessarily reflecting the topic's international applicability. In other words, the

selected criteria mostly offer individual case studies that consider only one country, without comparing it with other countries. Moreover, even the UIC –a leading international railway organisation – overlooked some of the 26 identified sustainability factors in their publication. These findings reveal the variation in sustainability reporting practices of different reporters and highlight the potential for the selected 26 HSR sustainability factors to formulate a balanced and holistic reporting framework which allows international comparisons.

The SDGs encourage the use of affordable and clean energy plus taking urgent actions to confront climate change and its effects (United-Nations, 2019). HSR respond to this vision as the system depends heavily on electricity which can be generated from renewable sources like hydro, wind, solar, and tidal power. Also, HSR can produce emissions that are almost 80 per cent lower than those of cars, short- and medium-haul flights. Moreover, the SDGs promote inclusive and sustainable economic growth and employment opportunities (United-Nations, 2019). HSR are capable of reviving regional economies by creating additional employment opportunities, hiring locals, and increasing accessibility to the job market. It is worth mentioning that Figure 3-5 only illustrates an indication of the relationship between the selected 26 sustainability factors and the SDGs rather than offering a full presentation. In other words, the 26 factors might – directly and indirectly – relate to more goals than Figure 3-5 shows.

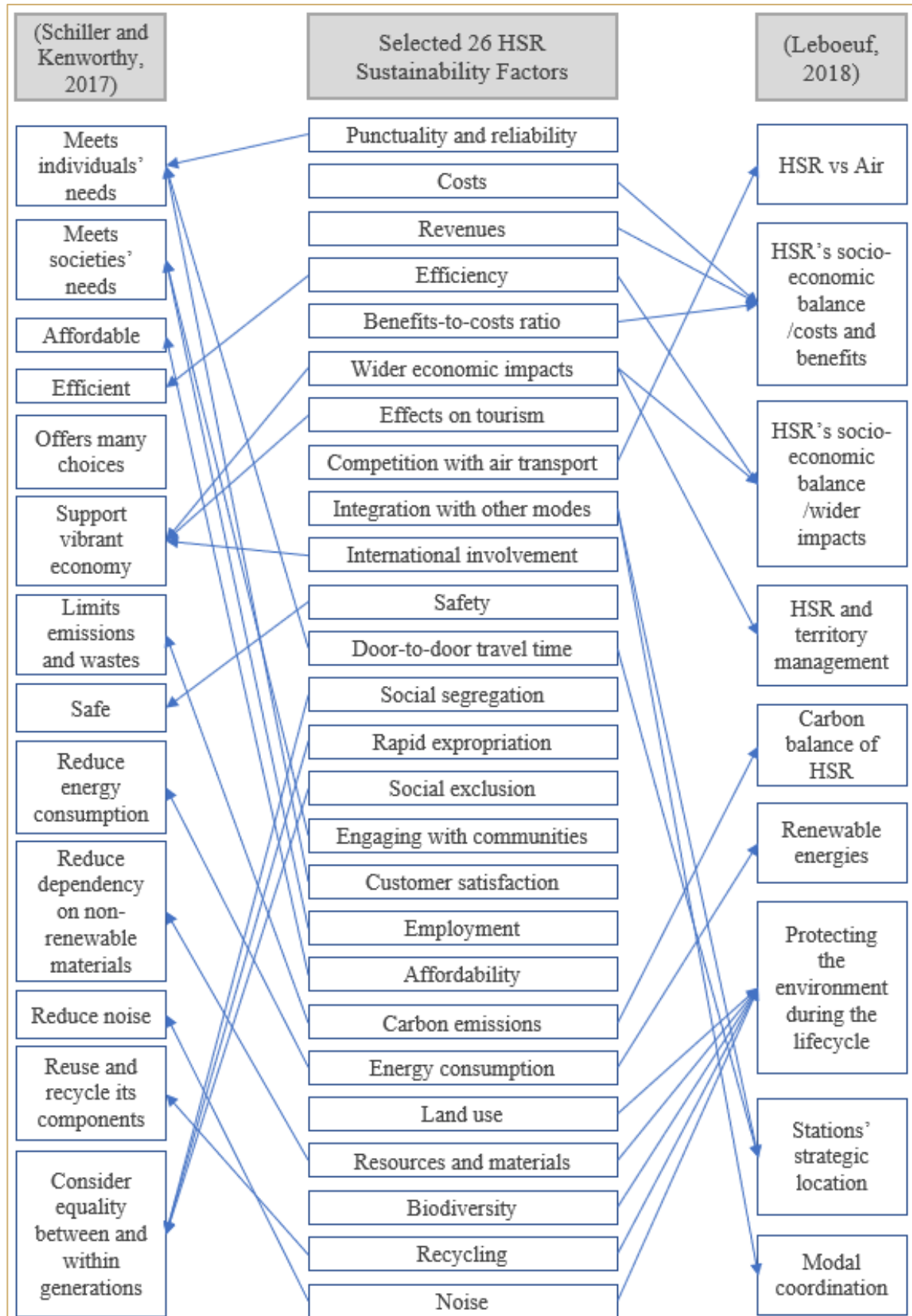


Figure 3-3: Matching the selected 26 factors with sustainability publications (1 + 2)

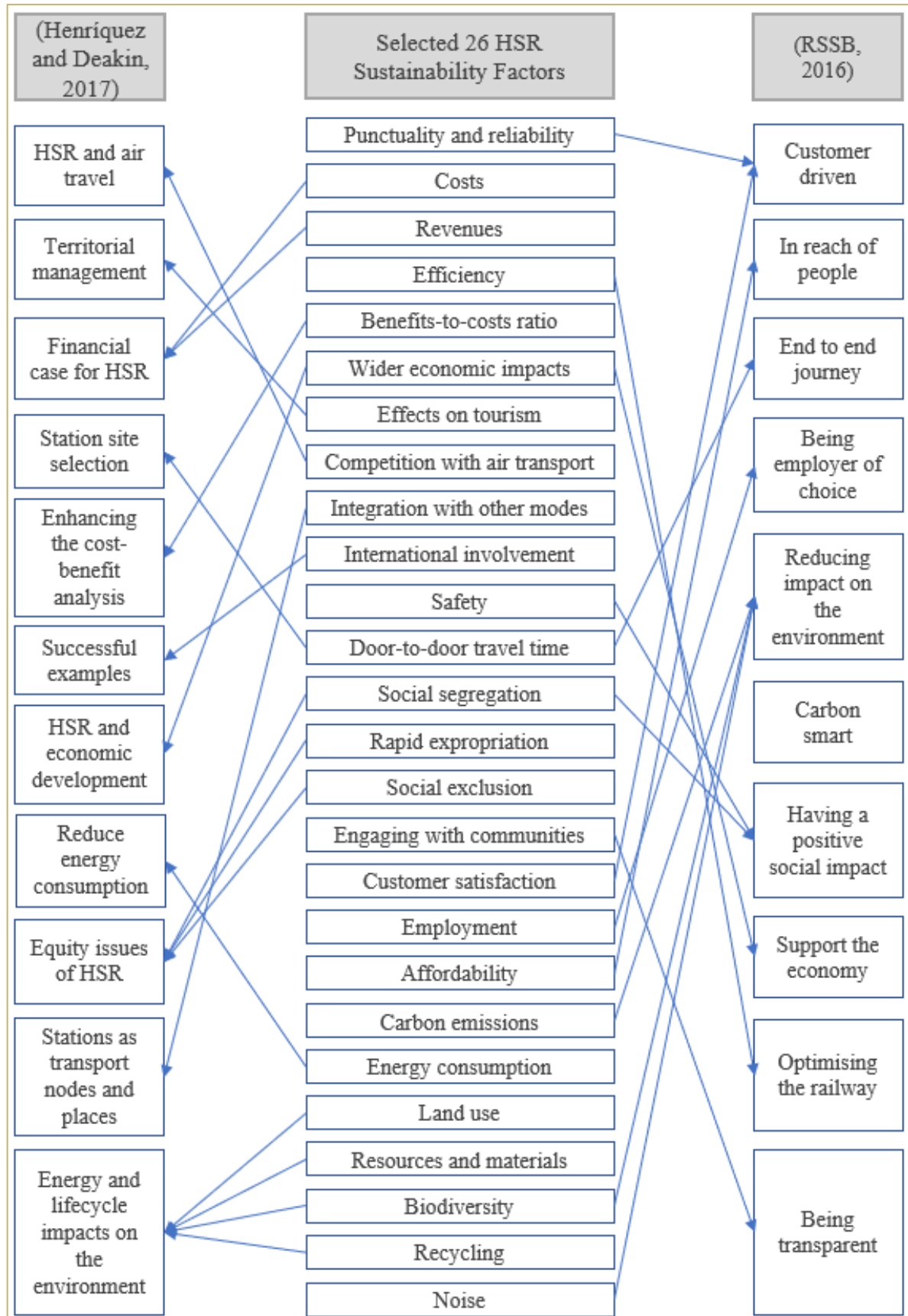


Figure 3-4: Matching the selected 26 factors with sustainability publications (3 + 4)

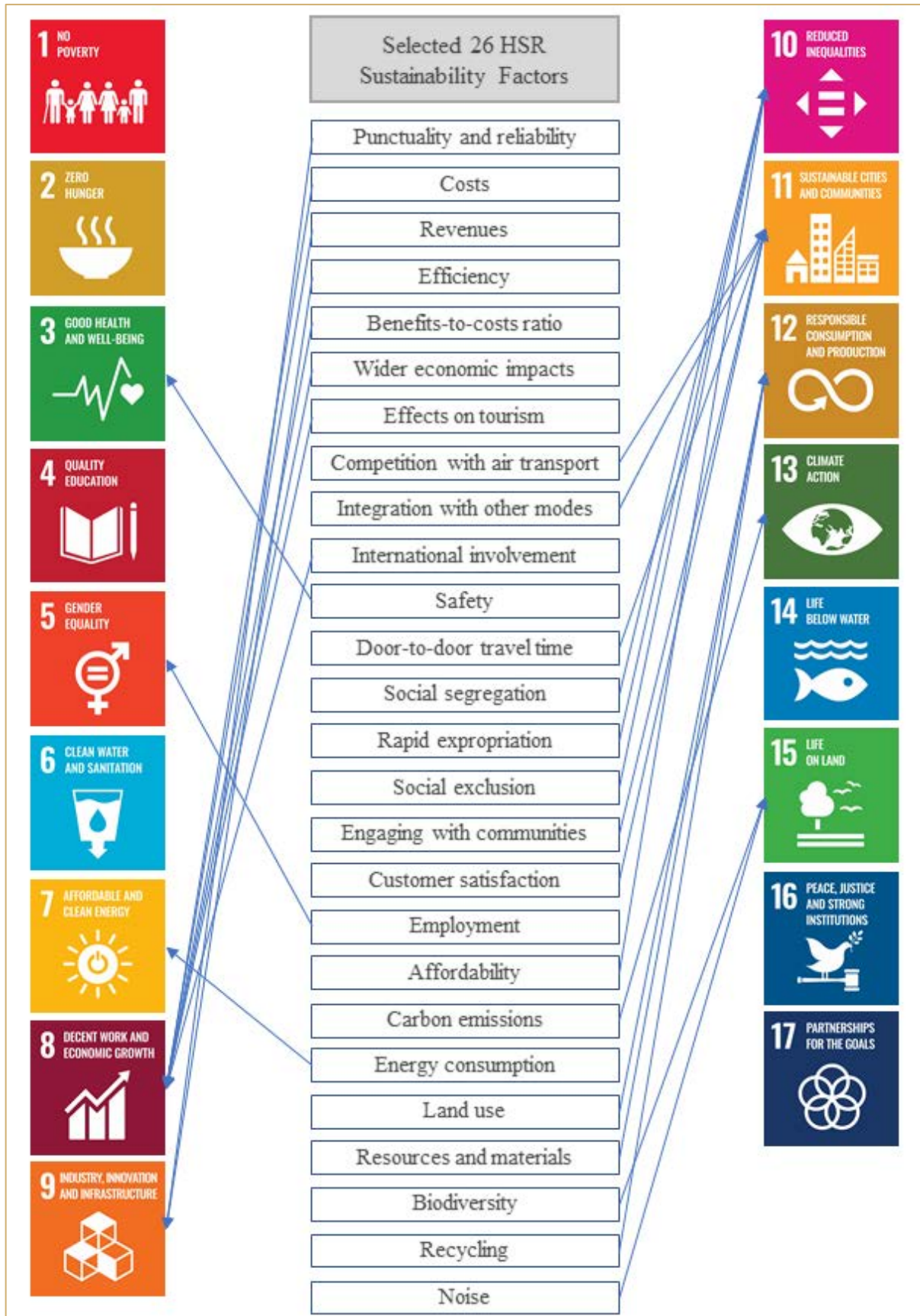


Figure 3-5: Matching the selected 26 factors with the sustainable development goals

3.1.2 Legitimising the selected HSR sustainability factors

In February 2019, the author undertook a one-week research trip to the UIC in Paris. The UIC is a respected worldwide association of railway operating companies that develops international standards and promotes collaboration across the railway industry. Its aims to; promote rail transport globally with the objective of meeting current and future mobility and sustainability challenges; facilitate forms of international collaboration among members from the railway industry; facilitate the sharing of best practices; and, propose new methods to enhance the economic, social, and environmental performance of rail.

The trip had the following purposes:

- Discussing the topic of the project, its importance, and potential improvements, see Appendix G and Appendix H;
- Legitimising the selection of the 26 HSR sustainability factors;
- Looking at possible parameters that can be used for expressing sustainability factors;
- Examining availability and collecting some data associated with the selected factors and related parameters;
- Gaining in-depth insights into methods for calculating indicators related to some factors such as emissions, energy consumption, noise, and DTD travel time;
- Discussing pathways to impact and the potential to adopt the framework by the UIC and railway companies.

Several face-to-face meetings were conducted with relevant experts from the HSR and sustainability departments including:

- **Carole Escolan Zeno:** at the time, the head of the Sustainable Development Unit at the UIC and a previous CSR project manager at SNCF. Carole and her unit focus on

sustainability of railways and look at topics such as emissions and fighting climate change, noise and vibration, soil management, circular economy, DTD solutions, and sustainable finance. She has participated as a keynote speaker in international conferences and represented the UIC at international level.

- **Marc Guigon:** the director of the Passenger Department at UIC and a previous adviser to the French Prime Minister in the field of transport policies, regional and spatial planning, and roads. Currently, Marc is responsible for 5 global sectors withing the UIC; intercity and HSR; passenger services; stations; commuter and regional trains; and tourism opportunities.
- **Paolo De Cicco:** Senior adviser at the UIC to coordinate all their HSR activities and senior project manager of asset management at Rete Ferroviaria Italiana. He is an expert in; European system of control, traffic management, telecommunication and signalling, safety management systems, and international cooperation.

Other meetings were conducted with experts in fields of emissions, energy, noise, door-to-door (DTD) solutions, materials, and land use. After being briefed on the study, the progress on the sustainability framework and its factors, the three named experts were asked to evaluate the importance of the 26 selected factors. They were asked to assign a score out of 10 for each factor depending on its importance and relevance to the sustainability of HSR and to the need to disclose information on it, using the following scoring criteria:

- Score 0: the factor is not related to the sustainability of HSR, and there is no need to report on it;
- Score 1–4: the factor is somewhat relevant; however, there is no need to disclose information about it;
- Score 5–7: the factor is relevant, and it is beneficial to report on it;

- Score 8–10: the factor is very relevant to the sustainability of HSR, and there is a vital need to report on it.

Table 3-2 presents the scores for each factor as assigned by the UIC's experts. Notably, it revealed the variation in experts' opinions. Some factors such as punctuality, safety, and emissions were judged to be very important to all experts. However, other factors were more controversial. For instance, biodiversity gained scores of 10 and 9 and one of 4. In other words, two experts consider biodiversity very relevant and important while the third expert did not necessarily agree. Other factors with differences included noise. Still, each of the 26 factors was important from the perspective of at least two experts.

Variations in scores might be related to the variation in experts' backgrounds. Experts with economic background favoured economic factors and assigned them high scores, while those who are more interested in the environmental sustainability assigned high scores to environmental factors. After averaging scores of each factor, all 26 factors fell in the third and fourth categories, confirming the author's evaluation of their importance to the sustainability of HSR. Specifically, the experts considered 14 factors to be very relevant with a vital need to report on them, while the other 12 factors were all considered beneficial to disclose information about them. The consultation helped the author to decide that for this research none of the selected 26 factors should be excluded from the framework.

Considering the significant variation in experts' opinions regarding some factors, averaging scores might not be the most appropriate method, nevertheless, it indicates a relative importance and relevance of each factor. More robust results could be obtained by considering opinions and scores of additional experts from diverse backgrounds and other railway organisations in the railway industry.

Table 3-2: Results of the consultation with experts of the UIC

Sustainability pillar	Sustainability factor	Expert 1	Expert 2	Expert 3	Average Score
Economic pillar	Punctuality and reliability	10	10	8	9.33
	Costs	6	5	7	6
	Revenues	6	5	10	7
	Efficiency	7	5	8	6.67
	Benefits-to-costs ratio	6	10	6	7.33
	Wider economic impacts	7	5	5	5.67
	Effects on tourism	6	10	8	8
	Competition with air transport	8	5	8	7
	Integration with other modes	8	10	8	8.67
	International involvement	8	8	8	8
Social pillar	Safety	10	10	8	9.33
	Door-to-door travel time	9	10	8	9
	Social segregation	8	5	6	6.33
	Rapid expropriation	8	10	5	7.67
	Social exclusion	8	10	6	8
	Engaging with local communities	6	10	8	8
	Customer satisfaction	6	10	8	8
	Employment	6	10	5	7
	Affordability and operators' initiatives	7	5	6	6
Environmental pillar	Carbon emissions	10	10	8	9.33
	Energy consumption and sources	10	10	8	9.33
	Land use	7	10	5	7.33
	Resources and materials	9	10	5	8
	Biodiversity	9	10	4	7.67
	Recycling	8	10	3	7
	Noise	7	10	3	6.67

Source: author's elaboration on scores assigned by UIC's experts

So far, the author has identified and selected 26 factors, and these formulate the proposed HSR sustainability reporting framework, which answers the first research question and constitutes the first finding of this study.

3.2 Searching for sustainability factors in operators' reports

After selecting the 26 HSR sustainability factors, the author searched for these factors in operators' publications, following the steps explained in subsections 3.2.1, 3.2.2, and 3.2.3 below. The findings of the search process are presented and discussed in Chapter 4.

3.2.1 Specifying criteria for selecting operators

The study looked at the publications of eight major HSR operators, namely, SNCF from France, Renfe from Spain, FS Italiane from Italy, DB from Germany, JR Central, JR East, and JR West from Japan, and Guangshen Railway from China. Several reasons were behind selecting these specific operators. First, they offer a rational mix combining companies from both Asia and Europe. Second, they are collectively responsible for operating and managing more than half the HSR activity around the world (Leboeuf, 2018). Third, all selected operators have extensive experience in operating HSR and other transport services. Fourth, they engage in different collaboration and exchange activities with the UIC and other railway organisations (UIC, 2019b). Finally, these operators produce a variety of sustainability publications.

Additional companies for two HSR systems at the construction stage were also considered, namely, HS2 in the UK and California High-Speed Rail in the USA. Since these companies represent two HSR systems in the construction stage, their publications might offer interesting lifecycle sustainability information, and hence they were included in the study.

3.2.2 Specifying criteria for selecting reports

The criteria for selecting companies' sustainability publications are based on five aspects, namely, the publisher, type, language, date, and availability of publications. Table 3-3 clarifies the criteria for selecting reports.

Table 3-3: Criteria for selecting company reports

Aspect	Criterion
Publisher	HSR operators who disclose information about their sustainability performance regularly and as identified in subsection 3.2.1
Type	Publications that include information about sustainability performance, such as annual, integrated, and sustainability reports
Language	Reports published in the English language. However, in the Chinese operator case, a report in its Chinese version was translated using Google Translate, since no reports were available in English
Publishing date	Recent publications published between 2015 and 2018
Availability	Reports which are available to the public via company websites

Source: Developed by the author

The selected HSR companies publish a wide range of reports in different languages, some of which are published regularly – on annual or quarterly basis – while others are related to specific dates and events. However, taking into consideration the criteria presented in Table 3-3, a total of 15 reports were considered. These include annual, integrated, sustainability, CSR, and responsible business reports.

The availability of a variety of reports is related to the fact that some operators do not disclose sustainability information in explicit and independent CSR publications. Instead, they enclose information about their social and environmental performance in their financial reports (Wolniak and Hąbek, 2016). Other operators such as FS Italiane, SNCF, and JR East offer separate documents for reporting on sustainability performance and provide several publications via their websites. So, at least two documents for each of these operators were included in the study. This finding itself reveals the variation in information disclosure practices

among HSR companies, which constitutes a remarkable obstacle that faces stakeholders who want to benchmark HSR sustainability for any reason.

It is worth mentioning that the author has thought to include reports from some major Chinese HSR operators such as CRBBG and CRSBG; however, there were no publicly available sustainability publications for these companies.

3.2.3 Designing scoring criteria for reviewing company reports

Having identified the 26 sustainability factors and selected sustainability reports, the study used a four-point scoring criteria to document the richness of information related to each sustainability factor in selected HSR company reports. The scoring criteria were originally offered by Daub (2007) and they were used in this study as the following:

- 0 points = there is no meaningful information related to the specific factor;
- 1 point = the factor is inadequately covered, with patchy information and lack of clarification, alongside limited use of charts and graphs;
- 2 points = good provision of information related to the factor, with good use of charts and graphs. However, not all aspects of the factors are addressed in the disclosure;
- 3 points = the reporting practice offers a comprehensive combination of quantitative data and qualitative explanation for the factor. Proper use of graphs, maps, and visuals plus presenting performance data for different years.

As explained earlier, for some companies like SNCF, JR East, and FS Italiane, at least two documents were included. In these cases, only the maximum score for each factor from a company's publications was considered. For, instance, two JR East publications were selected,

in which the scores for specific factors varied between 1 and 3 points. In this case, 3 points were allocated for JR East for each of these factors, while lower scores were ignored, see Figure 3-6.

	JR Central Annual report	JR East Annual report	JR East Sustainability report	JR East Final
Costs	2 ✓	3 ✓	1 ✗	3
Effects on tourism	2 ✓	2	2	2
Carbon emissions	3 ✓	1 ✗	3 ✓	3

Figure 3-6: Explanation of the scoring criteria

Applying the previously discussed scoring criteria to companies and sustainability factors meant that:

- The maximum score a sustainability factor can get across all companies is 3 (points)
× 10 (companies) = 30 points;
- The maximum score a company can get across all sustainability factors is 3 (points)
× 26 (factors) = 78 points.

3.2.4 Searching for sustainability factors in company reports

Having designed the scoring criteria, the author examined the selected company reports in search of evidence for the HSR sustainability factors in Chapter 4. The search process used visual observation and looked for quantitative and qualitative information related to the 26 sustainability factors, including but not limited to the parameters listed earlier in

Table 2-2,

Table 2-4, and Table 2-5. All parts of each report have been thoroughly checked at least twice, including the table of contents, highlight pages, main text, summaries, and appendices. The findings of the search process are presented and discussed in Chapter 4.

3.3 Proposing indicators for the 26-factor framework

The aim of Chapter 5, Chapter 6, and Chapter 7 is to propose parameters that express the selected economic, social, and environmental factors respectively plus testing the usability of some indicators through benchmarking exercises.

3.3.1 Selecting indicators

This study proposes a combination of quantitative and qualitative indicators for reporting on the selected 26 sustainability factors. The indicator selection process looked at three main sources: parameters used within operators' sustainability publications; indicators offered by the international reporting guidelines of the UIC, GRI and World Bank; and external studies and research projects, see Figure 3-7. The author tried where possible to select parameters which are used by more than one source. In some cases where there is no specific indicator for expressing a sustainability factor, the author suggested a new indicator for reporting on the factor.

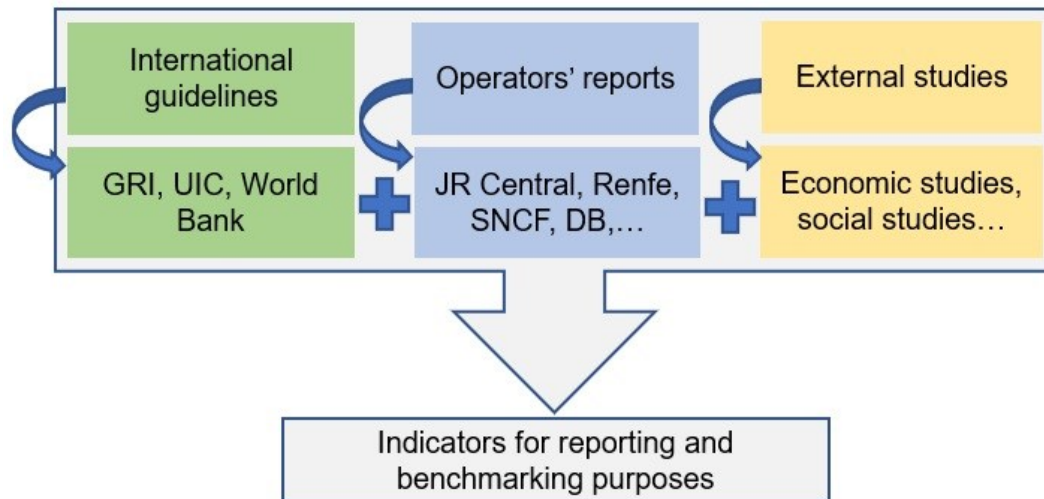


Figure 3-7: Sources of proposed indicators

All proposed indicators have the following purposes:

1. Enhancing the reporting practices of HSR companies, international railway agencies, scholars, and evaluation studies;
2. Guaranteeing a minimum level of reporting standardisation in future publications;
3. Some indicators could be used for conducting benchmarking exercises. These exercises could compare both corridors and operators.

3.3.2 Selecting corridors and operators for benchmarking exercises

As explained in subsection 3.3.1, some proposed indicators could be used for conducting benchmarking exercises. For this purpose, the study identified four HSR corridors and five HSR operators – that are responsible for operating the four corridors – to be benchmarked using the proposed parameters. These four corridors are the Tokyo–Osaka, Paris–Lyon, Madrid–Seville, and Beijing–Shanghai HSR corridors, and corridor operators are JR Central, SNCF, Renfe, CRBBG, and CRSBG respectively. All corridors and operators have been previously discussed in sections 2.7 and 2.8.

There are several reasons behind the selection of these specific four corridors for facilitating the benchmarking exercises in this study. First, they constitute some of the most successful HSR corridors around the world. Second, these corridors are considered as prototypes for disseminating lessons and from which other lines learn. Third, all selected corridors connect major economic zones in their countries (Adif, 2019a; JR-Central, 2019c; NUNO, 2018; SNCF, 2019c). Fourth, the selected corridors are relatively similar to each other in terms of length, taking into consideration that the Beijing–Shanghai corridor is managed by more than one operator, each of which is responsible for around 600 km. Finally, several studies and journal papers have tackled these four corridors, which offer access to some necessary data. In some benchmarking exercises, additional operators were considered, for highlighting a specific point or due to the lack of data related to the four operators originally selected. Besides benchmarking against other corridors, HSRs will be also benchmarked against other forms of mobility like cars and flights.

3.3.3 Testing the availability of data for selected indicators

Conducting benchmarking exercises in this study had two main purposes: to test the applicability of the proposed indicators by revealing whether data of quality were available for expressing them; and to gain insights into the sustainability performance of HSR companies.

A wide range of data sources were considered for facilitating the benchmarking exercises and for examining the availability of data for proposed indicators. These sources include:

- Operators' annual, sustainability, CSR, integrated, and financial reports plus fact sheets, highlights, brochures, and other publications;
- Operators' commercial websites;

- Operators' online open databases such as the SNCF Open Data website;
- Annual railway yearbooks of China Railways and Renfe;
- UIC online statistics database (RAILISA);
- UIC publications and reports;
- Eurostat website;
- Travel planning platforms, Google Maps, and commercial websites;
- Consultation with UIC experts;
- Database and publications of the IEA;
- Journal articles, peer-reviewed papers, and research centres studies;
- EU Commission studies, reports, and regulations;
- Organisation for Economic Co-operation and Development (OECD) publications;
- World Bank database and publications;
- Online articles, news, and other materials.

It is worth mentioning that the above-listed sources were available in English, Japanese, Chinese, French, Spanish, and other languages, and hence Google Translate was used extensively to extract the necessary data. Most benchmarking exercises focused on data that relate to 2016 and 2017; however, other reporting years were also considered in some cases. Also, in March 2018, the author conducted a 3-month research visit to Shanghai Jiao Tong University in China. The trip was useful for collecting some performance data related to the sustainability performance of CRBBG and CRSBG.

3.3.4 Testing the robustness and effectiveness of selected indicators

In their study, the Office of Road and Rail (ORR) proposed some benchmarking indicators that can enable comparisons of performance both between lines and overtime within

a specific line. Also, the study identified a number of objectives that should be met by the selected indicators (ORR, 2017):

1. **Comparability**: the parameter should allow meaningful and useful performance comparisons between companies and corridors, considering that they differ remarkably in terms of several aspects. For instance, corridors differ in terms of geography, ridership, scale, and technical features. Also, companies differ in terms of the size, scope, and types of transport and non-transport services managed. While it is not possible to control for all different aspects in the specification of a single indicator, normalisation is necessary to ensure that corridors and companies can rationally be held accountable for the levels of performance revealed;
2. **Ease of calculation**: the calculation of each indicator should be – where possible – clear and straightforward, as this reduces costs associated with collecting data and calculations and encourages companies to report on the chosen parameter;
3. **Consistency**: there should be interaction between different indicators within the framework, where changes in a certain indicator can lead to changes in others;
4. **Credibility**: the selected parameter should be capable of being understood by different stakeholders including railway companies, policymakers, passengers, and railway organisations.

After proposing indicators for the framework and testing them with benchmarking data, the author tested and discussed the effectiveness and robustness of proposed indicators by matching them against the 4-point criteria suggested by the ORR. The matching process is presented in Chapter 8.

3.4 Case study: the relationship between HSR and social exclusion in China

Chapter 9 examines the reasons that exclude specific groups from using the HSR service in China. For this purpose, an online travel survey was used, comprising a set of stated and revealed preference questions. Further detailed methodological explanation is provided in Chapter 9.

CHAPTER 4

EXAMINING THE AVAILABILITY OF SUSTAINABILITY FACTORS IN OPERATORS’ REPORTS

The 26-factor HSR sustainability framework has been identified in the previous chapters. This chapter responds to the second research question and examines the availability and extent to which the 26 factors are covered in HSR companies’ sustainability publications. After applying the scoring criteria explained in sections 3.2.3 and 3.2.4 to the publications identified in section 3.2.2, this chapter presents numerical results and reveals variations in reporting practices at the levels of sustainability pillars, sustainability factors, companies, and types of indicator. The current reporting situation, some currently used indicators, potential and required improvements, and reasons behind variations in reporting are all discussed at each of these levels, see Figure 4-1.

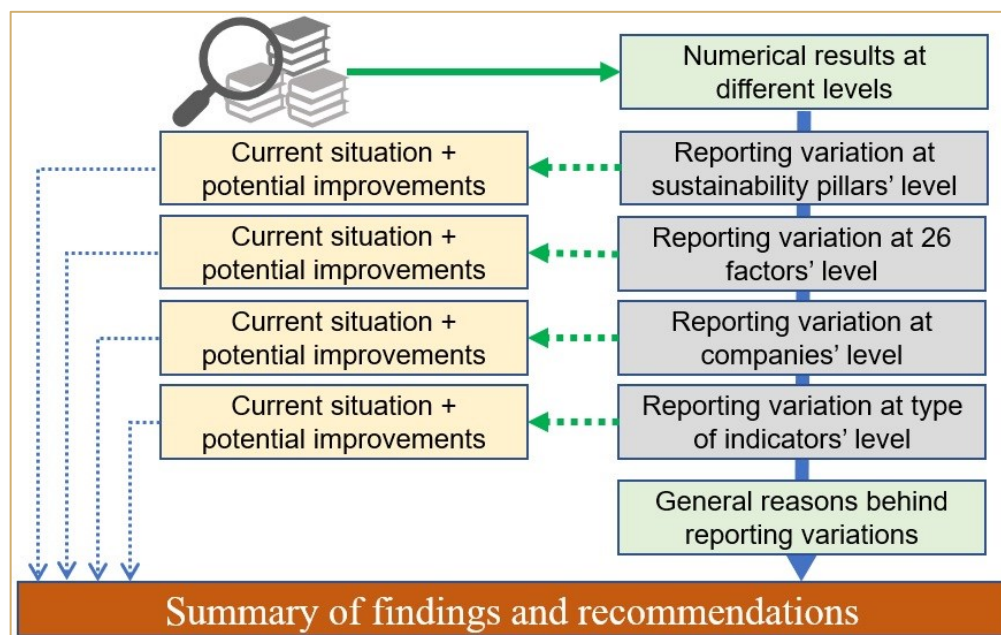


Figure 4-1: Structure of Chapter 4

4.1 Results

This section presents the results of searching for the selected 26 HSR sustainability factors in companies' publications. Detailed results are available in Appendix A and Appendix B.

4.1.1 Sustainability factor results

Appendix A evaluates the presence of the 26 selected sustainability factors in companies' publications, using the scoring criteria explained in section 3.2.3. Reporting on the economic pillar factors as presented in Figure 4-2 shows that costs and revenues achieved the highest scores with 23 points each, followed by punctuality and efficiency factors with scores of 21 and 19 points respectively, all out of a maximum score of 30 points. Factors such as integration of HSR with other modes, wider impacts, and effects on tourism gained less than half of the maximum score, with 14, 13, and 12 points respectively. The BCR obtained the lowest score among all economic factors, with a score of only 1 point.

Within the social pillar, Figure 4-3 illustrates that reporting on employment got the highest score followed by reporting on safety, with 28 and 27 points respectively. In contrast, reporting on rapid expropriation got the lowest score with only 3 points. Each of DTD travel time, social exclusion, social segregation, and affordability factors gained less than 10 points out of the maximum score of 30 points. Within the environmental pillar, Figure 4-4 shows that reporting on the carbon emissions got the maximum score of 30 points. Energy consumption, materials, and recycling showed good reporting performance with 24 points each. Biodiversity and noise achieved a mediocre performance with 16 and 14 points respectively. Finally, the land use factor got the lowest reporting score with only 6 points.

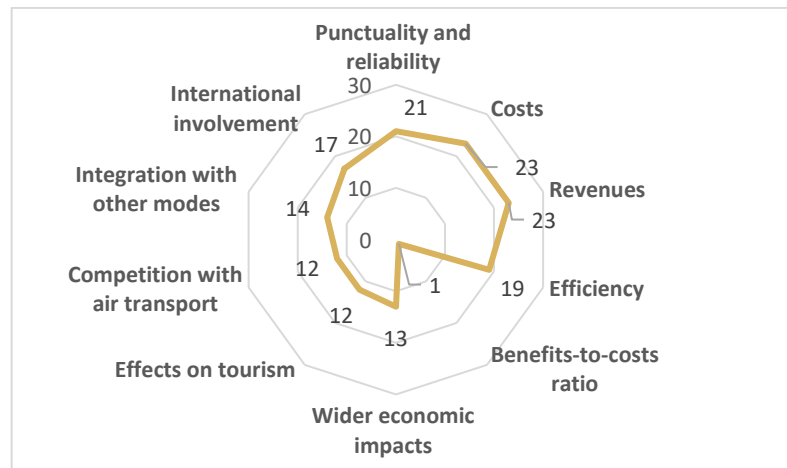


Figure 4-2: Economic factor scores

Source: Azzouz and Jack (2020)

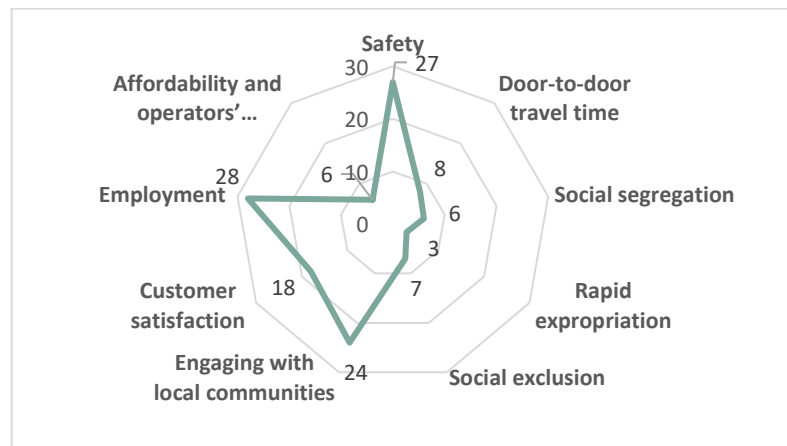


Figure 4-3: Social factor scores

Source: Azzouz and Jack (2020)

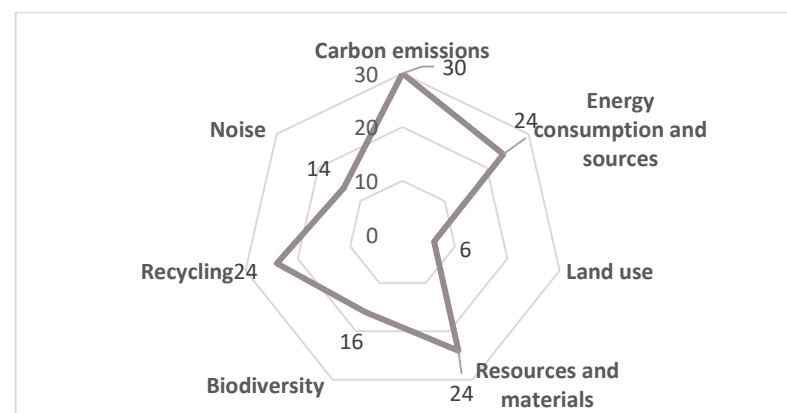


Figure 4-4: Environmental factor scores

Source: Azzouz and Jack (2020)

Considering all sustainability factors together, Figure 4-5 illustrates that 10 out of 26 selected factors obtained scores below the average score of 14 points. Carbon emissions achieved the highest score of 30 points, followed by employment and safety with 28 points and 27 points respectively. The BCR got the final rank, with a score of 1 point only, followed by rapid expropriation with a score of only 3 points. Most social factors obtained scores below the average score of 14 points.

Another finding is that the scores for the economic factors were relatively close to each other, especially when compared with the scores for social factors, which showed a remarkable variation. Similar variation is revealed among scores of the environmental factors.

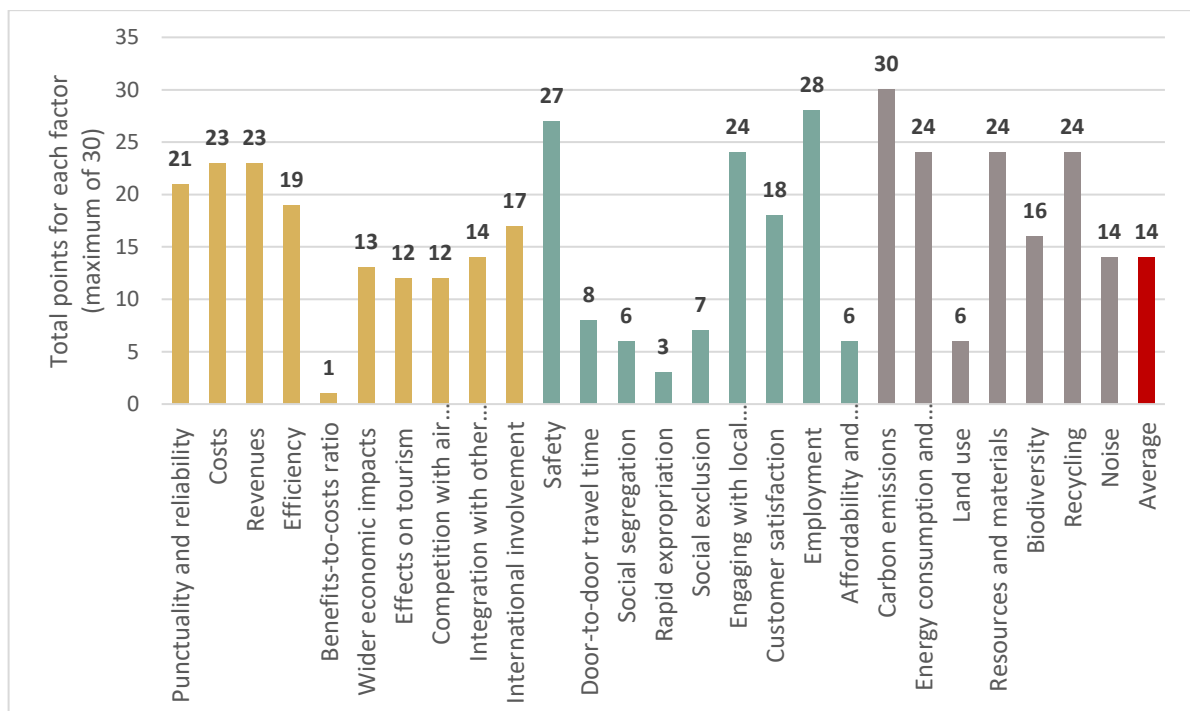


Figure 4-5: Sustainability factor scores comparison

Source: Azzouz and Jack (2020)

Figure 4-6 reveals that the environmental factors had the strongest representation in companies' reports, obtaining almost 66 per cent of the maximum possible environmental score. Reporting on the economic factors achieved almost 52 per cent of the maximum

economic score, while social factors showed the weakest representation, with a score of 47 per cent out of the maximum social score.

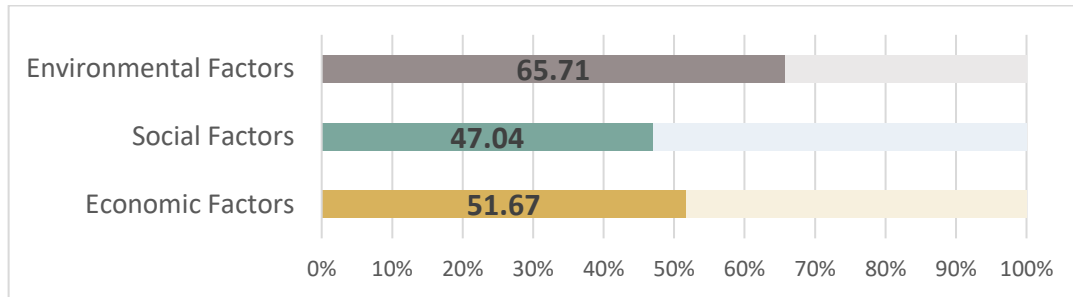


Figure 4-6: Cumulative scores for sustainability factors relative to the maximum score

Source: Azzouz and Jack (2020)

4.1.2 Companies' reporting quality result

Figure 4-7 illustrates the variation in companies' reporting scores. Around 60 % of HSR companies had scores close to or above the average score of 53.85 per cent. European HSR operators acquired the top three ranks: SNCF got the highest score of 70.51 per cent, followed by FS Italiane and Renfe with 66.67 per cent and 65.38 per cent respectively. The lowest reporting score was obtained for Guangshen Railways, reporting on only almost 35 % of HSR sustainability factors. Also, Figure 4-7 shows that some companies had almost identical scores for reporting on the three sustainability pillars. For instance, FS Italiane scored 57 per cent, 59 per cent, and 59 per cent for the economic, social, and environmental pillars respectively. In contrast, other companies showed remarkable variation in scores for reporting on the three pillars. For example, SNCF's social reporting score was 78 per cent, compared to 59.5 per cent and 50 per cent for the environmental and economic reporting respectively. HS2 and California High-Speed Rail (CHSR) revealed identical performance when reporting on the environmental factors, obtaining the same score of 55.56 per cent.

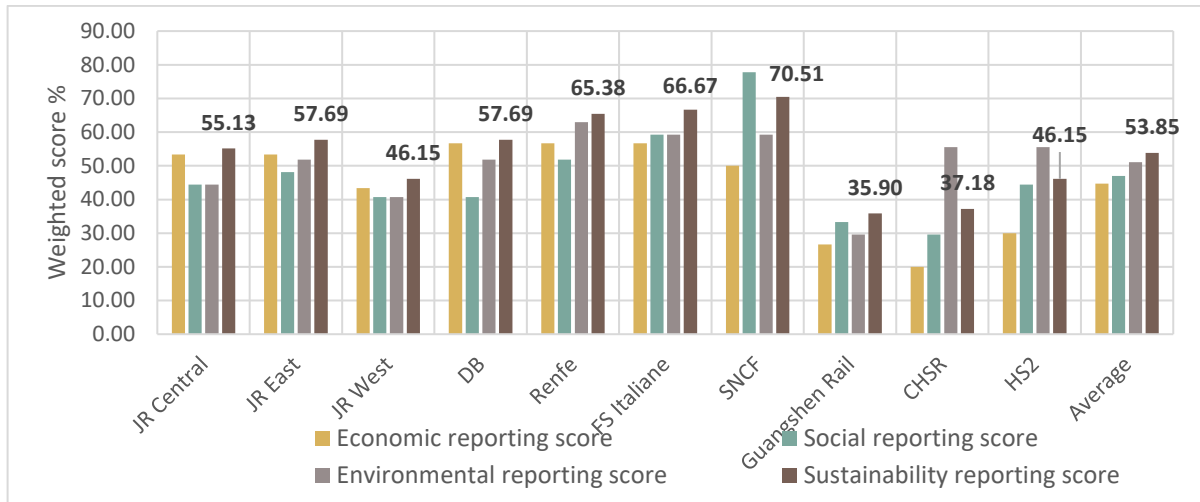


Figure 4-7: Companies' sustainability reporting scores

Source: Azzouz and Jack (2020)

4.1.3 Indicator results

Appendix B compares the 15 selected sustainability publications, showing that all HSR companies used both quantitative and qualitative indicators for disclosing information relating to the 26 HSR sustainability factors. Figure 4-8 shows that there is a balance in the use of quantitative and qualitative metrics, with a slight bias towards using qualitative parameters.

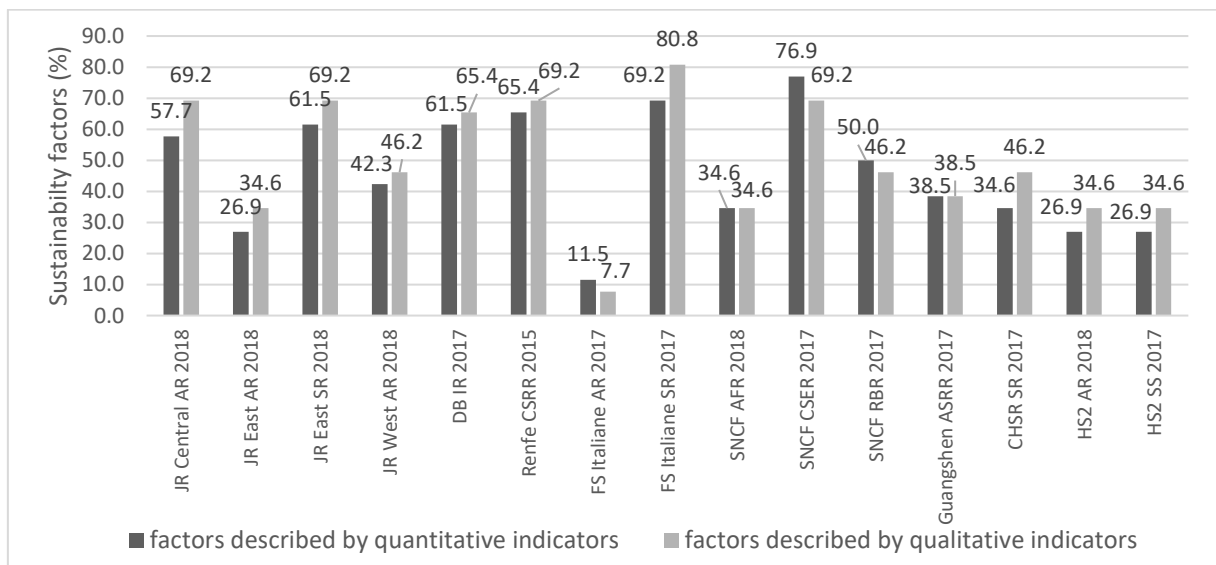


Figure 4-8: Representation of factors in companies' reports by the type of indicator

Source: Azzouz and Jack (2020)

Figure 4-9 demonstrates that most of the sustainability factors including employment, revenues, costs, safety, and customer satisfaction showed a balance in the use of qualitative and quantitative indicators in companies' documents. However, the integration of HSR with other transport modes, land use, and DTD travel time factors were mostly described by qualitative indicators. In contrast, quantitative parameters were mostly used for disclosing information about the factors of punctuality, materials, and resources.

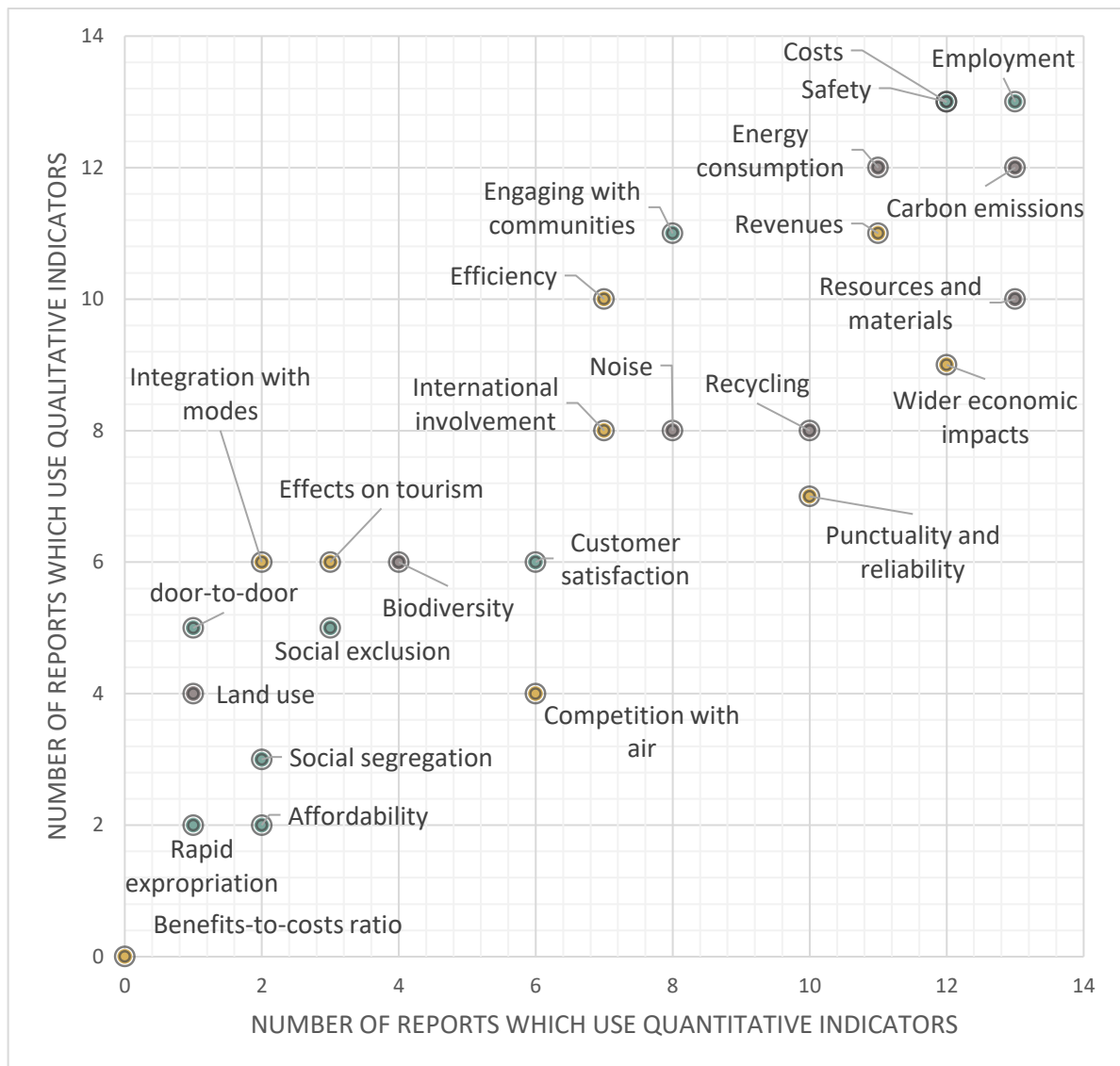


Figure 4-9: Use of quantitative and qualitative indicators for expressing the 26 HSR sustainability factors in all companies' reports

Source: Azzouz and Jack (2020)

4.2 Discussing current reporting practices and areas of improvements

This study has revealed reporting variations in firms reporting practices, and these variations are presented at the levels of sustainability pillars, 26 factors, firms, and indicators.

4.2.1 Reporting variation at the three sustainability pillars level

The first level of reporting variation is revealed among the three pillars of sustainability; these variations are presented in Table 4-1 alongside a reflection on improvements.

Table 4-1: Reporting variation at the three sustainability pillars level

	Current reporting situation	Areas of potential improvement
Economic pillar	Achieved mixed reporting performance, with around 52 per cent of economic factors being covered in reporting practices	Around 48 per cent of factors are not covered, and reporting could pay more attention to topics like competition with air travel, effects on tourism, wider impacts, and benefits-to-costs ratio
Social pillar	Obtained mixed reporting performance, with only 47 per cent of social factors being covered in current reporting practices	Social reporting could be enhanced by considering topics like social exclusion, social segregation, and affordability in companies' publications. Also, the UIC and GRI should pay more attention to social topics in both publications and reporting guidelines
Environmental pillar	Gained the highest performance, with almost 66 per cent of factors being covered in publications	Around 34 per cent of factors are not covered, and companies could improve reporting by disclosing more information about factors such as land use, biodiversity, and noise

The advanced environmental reporting performance – when compared with economic and social reporting – could be related to the fact that a wide range of studies, publications and reporting guidelines have tackled environmental factors like emissions, energy consumption, and recycling. At the same time, reporting can be influenced to a great extent by the regulatory requirements. The legal and regulatory reporting requirements enforced by governments and organisations at national and international levels have gradually stimulated environmental reporting and pushed towards the adoption of reporting guidelines (Andreas et al., 2012; G&AI, 2014). These cumulative and multiple efforts have resulted in the availability of many reporting frameworks, guidelines, and assessment methods that offer a variety of environmental parameters for tracking, measuring, and reporting on the topics of emissions and energy consumption. In contrast, the findings of this study highlight that the reporting practices of HSR companies have paid less attention to social topics and issues, which might be related to the fact these topics are inadequately covered in current sustainability reporting guidelines. In other words, there is a need to develop appropriate reporting mechanisms to boost the performance of social reporting. Also, international organisations such as the UIC and GRI should promote and push towards the adoption of newly developed social reporting mechanisms.

Despite the variation between the three pillars, the environmental reporting score of 66 per cent showed that even the highest-scoring pillar has failed to cover 34 per cent of environmental factors. Similarly, scores of 52 per cent and 47 per cent for the economic and social pillars show that HSR companies have not covered 48 per cent and 53 per cent of economic and social factors respectively. These figures show that there is a great potential for improving reporting practices across all sustainability pillars.

4.2.2 Reporting variation at the 26 sustainability factors level

The second level of reporting variation is among the selected 26 HSR sustainability factors.

Table 4-2, Table 4-3, and Source: Azzouz and Jack (2020)

Table 4-4 reflect on the current reporting situation and present some currently used indicators and areas of potential and required improvements.

Table 4-2: Findings and potential reporting improvements for factors with good reporting performance

		Current reporting situation	Areas of potential improvement
Factors with good reporting performance	Economic	Factors: costs, revenues, punctuality, efficiency. - A wide range of parameters were used such as total revenue, total operating revenue, total and operating costs, total assets, profits, long-term debts, equity, percentage of trains arriving within 5/15 minutes of the departure/arrival time, average delay per train in minutes, plus parameters that relate to the energy efficiency of locomotives.	- When reporting on costs and revenues, operators could distinguish between HSR and other transport and non-transport services managed by the company. In other words, operators could reflect on costs and revenues associated with operating HSR services. Also, operators could reflect on the net operating profits. - Operators could provide essential figures that relate to HSR activities expressed by passenger.km and train.km, as these allow the calculation of different efficiency indicators.
	Social	- Factors: safety, employment, engaging with local communities. - In terms of safety, reporting practices focus on numbers of train accidents by type, including derailments, collisions, on-board and track fires, and level crossing accidents. Also, numbers of staff accidents are often provided. - Extensive reporting on numbers of current and new staff by age, contract type, and gender, plus reflection on some benefits provided and numbers of training hours.	- More focus should be paid to numbers of injuries/fatalities caused to passengers/third parties due to railway activities. Also, operators could distinguish between HSR and other services when disclosing safety and employment data. - Operators could disclose information about the number of workdays lost due to site accidents. - Reporting on the 'engaging with local communities' factors should comprise both negative and positive impacts, rather than being limited to the positive effects of operators' initiatives.
	Environmental	- Factors: carbon emissions, energy consumption and sources, materials and recycling. - Most operators report on total amounts of energy consumption (MJ) and carbon emissions (tonnes) associated with their activities. - Some companies reflect on the per seat.km emissions and energy consumption, and reflect on the energy mix used for generating traction electricity. - Operators report on annually consumed quantities of water, sand, iron, ballast, and concrete (tonnes), and report on annual recycling rates and additional revenues generated by reselling used components.	- Distinguishing between HSR and other services in term of emissions and energy consumption. - The per seat.km emissions and energy consumption might not be enough, and should be accompanied by data related to the per passenger.km emissions and energy consumption. This is because the load factor of HSR trains is typically below 100 per cent. - Reflecting on amounts of NO_x, SO_x, particles, and other pollutants. - Reflecting on the source of purchased materials and pointing out whether it is sustainable. - Reporting on efforts to cut the consumption of water, paper, concrete, and other materials. - Disclosing information about amounts of hazardous and non-hazardous waste generated/transported.

Source: Azzouz and Jack (2020)

Table 4-3: Findings and potential reporting improvements for factors with average reporting performance

		Current reporting situation	Areas of potential improvement
Factors with average reporting performance	Economic	- Factors: international involvement, integration with transport modes, wider economic impacts. - Some operators disclose qualitative information about their involvement in international projects, reflecting on the type and the level of the involvement, the location of the project, its current status, and related milestones. - Some operators report on the provision of integrated ticketing and utilising mobile phones for providing journeys that combine HSR and other modes. Also, some companies disclose information about the availability of car parking spaces in and outside HSR stations. - Some operators report on economic opportunities created as a result of railway activities plus the number of jobs created locally and regionally.	- Quantitative reporting on revenues generated from involving in international projects. - Reporting on numbers of bus lines, regional lines, and metro lines available at the HSR stations. - Reporting on the number of available car parking spaces (per thousand passengers), alongside associated hourly/daily costs. These include in-station spaces and parking lots in the vicinity of the stations. Also, operators could distinguish between spaces available for electric cars and normal cars. - Reporting on the number of available bike parking spaces (per thousand passengers) plus available bike rental schemes, carpooling programmes, and other efforts. - Disclosing information about travel options available to passengers from HSR stations to nearest international and local airports, alongside reporting on associated duration and cost. - Reporting on the provision of information that relates to different transportation modes in HSR stations.
	Social	- Factors: customer satisfaction. - Operators often report on the overall passenger satisfaction ratio, distinguishing between HSR and other transport services.	- Reporting practices could reflect the compensation provided to unsatisfied customers. These include full and part refunds and compensation tickets. Also, operators could report on efforts provided as a response to customers' complaints and to enhance the overall experience and satisfaction of customers.
	Environmental	- Factors: noise, biodiversity. - Patchy information is provided regarding operators' efforts to reduce railway noise levels. - Some operators reflect on the length of noise-absorbing walls erected along the railway track (km), while others explain modifications to the body – the nose in particular – of the train. - Patchy information about efforts to protect the biodiversity is provided. Some operators disclose quantitative information about the environmental expenditure plus the number of trees planted to offset negative impacts.	- Quantitative reporting on noise levels associated with train lengths and operating speeds plus reductions in noise levels (dBA) associated with adopted technical solutions. - Reporting on biodiversity should reflect three main scopes: features and specifications of biodiversity zones along HSR tracks; operators' activities and associated impacts in/near biodiversity zones; and operators' efforts and initiatives to minimise negative impacts, either by protecting biodiversity zones or by adopting solutions in other areas to offset the negative footprint.

Source: Azzouz and Jack (2020)

Table 4-4: Findings and potential reporting improvements for factors with weak reporting performance

		Current reporting situation	Areas of potential improvement
Factors with weak reporting performance	Economic	- Factors: competition with air transport, effects on tourism, benefits-to costs ratio. - Few operators compare HSR and air transport in terms of daily and annual ridership along specific corridors. - Few reporting practices reflect the comparison between HSR and air transport in terms of the per passenger.km emissions and energy consumption. - Few operators disclose information about the provision of integrated tickets that allow access to some touristic attractions. The information includes qualitative explanation and quantitative indicators such as the number of tourist passes sold annually. - The benefits-to-costs ratio is rarely covered in reporting practices.	- Disclosing information that compares HSR and air transport in terms of daily and annual ridership, per passenger.km emissions and energy consumption, and per km pricing. This information could be related to specific corridors. - Reporting on changes in local and international tourist demand in towns and cities along HSR corridors. These changes reflect the number of local and international arrivals before and after the deployment of HSR. Also, HSR operators could report on their efforts to boost tourism. - Disclosing information about the benefits-to-costs ratio associated with new HSR projects in which the operator is involved. The benefits-to-costs ratio should consider user and society benefits plus the wider impacts.
	Social	- Factors: door-to-door travel time, social exclusion, social segregation, rapid expropriation, affordability and operators' initiatives. - Regarding social exclusion and social segregation, most reporting practices offer qualitative explanation of operators' efforts to enhance accessibility in stations and trains. Quantitative information includes the total number of stations with improved accessibility measures and number of lifts installed on platforms. - Some HSR companies report on the number of houses that will be demolished along new corridors. - Affordability is rarely tackled in operators' reports. However, few operators report on the number of discounted tickets sold annually as a percentage of total tickets.	- Disclosing information about the transfer quality expressed by the time required to transfer between HSR and other connecting transport modes within HSR stations (minutes). - Presenting results of travel surveys that examine the reasons behind exclusion of specific individuals/groups from using HSR services. - Reporting on rapid expropriation should include the number of different private and community properties that will be demolished plus information about the compensation offered to landowners. - Disclosing information about the per km costs of HSR tickets plus discounts and offers provided to different users including senior citizens, students, and children.
	Environmental	- Factors: land use. - HSR operators rarely disclose information about vegetation management along HSR tracks.	- Providing information about the per track.km costs and amount of herbicides used for vegetation management. These could be accompanied by reflecting on the area of application including tracks and sealed and unsealed surfaces.

Source: Azzouz and Jack (2020)

The discussion presented in Table 4-2, Table 4-3, and Source: Azzouz and Jack (2020)

Table 4-4 shows that HSR operators in their recent publications have reported on some economic, environmental, and social factors without necessarily updating their reporting mechanism to include new topics like those which are currently discussed by scholars and research papers.

Several potential reasons could explain the variation in reporting on the selected 26 sustainability factors. First, there is a possibility that companies avoid reporting on factors for which they have low performance, preferring to disseminate information about factors for which they have good performance (Lei et al., 2015). Second, the availability of performance parameters and frameworks plus international efforts could explain the advanced reporting on specific factors like emissions and energy (Andreas et al., 2012; G&AI, 2014). Third, HSR companies' interests might be different from the interests of international railway and reporting agencies (Bergendorff et al., 2008). Scores for the 26 sustainability factors as presented in Figure 4-5 vary remarkably from the scores assigned by the UIC's experts, see Table 3-2. For instance, the UIC's experts assigned the land use factor a score of 7.33 out of 10, while this factor achieved a score of 6 out of 30 – which is equal to 2 out of 10 – in companies' reports.

There are currently big gaps in the sustainability reporting practices of HSR companies across the selected 26 factors, offering great potential to enhance reporting performance on all sustainability pillars and related factors, especially by paying more attention to factors that are currently under-represented in reports.

4.2.3 Reporting variation at the HSR company level

The third level of reporting variations is revealed among HSR companies. Table 4-5 summarises these variations, reflecting on the current reporting situation and improvements.

Table 4-5: Findings and potential reporting improvements at the HSR company level

	Current reporting situation	Areas of potential improvement
Companies with a good reporting performance	- Companies: SNCF, followed by FS Italiane and Renfe. - SNCF achieved the highest reporting performance, covering a wide range of social issues and topics and a variety of parameters for reporting on factors such as engaging with local communities. - FS Italiane clearly distinguished between HSR and other transport services in their sustainability publications, offering extensive information regarding safety. - Renfe obtained the highest environmental reporting score among all companies, providing comprehensive information about the amount of materials used and the treatment of hazardous waste.	- SNCF could provide more information about the effects on tourism and integration between HSR and other modes, especially those managed by the operator. - FS Italiane should reflect on the affordability of the service plus providing information about discounts offered to different groups in society. Also, quantitative data regarding the competition with air transport is required. - Renfe could distinguish between HSR and other services, plus providing clear information about the net profits when discussing revenues.
Companies with an average reporting performance	- Companies: DB, JR East, and JR Central. - DB's reporting offered a well-structured report that clearly distinguishes between HSR and other services, plus providing comparison over different time periods. - A key feature of JR Central's and JR East's reports is that they focused on using indicators which show a superior performance in specific areas, such as zero fatalities due to railway operations and the per seat.km CO₂ emissions and energy consumption. - JR Central offers the most realistic recycling ratios among all companies.	- DB could disclose more information especially about numbers of injuries/fatalities caused to passengers and others. - JR Central and JR East could report on the per passenger.km emissions and energy consumption. Also, JR Central could report on the percentage of trains arriving/departing within 5 minutes of the scheduled arrival/departure time. - JR Central could include more safety data, especially regarding the number and type of accidents and casualties.
Companies with a weak reporting performance	- Companies: JR West, HS2, CHSR, and Guangshen Railways - JR West's reporting is relatively limited, especially when compared with its Japanese counterparts. - HS2's reports offered diverse information about the expected wider impacts of the project, in addition to information about the number of properties that will be demolished and the compensation. - CHSR covered a variety of environmental factors with a detailed explanation of the company's efforts to alleviate potential negative impacts on the environment. - Reporting practices of Guangshen Railways are limited to providing basic performance data.	- JR West could report on the punctuality of the HSR service, the operator's international involvement in different projects, and associated revenues. - Both HS2 and CHSR could provide more information about the economic and environmental lifecycle costs of the proposed projects. - Guangshen Railways' reporting should expand to cover other social, economic, and environmental factors. Also, there is a need to cover factors for which the operator has average and weak performance.

Source: Azzouz and Jack (2020)

Table 4-5 shows the variation in sustainability reporting performance of HSR companies. Lei et al. (2015) looked at the CSR disclosure of five Chinese railway firms after a major railway accident in China, concluding that these firms avoided providing any information about the accident. Also, Lei et al. (2015) expanded their findings, pointing out that for every aspect, Chinese firms tend to use sustainability publications and annual reports only to disclose information about rewards, achievements, areas of improvement, and honours gained without necessarily providing any practical performance data besides avoiding the disclosure of negative information.

The findings of this study partly agree with those of Lei et al. (2015); Chinese companies focus on rewards and achievements in their publications. However, there is remarkable evidence to dispute Lei et al. (2015)' claim that Chinese firms' publications do not offer useful information. This study revealed that the Chinese HSR operator included – albeit limited – key sustainability information regarding important factors such as costs, revenues, emissions, and employment.

4.2.4 Reporting variation at the type of indicator level

The fourth level of reporting variations is revealed regarding the use of quantitative and qualitative indicators for reporting on the 26 HSR sustainability factors. HSR companies used both quantitative parameters and qualitative explanations for reporting on most sustainability factors. Table 4-6 summarises reporting variations at the type of indicator level, alongside a reflection on areas of required improvements.

Table 4-6: Findings and potential reporting improvements at the type of indicator level

	Current reporting situation	Areas of potential improvement
Factors mostly described with quantitative indicators	Factors: punctuality, materials and resources, and wider impacts.	- Operators could provide qualitative explanation of major events and disruptions that hindered the punctuality of HSR services during the reporting year, along with a reflection on operators' solutions and responses. - The quantitative reporting on materials and resources could be enhanced by providing qualitative explanation of the source of these materials and companies' efforts to reduce the consumption of materials.
Factors mostly described with qualitative indicators	Factors: integration of HSR with other transport modes and the door-to-door travel time.	- Providing quantitative information regarding the coordination between HSR and other transport modes in HSR stations. These include reporting on numbers of bus, metro, and regional lines at the station, number of stations that can be reached without transfer, and the transfer quality expressed in minutes.
Factors mostly described using both indicators	Factors: all other factors.	- There is a need to develop new quantitative and qualitative indicators to facilitate reporting on poorly covered topics such as affordability, rapid expropriation, social exclusion, land use, and social segregation. - There is a need to standardise and normalise currently used indicators to allow benchmarking exercises.

Source: Azzouz and Jack (2020)

4.3 General discussion

Hahn and Kühnen (2013) pointed out that disclosing information about sustainability performance does not necessarily communicate a fair and true view of firms' actual sustainability performance. In other words, weaker reporting performance and poor disclosure practices do not necessarily refer to weaker sustainability performance. Companies' weak reporting performance could be related to one or more potential reasons. First, some operators might simply be reluctant to share their performance data with the public (Burritt and Schaltegger, 2010). Another reason might be the immature and inadequate disclosure culture adopted within companies, indicating the need for more training in this regard (Hahn and Kühnen, 2013). Also, the absence of necessary governmental pressure to report sustainability performance could discourage firms from reporting, especially considering the efforts and resources required for adequate disclosure (Azizul Islam and Deegan, 2008). Finally, governmental restrictions and censorship on firms' reporting practices might hinder or even completely prevent reporting on sensitive topics such as revenues and emissions (Azizul Islam and Deegan, 2008).

This study found that some HSR operators tend to report on sustainability factors for which they have good performance. The author believes that HSR companies should offer balanced sustainability publications which comprise information about both good and weak performance. Such balanced reports act as mitigation tools and address areas of required interventions. Reimsbach and Hahn (2015) clarified that the self-disclosure of negative and weak performance information does not affect stakeholders' perceptions, while reports and the judgement of third parties such as the media can do. Self-reporting of negative information might have a positive impact, possibly mitigating its apparent stigma. Guthrie and Farneti

(2008) and Isaksson and Steimle (2009) agree that well-balanced sustainability reports that encompass positive and negative information have a greater influence on stakeholder and audience perceptions than publications which only focus on achievements and praising the company.

4.4 Summary and key findings of this chapter

This chapter examines the availability and extent to which the 26 sustainability factors are covered in HSR companies' publications. It analyses the current reporting situation and reflects on areas of potential and required improvements. The findings of this chapter are summarised in the following key points:

1. Examining the availability of the 26 sustainability factors in companies' reports revealed reporting variations at the levels of sustainability pillars, sustainability factors, companies, and type of indicator;
2. Currently, there are big gaps in HSR companies' reporting practices at all levels discussed, and there is great potential for enhancing these practices at all levels mentioned;
3. At the three sustainability pillars level, environmental reporting showed a relatively good performance, when compared with that for economic and social reporting. Economic reporting showed a mixed performance, while social reporting obtained the weakest performance;
4. However, reporting on all pillars failed to cover almost 48 per cent, 53 per cent, and 34 per cent of economic, social, and environmental topics respectively. So, there is great potential for enhancing the disclosure of sustainability information that relates to the three pillars;
5. At the 26 factors level, there is no common set on which HSR companies report today. Costs, revenues, safety, employment, emissions, and energy consumption achieved high

reporting performance. Mediocre performance was obtained for factors like international involvement, integration with other modes, customer satisfaction, biodiversity, and noise. Factors such as social exclusion, social segregation, rapid expropriation, land use, and BCR gained the weakest reporting performance;

6. Even for factors with good reporting performance, the exact nature of reporting often differs, imposing normalisation and standardisation issues. Reporting practices for factors like emissions, energy consumption, costs, and revenues tend to provide aggregate values, while less attention is paid to the per passenger.km figures;
7. At the company level, SNCF followed by FS Italiane and Renfe achieved the highest reporting performance. DB, JR Central, and JR West obtained mediocre performance, while JR West, HS2, and CHSR showed weak reporting performance. Guangshen Railways gained the weakest disclosure performance among all companies;
8. Even companies with the highest reporting performance have failed to cover some sustainability factors and key performance parameters. Adopting the 26 factors framework could greatly enhance and fill gaps in the reporting practices of all HSR companies;
9. At the type of indicator level, most factors showed a balance in the use of both quantitative and qualitative indicators. However, reporting on the DTD travel time and integration with other modes could be enhanced by providing more quantitative data, which are also necessary for benchmarking exercises;
10. There is a need to develop new – quantitative and qualitative – parameters to enhance future reporting practices on factors which are currently under-represented in companies' publications. The scope of UIC and GRI guidelines could be expanded by developing new HSR-specific parameters to facilitate reporting on the poorly covered factors identified in this study;

11. Some reporting practices did not distinguish between HSR and other transport and non-transport services managed by the company, offering aggregate figures that relate to all services. To allow benchmarking exercises, it is necessary to offer data that relate exclusively to HSR;
12. Some operators focused their reporting on factors for which they have superior performance, plus highlighting awards and achievements. However, balanced sustainability publications that reflect different aspects of performance, combining positive and negative information, are recommended;
13. There are different reasons behind the variations in reporting practice, some of which are internal while others are external.

This chapter has answered the second research question by revealing the extent to which the 26 sustainability factors are covered in operators' publications, reflecting reporting variations at different levels.

CHAPTER 5

REPORTING ON AND BENCHMARKING THE ECONOMIC SUSTAINABILITY OF HSR

The previous chapter examined the availability of the 26 sustainability factors in HSR companies' reports, revealing significant variations at different levels. This chapter proposes a set of quantitative and qualitative indicators that express the selected economic sustainability factors and offers a suggested minimum level of reporting standardisation. Each proposed indicator is given a specific suffix and number, see Figure 5-1.

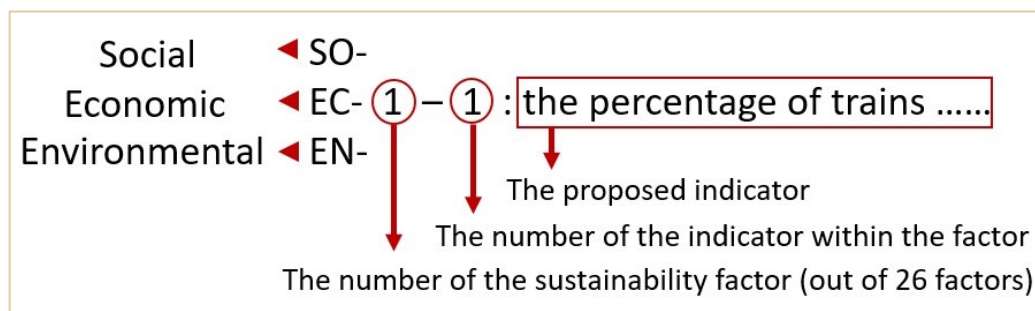


Figure 5-1: Format of proposed indicator names

Also, this chapter – where possible – reflects on methods for calculating quantitative parameters. Regarding qualitative indicators, a comprehensive list of points and topics that can be covered when reporting is provided. As explained in Chapter 3, each indicator is proposed after considering its availability in at least two of the following three sources:

1. Operators' publications;
2. Reporting guidelines of international organisations like the UIC and GRI;
3. Independent studies offered by scholars and research institutes.

In rare cases, none of the previous sources offer suitable indicators for expressing a specific sustainability factor. In such cases, the author suggests a new parameter for expressing that factor.

This chapter also offers a variety of benchmarking exercises, which have two purposes: to test the usability of some proposed indicators, and to provide insights into the economic performance of HSR operators and corridors. Also, the chapter comments on the availability and sources of data for benchmarking exercises and highlights the key results of these comparisons, without discussing findings and performance drivers. This is because Chapter 8 offers an extensive discussion regarding the economic, social, and environmental performance of HSR operators and corridors. Benchmarking exercises do not use a specific currency; instead, they mostly present currencies that have been used by the original sources. Figure 5-2 illustrates a step-by-step process of proposing indicators for each economic factor.

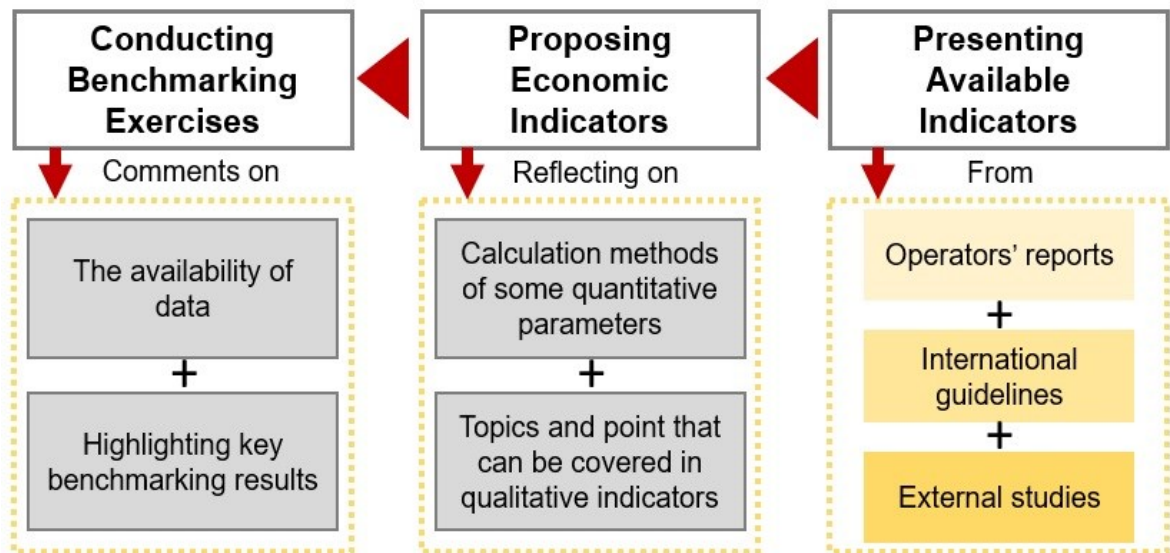


Figure 5-2: Step-by-step process of proposing indicators for each economic factor

5.1 Punctuality and reliability

HSR operators report on the reliability and punctuality of their services using a variety of indicators. Some operators make a clear distinction between railway services while others use the same punctuality value for all railway operations, including regional, high-speed, subway, and regular services.

Cancellation is a common measure in the railway industry, although there are issues with this specific measure. First, different rail providers use different cancellation measures and so there are standardisation issues. For example, Network Rail define cancellation as the percentage of services that were cancelled and differentiate between ‘half cancellation’ and ‘full cancellation’. Half cancellation is when a train fails to stop on one or more of its scheduled stations, while a full cancellation is when a train completes less than 50 per cent of the planned journey (NetworkRail, 2019). FS Italiane utilise the cancellation measure to report on service regularity and use the percentage of trains that are limited, cancelled, or arrived over 120 minutes late as an indicator (FS-Italiane, 2017). JR East use the total number of what they call ‘transport disorder’ cases, which includes train service cancellations or delays to passenger trains for over 30 minutes or other trains for over 1 hour (JR-East, 2018b). Second, some rail providers do not publish any cancellation measure. For instance, both DB and SNCF did not use it in the selected reports.

Most operators use the percentage of trains that arrive within 5–15 minutes of the scheduled arrival time as an indicator for reporting on punctuality. Also, the UIC suggests the percentage of trains that arrive within 15 minutes as a punctuality indicator (KORAIL, 2015). However, the UIC’s indicator does not distinguish between different railway services. For many travellers, the main advantage of using HSR is travel time savings, and a 15-minute delay using

an HSR service could be perceived as much worse than a similar delay using the regular railways. In other words, while 15-minute delays might be relevant in the case of regular rail services, 5-minute delays could be more practical and suitable for HSR.

Some operators report on – systematic and proximate causes – behind significant delays and disruptions, reflecting on signalling and technical failures, natural disasters, financial shortcomings, and the construction of new projects. Others offer detailed explanation of compensations offered to customers.

For a minimum level of reporting standardisation, this study suggests the following reliability and punctuality indicators:

- EC-1-1: the percentage of trains arriving within 5 minutes of the scheduled arrival time
- EC-1-2: a qualitative explanation of the reasons behind major delays, expected future delays and disruptions, operators' responses and initiatives for tackling delays, and details regarding available compensation.

In addition to the EC-1-1 and EC-1-2 indicators, HSR operators are encouraged to report on cancellation measures. Indicators proposed by the framework constitute only minimum requirements and operators are welcome to use additional parameters to present a balanced account of their performance.

Reporting and benchmarking exercise

Figure 5-3 illustrates a benchmarking exercise comparing the punctuality of HSR services and testing the availability of data for the proposed EC-1-1 indicator. Data were available for several Asian and European operators in both 2016 and 2017, most of which were obtained from operators' reports. JR Central used the average delay time per train service as a punctuality indicator, which was standardised into the proposed EC-1-1 indicator. The

comparison shows that the HSR services of the Asian operators were more punctual than their counterparts in Europe. DB's HSR service was the least punctual among all services, with 78.5 per cent of trains arriving within 5 minutes of the scheduled arrival time.

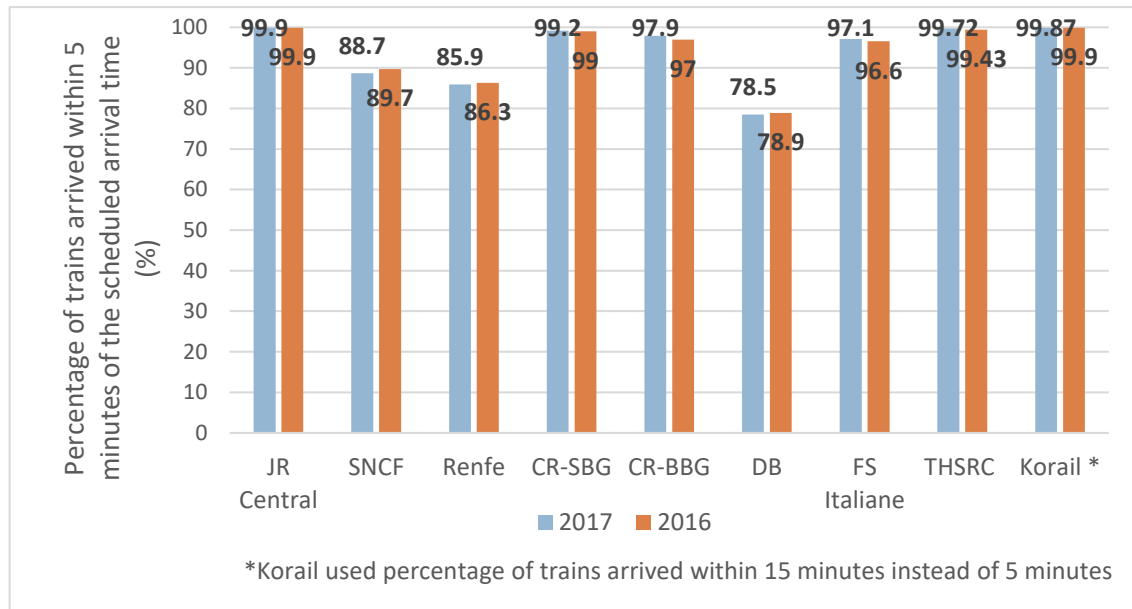


Figure 5-3: Punctuality comparison of HSR services

Source: author's elaboration on (DB, 2017; FS-Italiane, 2017; KORAIL, 2016; KORAIL, 2017; Renfe, 2017; SNCF, 2017a; ThinkTank, 2019; THSR, 2016; THSR, 2017)

5.2 Costs

The economic sustainability of HSR considers the whole lifecycle of HSR projects, reflecting on all costs of planning, constructing, operating, maintaining, and recycling of each project. Most HSR operators concentrate their reporting efforts on operating costs and associated expenses, without necessarily distinguishing between HSR and other transport services. Less attention is paid to lifecycle costs. Some operators like JR Central and JR East reflect on the lifecycle costs of HSR projects that are in planning/construction stages. Also, scholars and economic institutions conduct studies that investigate the lifecycle costs of key HSR corridors around the world (Le Maout and Hironori, 2009). The purpose of these studies

is to assess the economic viability and performance of major HSR corridors plus extracting lessons to assist decisions for the planning and construction of new lines.

The UIC and European railway agencies pay specific attention to track access charges (TACs), which are absent in most operators' reports. At the same time, TACs are vital for the appeal of HSR services, imposing high costs on HSR operators and playing a role in regulating competition within the HSR industry. Recycling is not a cost-free process and associated costs include costs of collecting, sorting, processing, reusing or selling recycled materials. HSR operators could enhance their economic reporting practices by providing information about the lifecycle costs of major HSR corridors plus projects and lines which are in the planning and construction stages. The proposed framework suggests the following indicators to improve reporting on costs:

- EC-2-1: the construction cost of major/new HSR lines per km
- EC-2-2: the operating cost of major/new HSR lines per km
- EC-2-3: the maintenance cost of major/new HSR lines per km
- EC-2-4: the recycling cost of major/new HSR line per km
- EC-2-5: the track access charge per train-km of HSR lines

Reporting and benchmarking exercises

Figure 5-4 illustrates TACs for different European HSR corridors and countries in 2017. Since data were not available in operators' reports, all figures were collected from UIC publications plus other online sources. The Paris–Lyon line had the highest TAC of €30.62 per train-km, which was higher than the average TAC for France by almost 70 per cent.

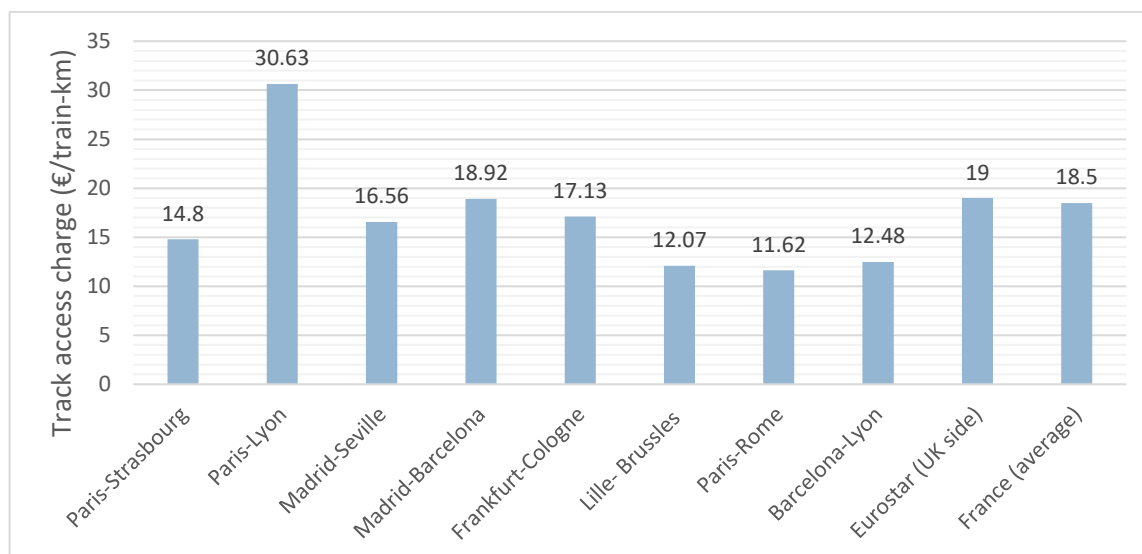


Figure 5-4: Comparison of track access charges in 2017

Source: author's elaboration on (Pittman and Choi, 2013; Desmaris, 2016; EU, 2019; Leboeuf, 2018)

Figure 5-5 looks at the construction costs of the four selected HSR lines. Values were collected from different studies and online articles, and there was no one primary source for such information. Since these studies date back to different years, and to allow a fair comparison, all costs were calculated in 2017 dollars. The comparison shows that the Beijing–Shanghai line had the highest total and per km costs compared to the other lines, while the Madrid–Seville line had lowest costs. Also, the per km construction costs of the Asian lines were higher than those of their European counterparts. Apart from the Beijing–Shanghai line, all lines had per km construction costs that are lower than the average construction costs in their countries. In contrast, the per km construction cost of the Beijing–Shanghai line was higher than the average construction cost in China by around 35 per cent.

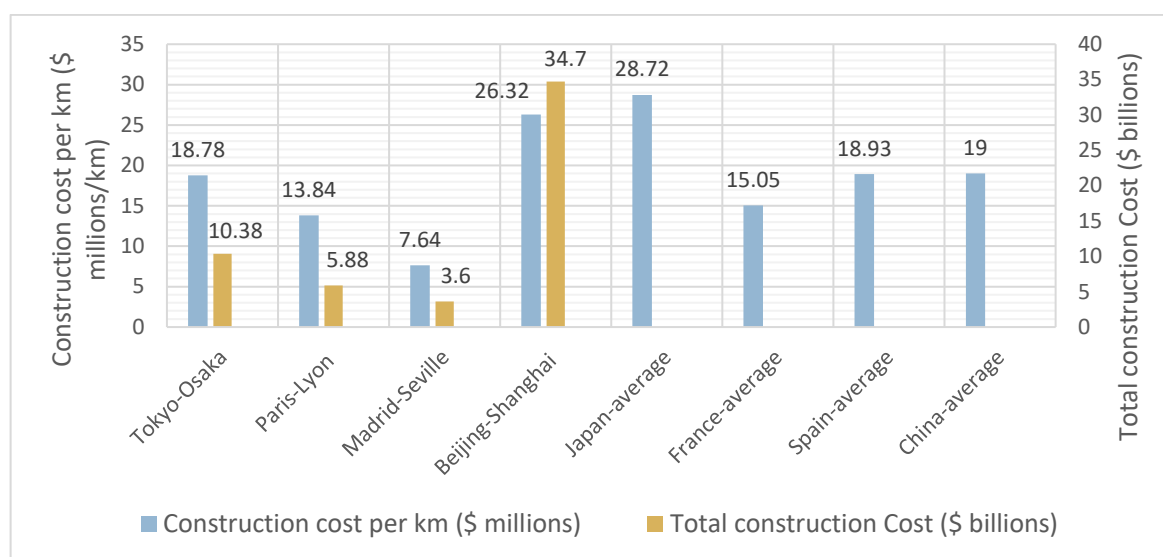


Figure 5-5: Construction costs of selected HSR lines in 2017 dollars

Source: author's elaboration on (Almujibah and Preston, 2019; Barrón et al., 2009; Feigenbaum, 2013; Ollivier et al., 2014)

5.3 Revenue

In their publications, HSR operators provide a wide range of financial indicators reflecting the revenue associated with their activities. Economic reporting covers topics such as operating revenues, operating expenses, profits, depreciation and amortisation, total assets, equity and its ratio, capital expenditure, and investments in new technologies. Earnings before interests, taxes, depreciation, and amortisation (EBITDA) is an essential measure of a company's economic performance. Also, the net profit indicates a firm's financial health and its capability to contain its expenses without the need for subsidies plus the ability to invest in future projects and technologies (JR-Central, 2018; Mitchell and Liu, 2018; Nunno, 2018).

Revenues and economic profits of a specific HSR corridor are rarely considered in operators' publications, while independent scholars and agencies usually examine them. Reporting on the profits of specific corridors is necessary since it reveals the variation among them in terms of their profitability. The most profitable lines typically have certain features like

high ridership, appropriate pricing, and appropriate distance. Under such features, HSR corridors generate profits, and identifying these corridors could draw lessons for other HSR lines. The proposed framework suggests the following key indicators:

- EC-3-1: operating profits (EBITDA) per HSR route km
- EC-3-2: net operating profits per HSR route km
- EC-3-3: net operating profits of major HSR corridors per km

Reporting and benchmarking exercises

Figure 5-6 compares the net operating profits of the four selected HSR corridors. JR Central provided comprehensive and detailed information about the earnings of the Tokaido Shinkansen. However, other operators did not provide enough information about the profits of specific corridors. So, most data were extracted from online articles that discuss the profitability of the relevant HSR lines. The benchmarking exercise illustrates that all four corridors were profitable. However, the Tokyo–Osaka line was significantly more profitable than the other lines, with net operating profits that were higher than the profits of all other lines combined.

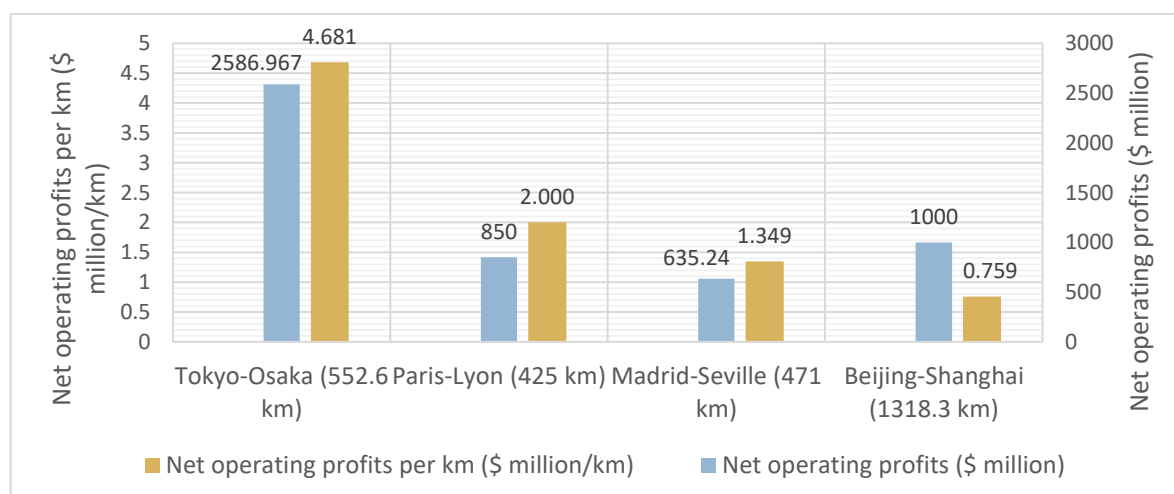


Figure 5-6: Operating profits comparison of four corridors in 2017

Source: author's elaboration on (Briginshaw, 2014; JR-Central, 2018; Kumagai, 2016; Nunno, 2018; Rus, 2015)

Figure 5-7 and Figure 5-8 examine operators' total and net profits in 2017. Most data were obtained from operators' financial reports. Still, due to reporting gaps, online articles and journals were used to fulfil the benchmarking exercise. For instance, Renfe did not disclose their 2017 net profits in their 2017 report.

Figure 5-7 shows that the EBITDA of China Railways were the highest, followed by those for Japan and SNCF. However, when it comes to net profits, all operators were capable of making profits, with JR Central making the highest net profits, followed by SNCF. In contrast, Renfe generated net profits of around €70 million. Also, JR Central obtained the highest net-to-total profits ratio of 0.6 followed by SNCF with 0.32, whereas China Railways gained the lowest ratio of 0.04.

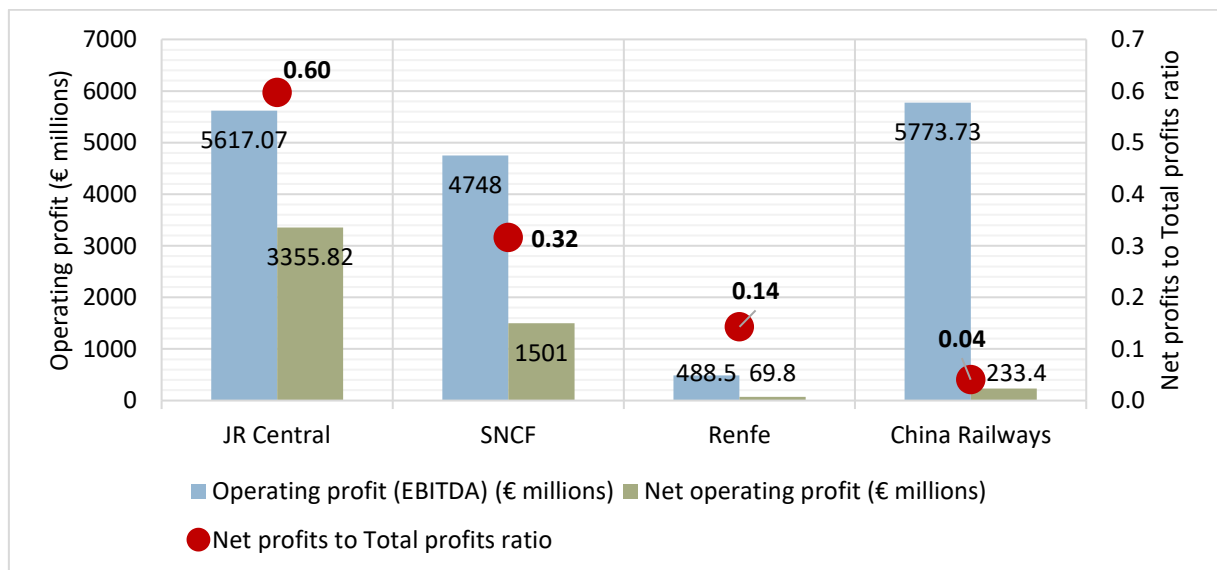


Figure 5-7: Operating profits comparison

Source: author's elaboration on (Caixin, 2019; Expansion, 2018; JR-Central, 2018; Mitchell and Liu, 2018; Renfe, 2017; SNCF, 2018b)

Figure 5-8 illustrates that JR Central generated net profits of almost €6.1 million for each HSR route kilometre the company operates, which was almost 11 times higher than

SNCF's corresponding profits. The profits of Renfe and China Railway were small when compared with the other operators.

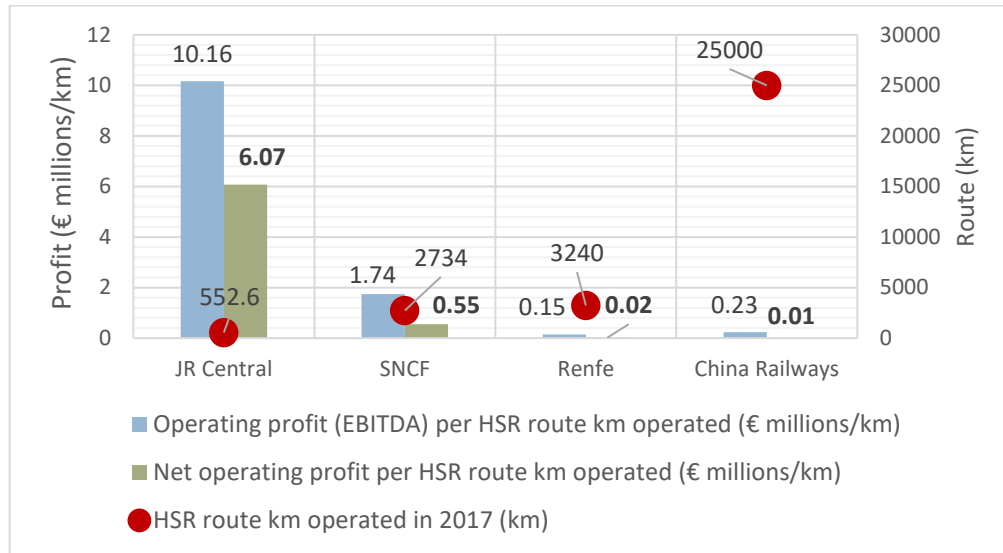


Figure 5-8: Operating profits per km comparison

Source: author's elaboration on (Caixin, 2019; Expansion, 2018; JR-Central, 2018; Mitchell and Liu, 2018; Renfe, 2017; SNCF, 2018b)

5.4 Efficiency

Railway efficiency is a very broad term and it can be considered from several perspectives. These include the operational efficiency, financial efficiency, energy efficiency and infrastructure efficiency. International railway agencies have identified a wide range of efficiency indicators, each of which can be used for examining a specific performance aspect. Moreover, these indicators vary in terms of the time and effort required for data collection and calculation (Doomernik, 2015; SDG, 2017).

Despite presenting basic financial efficiency metrics such as the revenues-to-costs ratio, HSR operators do not report directly on efficiency indicators. Instead, they partly provide information that could be used for calculating efficiency indicators. SDG (2017) discussed that

several railway efficiency indicators do not facilitate ease of calculation, which might hinder efficiency reporting practices.

In their discussion paper, the OECD International Transport Forum identified a set of railway efficiency indicators. These indicators focus on railways' economic sustainability including: operator's cost-to-revenue ratio; infrastructure manager's cost-to-revenue ratio; utilisation of railway infrastructure; staff expenses per train-km; revenues per train-km; and number of staff per train-km (Beck et al., 2013). Since the proposed framework discusses efficiency from an economic perspective, and considering the availability of data plus seeking indicators that feature ease of calculation in future reporting, the following indicators are suggested:

- EC-4-1: operating revenue per train-km (monetary unit/train-km)
- EC-4-2: operating cost per train-km (monetary unit/train-km)

The operating revenue includes revenues generated from operating HSR services such as selling tickets and in-station and in-train services. Operating costs comprise the costs of personnel, equipment, purchases, and other operating expenses.

Reporting and benchmarking exercise

Figure 5-9 presents a benchmarking exercise comparing the economic efficiency of seven HSR operators in 4 years. The exercise shows the availability of the data required for calculating the proposed EC-4-1 and EC-4-2 economic efficiency indicators. HSR operating revenues were available in operators' annual, financial, and sustainability reports. Operating costs were partly available in these reports, and some values were calculated using EBITDA values provided by operators. Values of HST runs expressed by train-km were extracted from RAILISA, the UIC's online database.

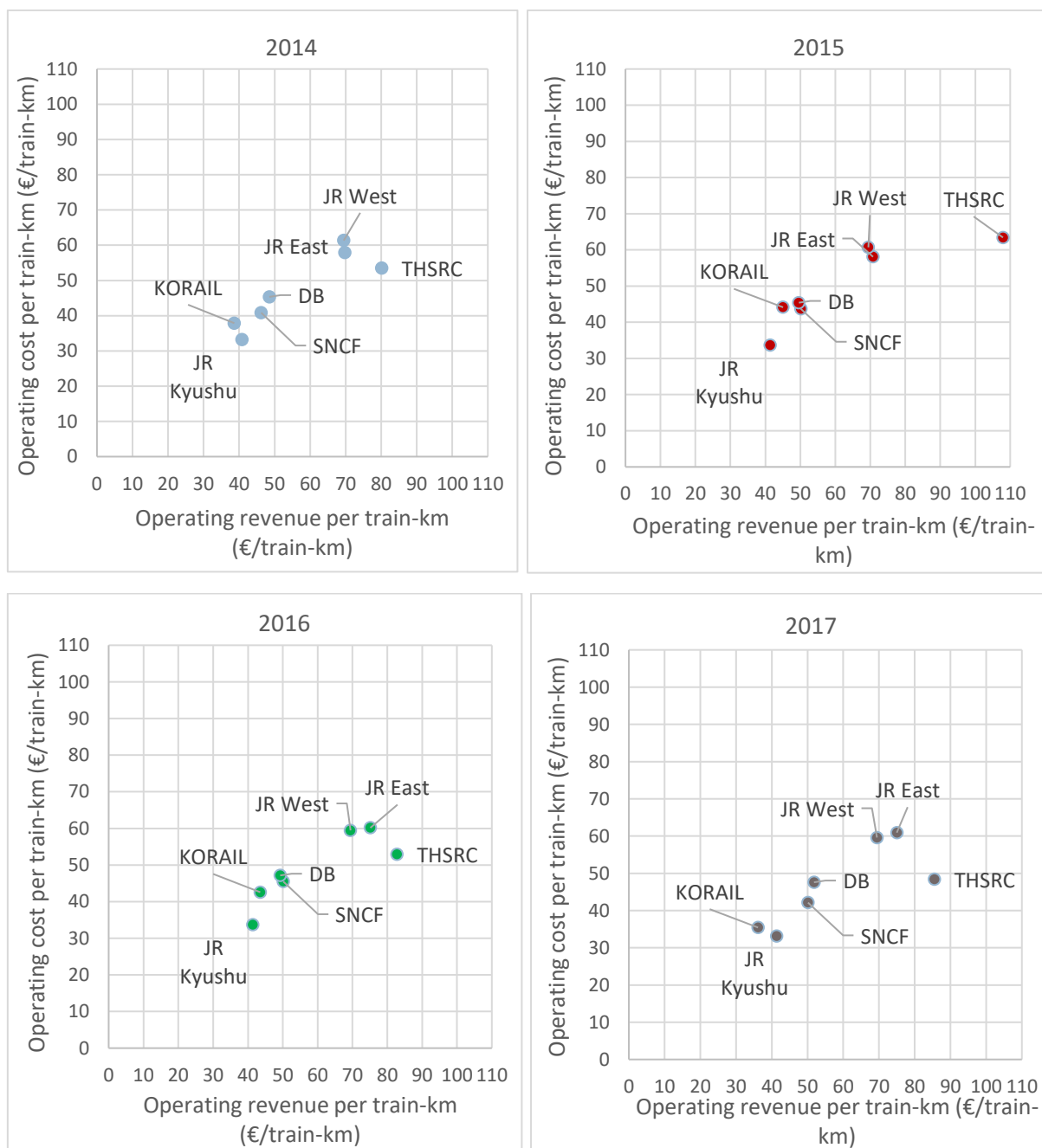


Figure 5-9: Economic efficiency comparison of different HSR operators

Source: author's elaboration on (DB, 2015; DB, 2016; DB, 2017; JR-East, 2018a; JR-East, 2018b; JR-Kyushu, 2018; JR-West, 2018; KORAIL, 2015; KORAIL, 2016; KORAIL, 2017; SNCF, 2015; SNCF, 2016b; SNCF, 2017b; THSR, 2014; THSR, 2016; THSR, 2017; UIC, 2019c)

Figure 5-9 illustrates that THSRC was the most efficient in terms of revenue during the 4 years, with operating revenues that ranged between €80 and €109 per train-km. KORAIL and

JR Kyushu showed the highest operating cost efficiency, with operating costs that ranged between €30 and €42 per train-km. SNCF and DB showed medium cost and revenue efficiency and their performance was close to each other.

5.5 Benefits-to-costs ratio and wider economic impacts

Practices of HSR operators are not only limited to operating railway services; they are often involved in planning, constructing, and deploying new corridors locally and internationally, while annual and sustainability reports contain detailed information about costs and revenues of operations, lifecycle costs, and the benefits of existing and new corridors are rarely discussed. Some Japanese operators discuss the deployment of new projects in their publications. For instance, JR Central discloses information about the development of the Chuo Shinkansen, a project that will use the superconducting maglev system to connect Tokyo, Nagoya, and Osaka. JR Central outlines the key costs of rolling stock and construction of the project without commenting on the direct and indirect benefits expected (JR-Central, 2017; JR-Central, 2018).

A basic cost–benefit analysis (CBA) considers direct benefits such as travel time savings and revenue from tickets as well as construction, operation, and maintenance costs (De Rus, 2012). However, this basic CBA can be greatly enhanced by considering the WEIs of the project (Delaplace and Dobruszkes, 2016; Henríquez and Deakin, 2017). A comprehensive CBA generates an enhanced BCR which is proposed as an indicator such as in the following:

- EC-5: the enhanced benefits-to-costs ratio of new HSR projects
- EC-6: a quantitative and qualitative explanation of the projected wider economic impacts associated with new HSR projects

The enhanced BCR could be calculated by considering all benefits and costs associated with the project. Reflecting on the work of Rothengatter (2019), ECoA (2018), Pagliara (2018), Atkins et al. (2017), Chèze and Nègre (2017), Henríquez and Deakin (2017), Delaplace and Dobruszkes (2016), and Doomernik (2015) reporting on benefits should include:

- 1) Operating revenues and direct benefits to travellers such as travel time savings and comfort;
- 2) WEIs which encompass:
 - Employment and creation of new job opportunities within the project;
 - Allowing more people in areas that will be connected by HSR to access job markets;
 - Agglomeration effects and the relocation of offices and companies which could increase the overall productivity of specific industries such as finance and technology;
 - Changes in the value of land, houses, and properties, especially those along the corridor and around HSR stations;
- 3) Externalities which incorporate:
 - Safety effects and fewer accidents due to less driving;
 - Environmental effects and pollution reduction as a result of shifting from airplanes and cars;
 - Reliability improvements;
 - Reductions in operation and maintenance costs of other modes;
 - Less congestion for both railways and roads.

On the other hand, reporting on costs could involve planning, construction, operating and maintenance costs, and train purchases plus additional external costs such as those associated with alleviating negative environmental impacts and biodiversity protection efforts. Tax losses arising from less driving should be included in costs.

When reporting on the enhanced CBA, it is essential to consider three points. First, some WEIs might be negative; in such cases, they should be deducted from total benefits (Henríquez and Deakin, 2017). Second, calculating the BCR should not be limited to a specific formula, and it could always be enhanced by considering all costs and benefits associated with the project and which occur to both individuals and societies. Some of these costs and benefits might be relevant to specific projects or contexts and would not apply in others. Third, both ex-ante and ex-post analyses might be considered as these compare projected costs and benefits with real values. Ex-post analysis is important since it gives a more realistic evaluation. WEIs usually take effect after several years of project implementation and it is hard to provide an accurate estimate of these effects through ex-ante analysis.

Reporting and benchmarking exercise

Table 5-1 presents some results of studies that conducted a CBA for different corridors. These studies date back to different years, so, the inflation rate of each country was considered, and all values were converted to billions of 2017 dollars, pounds, and euros. Most of the studies covered the basic components of the CBA. Still, there is evident variation in reporting and evaluation practices, and ‘N/A’ refers to gaps in reporting for specific points. Apart from the HS2 appraisal, no studies considered the WEIs in their assessments, which might have degraded benefits when compared to costs. Also, some studies provided final cost values without necessarily revealing how those costs are distributed across the lifecycle of the project. Also, Table 5-1 shows that total costs of the Paris–Lyon, Madrid–Seville, Madrid–Barcelona, and Frankfurt–Schiphol HSR lines were expected to exceed total benefits, whereas the benefits of the Hong Kong–Shenzhen, CHSR, and HS2 projects were projected to surpass costs. However, different durations and discount rates were considered for each project. The huge variations in figures for different corridors might refer to miscalculations in reports and studies.

Table 5-1: Benchmarking for estimated costs and benefits of major HSR corridors

	Paris–Lyon	Madrid–Seville	Madrid–Barcelona	Frankfurt–Schiphol	Hong Kong–Shenzhen	California HSR	HS2 (full network)
Duration (years)	40	40	40	N/A	50	30	60
Units	€ billion	€ billion	€ billion	€ billion	\$ billion	\$ billion	£ billion
Discount rate	3%	3%	3%	4%	6%	7%	7%
Ridership scenario	Normal	Normal	Normal	High	Normal	High	Normal
Time savings for users	0.561	1.8	3.19	0.33	8.184	N/A	52.921
Operating revenue	0.3	0.911	1.253	0.22	12.9	23.57	36.043
Wider impacts on economy	N/A	N/A	N/A	0	N/A	N/A	15.4
External benefits	N/A	1.14	3.758	0	6.191	8.01	17.33
Total benefits	0.861	3.851	8.201	0.55	27.275	31.58	121.694
Construction costs	2.005	3.36	N/A	2.848	10.1	20.557	N/A
Operating costs	N/A	1.597	N/A	0.11	14.575	7	N/A
Maintenance costs	N/A	0.453	N/A	0.767	N/A	N/A	N/A
Implementation costs	N/A	5.41	N/A	3.725	24.675	N/A	72.532
External losses and costs	N/A	0.205	N/A	N/A	0.001	N/A	3.372
Total costs	2.005	5.62	14.12	3.725	24.676	27.557	75.904
Net present value (NPV)	–1.144	–1.769	–5.919	–3.175	2.599	4.023	45.79

Source: author's elaboration on (Carrera-Gomez et al., 2006; DfT, 2013; Dijkman et al., 2000; Henríquez and Deakin, 2017; Kockelman, 1994; McDermott, 2013; Tao et al., 2011)

Figure 5-10 illustrates a BCR comparison of selected HSR corridors; all values were calculated using the figures provided in Table 5-1. Most corridors were expected to have a BCR close to or below 1. In the UK, more than 90 per cent of transportation projects which obtain the Department for Transport's approval have a very high value for money, with a BCR of at least 2:1 (Atkins et al., 2017). Under such criteria, and considering their low BCRs, no existing HSR corridors listed would be justified at such BCR terms. This does not necessarily mean

these HSR corridors are not profitable. Instead, it might refer to weaknesses in appraisal studies, which adopted the CBA in its basic form, while neglecting WEIs. So, it is imperative to enhance calculations and to report on BCRs by fully considering all previously listed WEIs, both in operators reports and in appraisal studies.

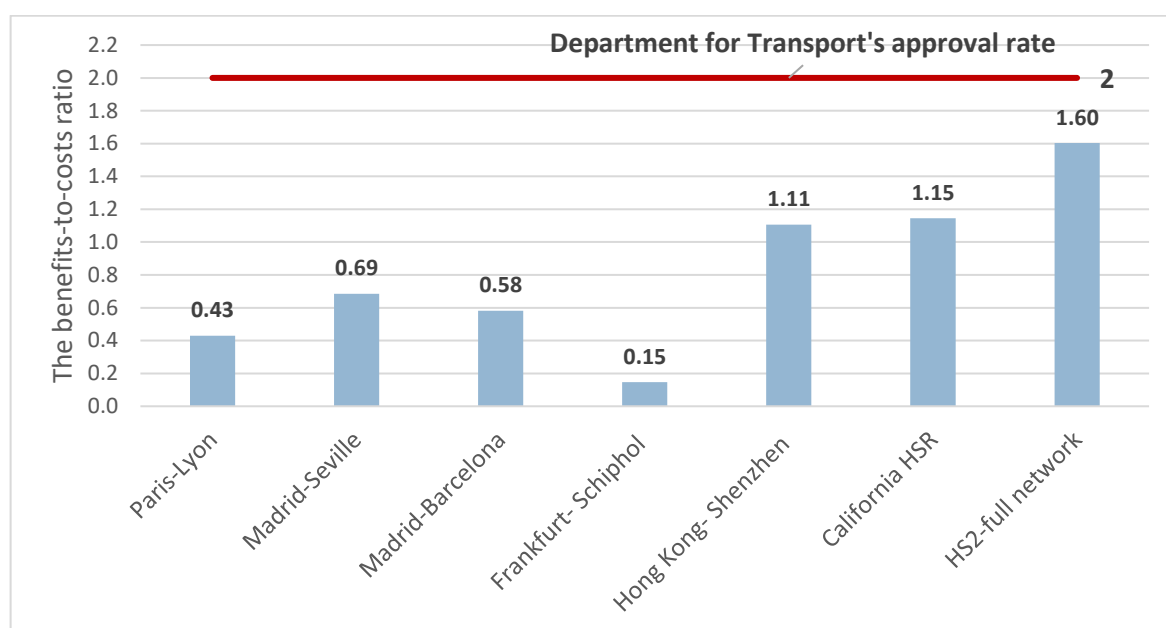


Figure 5-10: Comparing the BCR of different HSR corridors

Source: author's elaboration on (Carrera-Gomez et al., 2006; DfT, 2013; Dijkman et al., 2000; Henríquez and Deakin, 2017; Kockelman, 1994; McDermott, 2013; Tao et al., 2011)

5.6 Effects on tourism

In their publications, some HSR operators provide a qualitative explanation of their efforts and initiatives to promote tourism. These include launching tourism campaigns and selling integrated tickets that grant discounted access to tourist attractions. However, there is no clear information on how HSR operations are affecting the tourism demand of regions and locations along HSR lines. Some operators disclose information about the number of tickets that have been purchased by international passengers.

Several studies discuss the correlation between HSR and changes in tourism demand (Albalade et al., 2017; Albalade and Fageda, 2016; Campa et al., 2018; Campa et al., 2016; Chen and Haynes, 2012; Chen and Haynes, 2015; Gao et al., 2019; Gare-de-Lyon, 2019; Kurihara and Wu, 2016; Li et al., 2019), [see 2.4.3](#). Most of these investigations used the change in domestic and international arrivals as an indicator for reporting on the effects of HSR on tourism. After a thorough exploration of these studies and the way in which they present their findings, the following indicators are proposed:

- EC-7-1: changes in domestic tourism demand in cities along HSR corridors
- EC-7-2: changes in international tourism demand in cities along HSR corridors
- EC-7-3: a qualitative explanation of operators' efforts and solutions to promote tourism

When reporting on changes in tourism demand, three types of change could be considered: positive changes, negative changes, and the overall impact. A positive shift in tourism demand means that a specific city has experienced increments in the number of tourists after introduction of the HSR service. Cities with negative changes suffer reductions in tourist arrival numbers. The overall change provides a holistic view considering all cities in one region.

Indicators EC-7-1 and EC-7-2 can be calculated by looking at the change in tourism demand over a specific period, usually a year or more. Many factors should be considered in the model like tourism status in the whole country, the development of the city and its preparedness to host tourism activities, and the availability of tourist attractions.

Reporting and benchmarking exercise

Figure 5-11 examines the effects of HSR on domestic and international tourism in China, Spain, and Japan. Data for the benchmarking exercise were obtained from different studies, all of which used changes in domestic and international tourism demand as reporting

indicators. However, the scope and the period during which effects were considered by the analyses vary significantly. For instance, some studies reported HSR's effects on tourism at the country level, while others focused on specific cities within a specific region. Also, some studies looked at impacts that occurred within 3 years of the introduction of the HSR, while others considered longer periods.

Generally, Figure 5-11 shows that HSR were mostly associated with positive changes in domestic and international tourism demand in China, Spain, and Japan. Also, changes in tourism demand in locations that are positively affected were much stronger than changes in locations that witnessed negative impacts. However, all changes in both locations of positive and negative changes varied significantly among periods and locations.

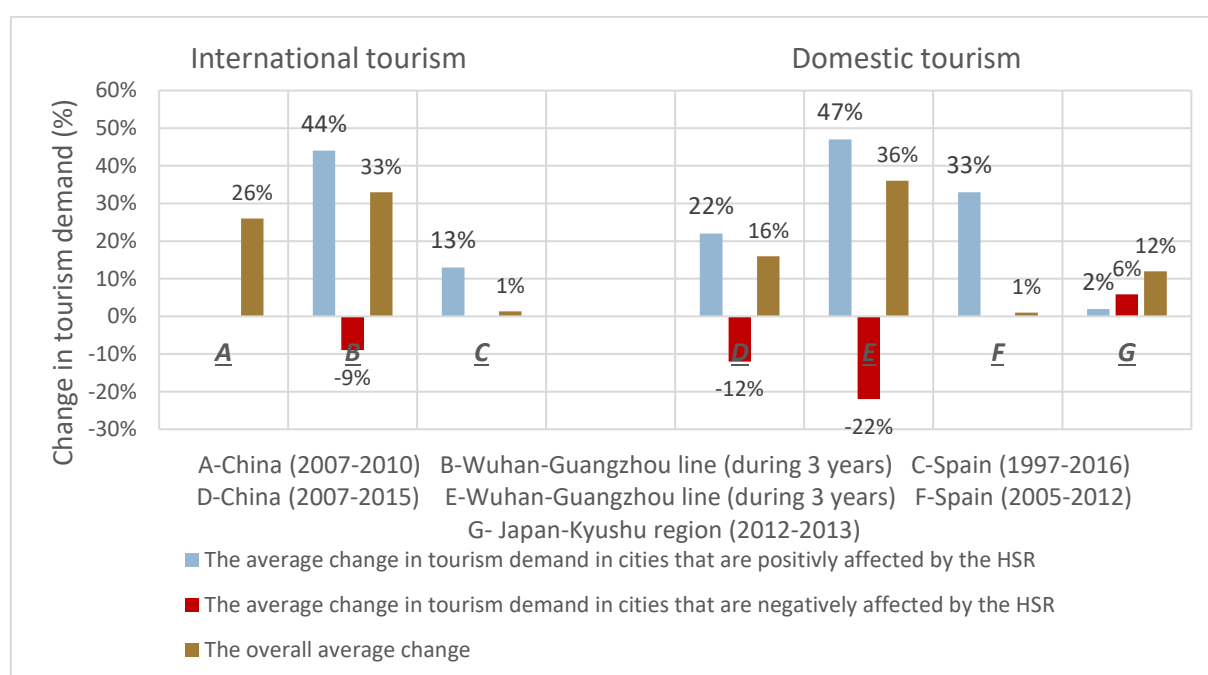


Figure 5-11: Comparison of changes in domestic and international tourism demand

Source: author's elaboration on (Albalate et al., 2017; Albalate and Fageda, 2016; Campa et al., 2018; Campa et al., 2016; Chen and Haynes, 2012; Chen and Haynes, 2015; Gao et al., 2019; Kurihara and Wu, 2016; Li et al., 2019)

5.7 Competition with air transport

The competition with air transport factor is poorly covered in operators' reports. JR Central presents data related to the competition between the Tokaido Shinkansen and airlines along the Tokyo–Osaka corridor, reflecting on some parameters such as distance, daily ridership, and the market share of both modes. Also, Renfe presents similar data which relate to the Madrid–Seville and Madrid–Barcelona routes. However, Renfe's reporting practices are inconsistent across years, especially when compared with JR Central's disclosure (JR-Central, 2017; JR-Central, 2018; Renfe, 2015; Renfe, 2017).

The UIC provides similar information regarding the competition between air transport and HSR in France. This information tackles several origin–destination pairs while focusing on the market share and travel time (Leboeuf, 2018). Also, some journal articles study the competition between HSR and airlines along specific transport corridors, deriving data mainly from revealed preference (RP) surveys. The results of these studies reflect on the market share of both modes, taking into consideration the age, gender, income, education, and other socioeconomic features of travellers.

There are no standardised indicators to express the competition between HSR and airlines, so the following indicators are proposed for the framework:

- EC-8-1: the market share of HSR against airlines on major corridors
- EC-8-2: the daily and annual ridership of HSR and airlines on major corridors
- EC-8-3: HSR–airline pricing comparison on major corridors

HSR operators could use these three indicators in their reports to provide information related to the HSR–airline competition along the major corridors of their choice and within their operating area. Also, they could compare their market share, ridership, and prices with other

operators' corridors that share similar characteristics to their own. The reporting process could cover the following points:

- Defining both the origin and destination of each corridor;
- Defining the length of the corridor expressed by operating kilometres;
- Providing some information explaining the importance of the corridor, its history, and development.

Reporting and benchmarking exercise

Figure 5-12 illustrates the market share of HSR and airlines in the air–HSR market. Data were retrieved from a combination of sources including annual reports, online articles, and journal papers. The comparison shows that shorter corridors facilitate higher market share for HSR and lower share for air transport. For instance, the Paris–Lyon corridor – which is the shortest corridor – had the highest HSR market share, with around 92 per cent of trips made by HSR, compared to only 8 per cent of trips made by air transport. The market shares for HSR and air transport along the much longer Beijing–Shanghai corridor was 50 per cent each.

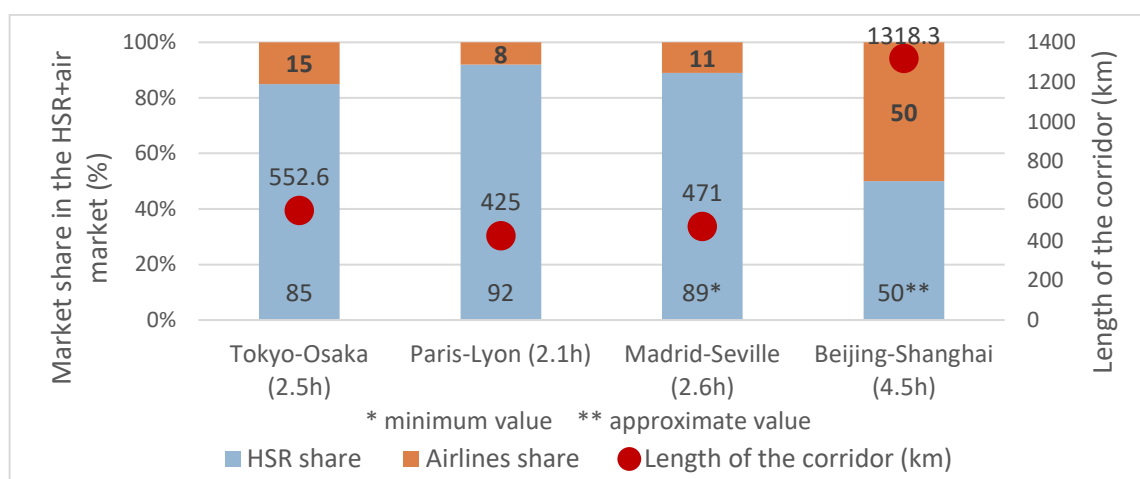


Figure 5-12: Market share of HSR vs airlines in 2017

Source: author's elaboration on (JR-Central, 2018; Leboeuf, 2018; Renfe, 2017; SNCF, 2019c; Songsong, 2019; Su et al., 2019)

Figure 5-13 introduces the annual and daily ridership figures for HSR and air transport along the four selected corridors. Similar to the previous benchmarking exercise, data were obtained from different sources. The daily and annual ridership figures varied significantly for the selected corridors. In the Beijing–Shanghai corridor, the daily and annual HSR and air transport ridership figures were significantly higher than their counterparts in other corridors. For example, the daily HSR ridership for the Beijing–Shanghai corridor was more than three times that for the Tokyo–Osaka corridor. Considering the European corridors, the daily HSR ridership of the Paris–Lyon corridor was almost 10 times higher than that for the Madrid–Seville corridor.

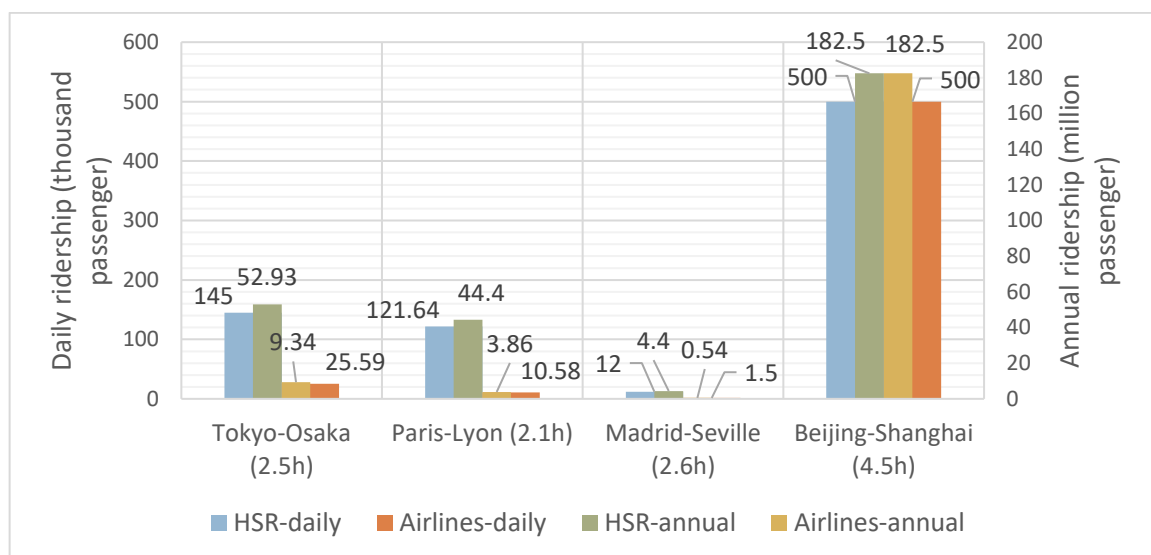


Figure 5-13: Daily and annual ridership of HSR vs airlines in 2017

Source: author's elaboration on (JR-Central, 2018; Leboeuf, 2018; Renfe, 2017; SNCF, 2019c; Songsong, 2019; Su et al., 2019)

Figure 5-14 compares HSR with flights in terms of the duration of the journey and the cost of tickets along the four corridors. Prices of tickets and durations were obtained from commercial websites. Significant variations in price between HSR and air transport were found in three out of four corridors.

The cost of HSR tickets for the Tokyo–Osaka corridor was higher than the cost of air tickets by around 125 per cent. Also, for the Madrid–Seville corridor, the cost of an air ticket was almost half the cost of the HSR ticket. In contrast, travelling by HSR on the Paris–Lyon corridor was around six times cheaper than travelling by air. The cost of travelling by HSR and air transport along the Beijing–Shanghai corridor was similar, with the HSR ticket being slightly cheaper than the airfare.

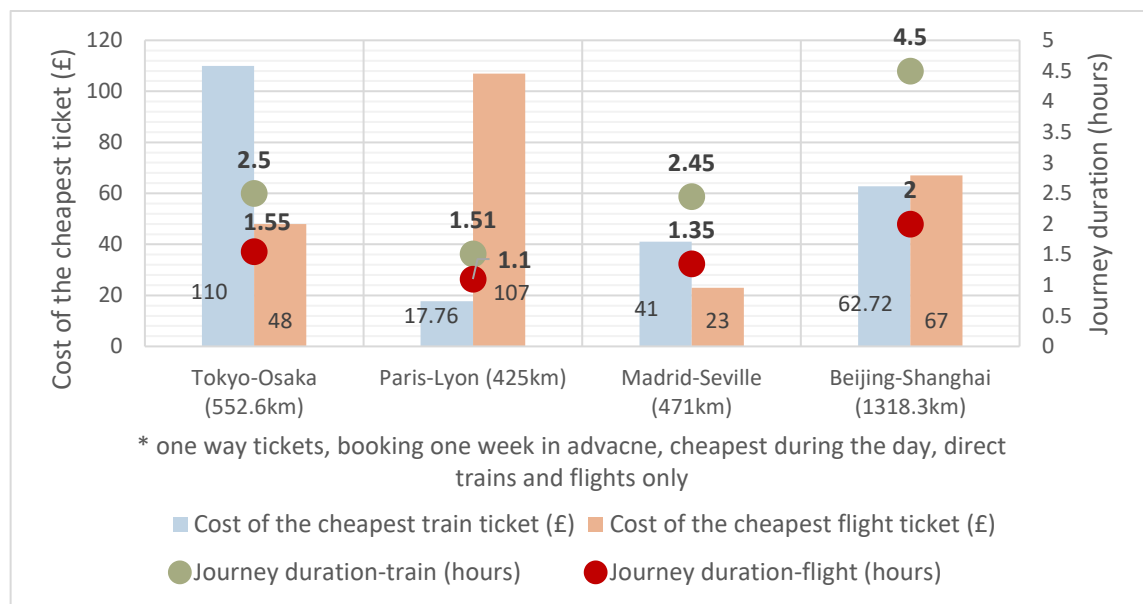


Figure 5-14: HSR–flight pricing comparison

Source: author’s elaboration on (China, 2019; JR-Central, 2019e; Skyscanner, 2019; Trainline, 2019)

5.8 Integration with other transport modes

HSR are parts of transportation systems that comprise public transport modes such as buses, coaches, metros, and regional trains and private modes like driving, walking, and cycling. HSR stations constitute the interaction points between HSR and other transportation modes. Annual and sustainability reports usually focus on the performance of HSR, paying less attention to the coordination with other modes. Via their websites, some HSR operators and

infrastructure managers provide necessary accessibility information about how to reach stations by different modes plus the availability of car parking spaces (SNCF, 2019f).

The UIC has a broader scope, explaining that coordination with all transport modes should be considered for efficient operations and seamless journeys, and suggesting a wide range of benchmarking parameters (Leboeuf, 2018). Seeking standardised reporting on the integration between HSR and other modes, the proposed framework suggests the following indicators:

- EC-9-1: the number of metro, regional train, and bus lines at the HSR station
- EC-9-2: the number of metro stations and bus stops that can be reached directly from HSR stations without transfer
- EC-9-3: the quality of the transfer between HSR services and other transport modes expressed in minutes
- EC-9-4: the number – and cost – of parking spaces in and within 500 metres of stations, considering both fuel-powered cars and charging points for electric vehicles
- EC-9-5: time and monetary costs associated with transferring from the HSR station to the nearest international airports
- EC-9-6: the number of parking spaces available for bikes and motorbikes
- EC-9-7: a qualitative explanation of operators' efforts to improve integration with other modes

EC-9-7 might reflect on; integrated ticketing, car and bike rental services, the availability of taxis, carpooling services, utilisation of communication technology and robots, and ergonomics at the station. Using the proposed parameters in benchmarking exercises could indicate how to increase the attractiveness of HSR services. For instance, the transfer quality

expressed in minutes indicates how easy it is to switch between modes in stations, referring to potential improvements in the ergonomic design of different spaces and facilities.

Reporting and benchmarking exercise

Figure 5-15, Figure 5-16, Figure 5-17, and Figure 5-18 present several benchmarking exercises, confirming the availability of data for some of the proposed indicators. Data were extracted from different sources such as travel planning and commercial websites, parking agencies, Google Maps, transportation maps provided by city councils, and online articles. Some basic data, such as daily passenger numbers in stations were not available through operators' public sources in most cases. Figure 5-15 illustrates that apart from Seville Santa Justa, all benchmarked HSR stations were connected to a subway network, and at least one subway line reaches the station. Through its connectivity with three metro lines, Shanghai Hongqiao station featured the highest number of metro stations that can be reached without further transfer.

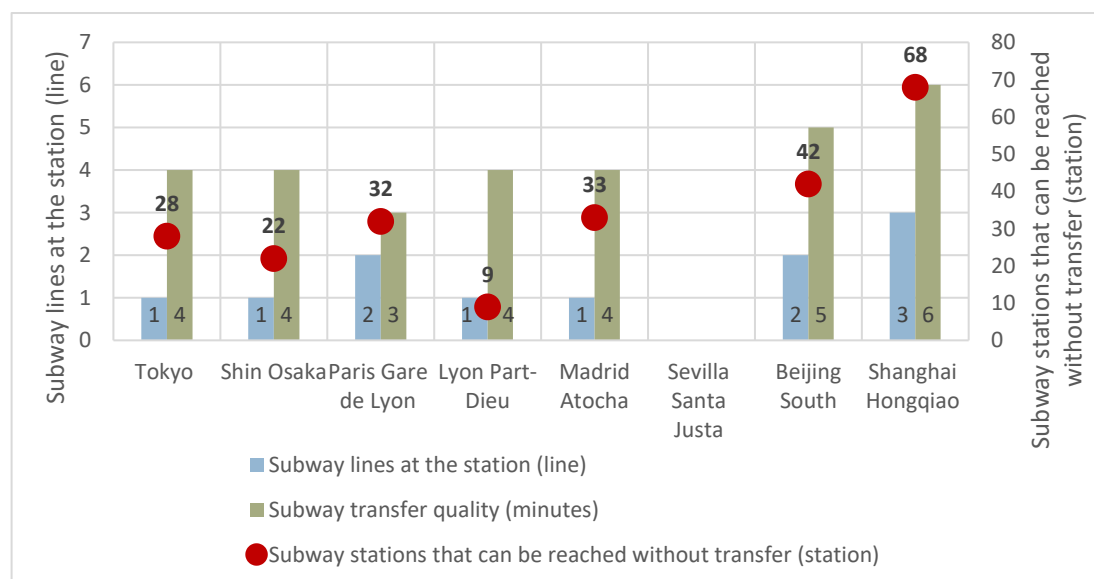


Figure 5-15: Benchmarking the integration with metros at HSR stations

Source: author's elaboration on (CH, 2019b; Gare-de-Lyon, 2019; Renfe-SNCF, 2019; SNCF, 2019f; TCG, 2019; Tokyo, 2019)

Figure 5-16 shows the integration between HSR and buses. All benchmarked HSR stations were connected to the bus network. Madrid Atocha followed by Beijing South had the highest number of at-station bus lines, with 20 and 17 lines respectively. These lines allow direct reach to 534 and 320 bus stops respectively.

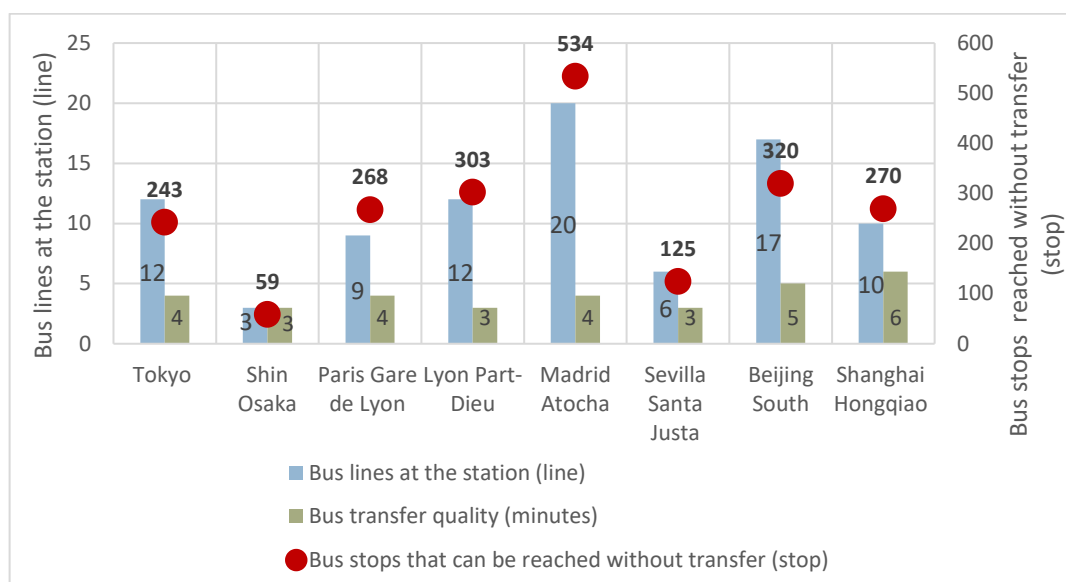


Figure 5-16: Benchmarking the integration with buses at HSR stations

Source: author's elaboration on (Busmap, 2019; CH, 2019b; Gare-de-Lyon, 2019; Madrid-Atocha, 2019; Moovit, 2019; Osaka-City, 2019a; Renfe-SNCF, 2019; SNCF, 2019f; TCG, 2019)

Figure 5-17 illustrates the integration between HSR and cars, showing the availability of car parking spaces within and in the vicinity of the benchmarked HSR stations. Shanghai Hongqiao station followed by Tokyo station featured the highest number of car parking spaces, with 6500 and 4767 spaces respectively.

However, considering the daily ridership of each station, Lyon Part Dieu achieved the greatest number of car parking spaces per passenger, with around 20 spaces per thousand daily passengers, followed by Seville Santa Justa with almost 15 parking spaces per thousand daily passengers. The daily cost of parking in the vicinity of Tokyo station was the highest, at around

€68 per day. In contrast, Shanghai Hongqiao offered the cheapest parking, at around €7.7 per day.

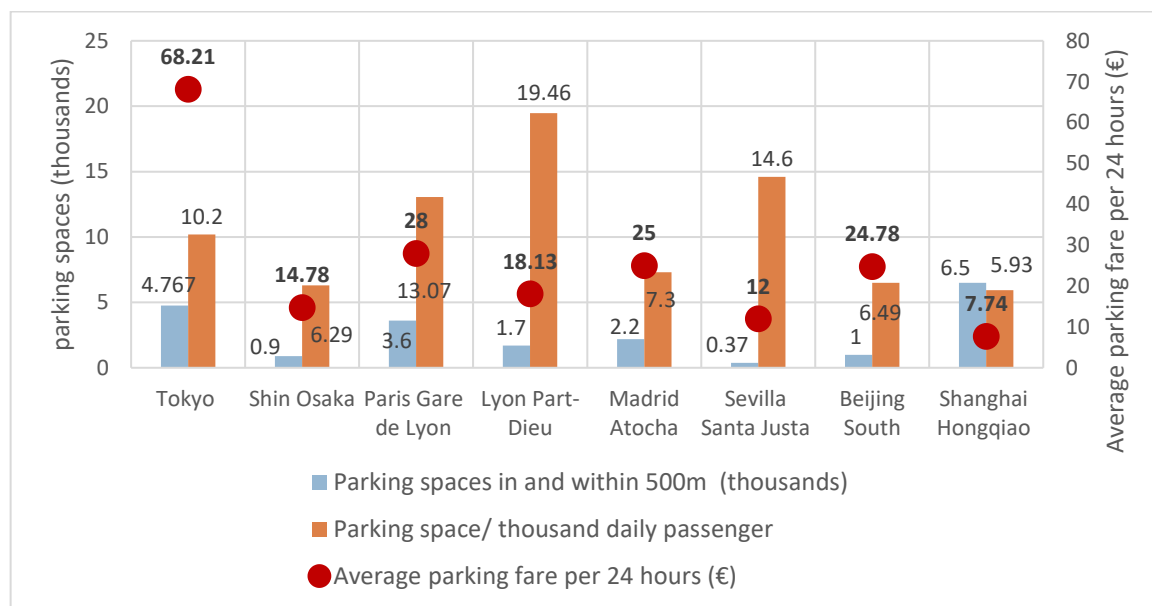


Figure 5-17: Benchmarking the availability and cost of parking spaces

Source: author's elaboration on (Prkimeter, 2018; Tribuna, 2019; Sina, 2019; SNCF, 2019b; Wangshuli, 2018; Inaba, 2019; Osaka-City, 2019b; Yaechika, 2019; NaviTime, 2019; Marunouchi, 2019; Toppi, 2019)

Figure 5-18 illustrates the integration between HSR and air transport. Apart from Shanghai Hongqiao station, reaching the nearest international airports from the benchmarked HSR stations using public transport required between 35 and 60 minutes. Transferring to airports by taxis required between 9 and 125 minutes.

Taxi and public transport fares varied significantly. Reaching the nearest airports from Beijing South and Shin Osaka stations – by public transport – required 70 and 50 minutes respectively. However, the cost of the transfer from Shin Osaka station was around six times higher than the transfer from Beijing South station. Also, taxi fares in the Japanese cases were the highest. Taxi transfers from Tokyo and Shin Osaka stations cost around €150 and €66 respectively. In contrast, the taxi transfer from Beijing South station was the cheapest, costing

a minimum of €15.30. Shanghai Hongqiao is a hub station, combining an HSR station and an international airport which are within walking distance of each other.

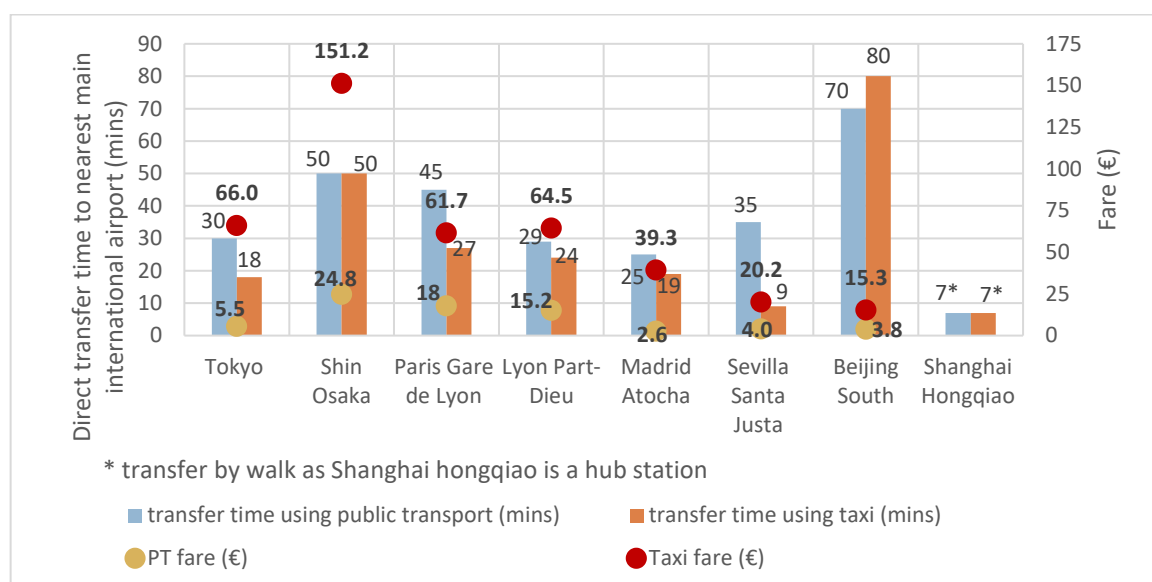


Figure 5-18: Benchmarking costs of reaching international airports from HSR stations

Source: author's elaboration on (Aena, 2019; Gare-de-Lyon, 2019; KIX, 2019; Rhônexpress, 2019; Rome-2-Reo, 2019; Tokyo, 2019)

5.9 International involvement

The international involvement factor reflects the internationalism, worldwide deployment, and participation of HSR operators in global projects, agreements, programmes, and initiatives. Some HSR operators disclose limited information about their international involvement reflecting projects, costs, durations, academic, and technical exchanges. Reporting guidelines do not provide a specific parameter to express operators' global engagement. So, new two indicators have been designed and proposed after considering the themes and topics that are presented in operators' reports:

- EC-10-1: a qualitative and quantitative explanation of how the operator is involved in the international HSR market

- EC-10-2: the share of the international market revenue in the total annual revenue as a monetary value

HSR operators could use the proposed EC-10-1 indicator to reflect on six key points:

- 1) Projects in which the operator is involved – both when offering and receiving assistance – including details of the cost, duration, and parties involved in the project;
- 2) Operator's contribution and level of involvement which could be: full implementation, consultation, sales, management, technical assistance, and training;
- 3) Cooperation, agreements, and dialogue channels with organisations regarding legislation plus technical standards and environmental policies;
- 4) Conditions under which the operator selects a specific country for collaboration, such as political stability, respecting intellectual property, and financial readiness for huge investments;
- 5) Other forms of international exchange such as collection of railway data, sending and hosting exchange scholars, and cooperation with universities and research institutes;
- 6) Reasons for which the operator is willing to become involved internationally, reflecting their philosophy and vision. This could be building an international reputation, generating additional revenue and fulfilling political commitments.

Reporting and benchmarking exercise

The following subsections present examples of how HSR operators have covered some of the six points identified to express the EC-10-1 indicator in their reports and online materials. Neither CRSBG nor CRBBG provided specific information related to their international involvement in their publications, hence data from China Railway (CR) – the parent company – were used.

- **JR Central**

Rather than leading the body implementing the project, JR Central's activity is mainly one of facilitation by providing consultancy and training. Also, JR Central promotes the deployment of HSR systems as full systems, including civil and electrical engineering, rolling stock, signalling, management, and maintenance systems. Internationally, the company is involved in several projects, such as providing technical consultation to the Taiwanese HSR plus two main projects in the USA, namely, the Texas Central Project and the Northern Corridor Project (JR-Central, 2017; JR-Central, 2018). Maintaining and strengthening the technology and skills of Japanese HSR producers plus generating cost reductions constitute factors that motivate JR Central to become involved in the international market. The company says it targets countries which are politically stable and have the financial strength to invest in mega-infrastructure projects, while intellectual property rights are protected. JR Central gathers railway data through its overseas offices and hosts scholars from different countries plus exchanging technical information and expertise with international professionals. JR Central works through the International High-Speed Rail Association (IHRA) to promote their core value of 'crash avoidance' as an international standard (JR-Central, 2017; JR-Central, 2018).

- **SNCF**

The philosophy of SNCF is to become the benchmark for mobility solutions locally and internationally; its share of international market revenue – considering a variety of transport and non-transport activities – is around €11.2 billion, almost the third of its total annual revenue. The company has international presence: SNCF owns 55 per cent of Eurostar's shares and operates the TGV Italia, the high-speed service that links France and Italy. Moreover, SNCF is the parent company of Thalys, the high-speed service which connects Belgium and France. The

company has dialogue channels with different international institutional networks and partners such as the EU, UIC, the Community of European Railway and Infrastructure Companies (CER), and the Transport Decarbonization Alliance (SNCF, 2016b; SNCF, 2017a).

- **Renfe**

Renfe's international involvement is translated through providing technical consultation, training courses and seminars, assistance services, research visits, and materials, and these are facilitated in several projects. For instance, Renfe managed the Haramain HSR project in Saudi Arabia during its construction and commercial operation phases, with a total cost of around €6.74 billion. Moreover, in partnership with ADIF and Globalvia, Renfe won a bid to contribute to the development of the CHSR project in the USA (Renfe, 2015; Renfe, 2017). Renfe's contribution will be translated during two phases: preparing the design and the technical definitions, and developing the operation.

Also, Renfe has delivered several seminars and training courses to the Japan Railway Engineers Association and other institutions in Korea, Israel, and Columbia. The company is a member of multiple international organisations such as the UIC and the International Association of Public Transport (UITP). Moreover, Renfe has signed several cooperation agreements with railways companies in France, Portugal, Japan, India, Ukraine, and Ecuador. Renfe's reports state that its vision and core values are to maintain and strengthen its existence in current international locations while expanding to new markets (Renfe, 2015; Renfe, 2017).

- **China Railway Beijing Bureau Group (CRBBG) and China Railway (CR)**

Internationally, CRBBG is involved in the management and operation of transportation links – buses and trains – that connect Beijing with Moscow, Ulaanbaatar, Pyongyang, and Hanoi in Russia, Magnolia, North Korea, and Vietnam respectively. However, the more

extensive international involvement is mainly featured by China Railway – the parent company of both CRBBG and CRSBG – through a wide range of overseas projects that vary in their size and cost. Most of these projects are located in Asia, Eastern, and Central Europe. For instance, CR is a player in a Hungarian Railway project which connects Hungary and Serbia, with a total length of 342 km. Another project is the China–Laos rail line with a full length of 414 km and a cost of around \$7 billion (CR, 2018c). CR is leading the project, and the design, construction, and operation will follow Chinese standards. Also, CR is involved in other projects in Indonesia, Pakistan, and Thailand. The vision of CR supports the ‘One Belt One Road Initiative’, which is a global development strategy adopted by the Chinese government comprising 152 countries (CR, 2018c).

The four HSR operators have qualitatively covered several points of the proposed EC-10-1 parameter, confirming the possibility of using it as a standardised indicator in future reporting. However, only SNCF quantitatively reported on the proposed EC-10-2 indicator, reflecting on revenues generated from involvement in international projects (SNCF, 2017a; SNCF, 2017c).

5.10 Summary

This chapter has partly answered the third research question of this study, by proposing indicators for expressing the economic factors of the sustainability framework.

The proposed economic indicators offer a ready-to-use template that can be used as the backbone of HSR providers’ economic reporting in the future. Also, they facilitate the minimum level of standardisation that is desired and required for conducting economic benchmarking. The usability of indicators and availability of data were tested through benchmarking exercises which have offered insights into the actual economic sustainability

performance of HSR operators and corridors. Benchmarking data sources were mentioned, and key comparison results were highlighted, revealing significant performance variations among benchmarked corridors and companies. However, these results and variations were not discussed as this will be presented in Chapter 8.

The proposed economic indicators constitute a set of parameters on which most HSR operators plus international organisations agreed and used in their publications. Despite being necessary for reporting and benchmarking, the proposed indicators are neither inclusive nor sufficient. This chapter showed that a variety of indicators can be used to report on economic performance, but these bring standardisation issues, especially when operators use their own definitions and formulas. In addition to the proposed indicators, HSR operators are encouraged to use more parameters that suit their visions and reporting requirements. These could be standardised through exchange and collaboration between different operators. At the same time, international organisations such as the UIC could play a role in facilitating standardisation and normalisation.

CHAPTER 6

REPORTING ON AND BENCHMARKING THE SOCIAL SUSTAINABILITY OF HSR

The previous chapter suggests a variety of indicators that can be used for expressing the selected economic factors of the HSR sustainability framework. Similarly, this chapter proposes a range of quantitative parameters and qualitative indicators for reporting on and benchmarking the selected social factors of the sustainability framework.

The usability of the proposed indicators and the availability of associated data are tested with benchmarking exercises that tackle the social factors at company and corridor levels. A comprehensive explanation of topics and points that can be covered when reporting on the qualitative social indicators is also provided. Figure 6-1 illustrates the step-by-step process of proposing indicators for each social factor.

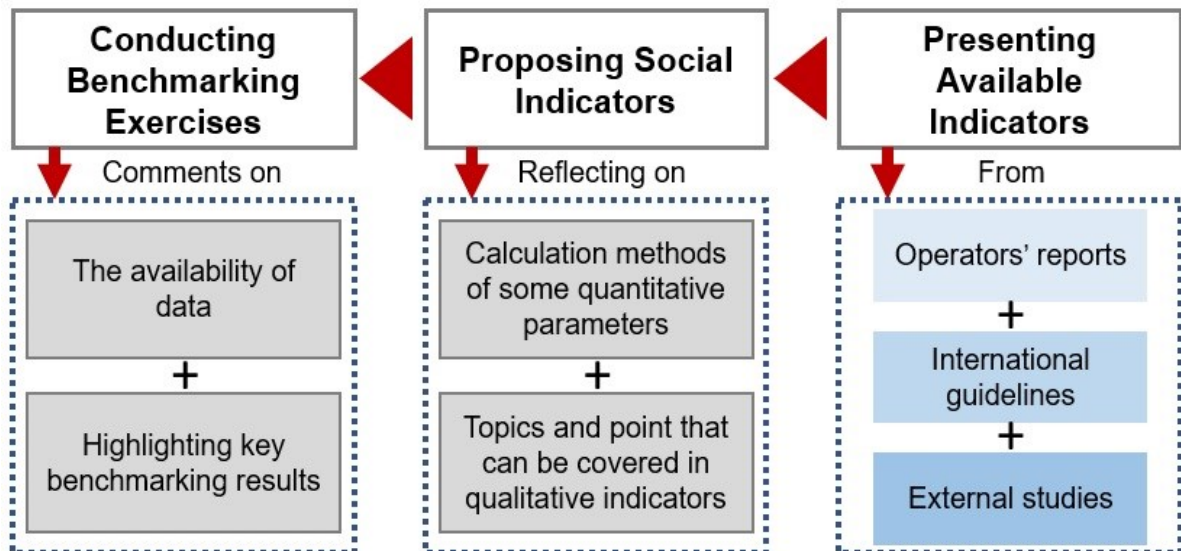


Figure 6-1: Step-by-step process of proposing indicators for each social factor

6.1 Safety

HSR operators use a wide range of parameters for expressing the safety factor. Table 6-1 presents some of these parameters. Some indicators look at the number and type of railway accidents, including derailments, train collisions, on-board fire, and level crossing accidents. Other indicators focus on the impact of railway activities on humans, reflecting on the number and type of fatalities and serious and minor injuries. Moreover, some railway operators distinguish between accidents caused to passengers and those caused to employees in the workplace, or third parties such as pedestrians and drivers. Also, some reports and publications use specific safety and risk indices which feature advanced calculations comprising a set of parameters. All operators provide extensive quantitative and qualitative information about their efforts to promote safe operations and enhance the safety culture in their organisations. Such information reflects on the number of training hours, safety courses and associated investments.

Table 6-1 shows that the Japanese operators tend to focus more on the type and number of train accidents, plus providing some reflection on accidents caused to railway staff. In contrast, most European operators offer more detailed information about the number of fatalities and injuries caused to passengers, employees and third parties. Also, HSR operators do not agree on a specific indicator, which hinders any potential benchmarking exercise. Even when agreeing on the same index, different units are used, imposing standardisation issues. Finally, most safety reporting practices do not distinguish between HSR and other services. The Fatality weighted Injuries (FWI) measure can be used to benchmark safety performance and is widely used in the railway industry (NetworkRail, 2020). It takes all the non-fatal injuries and adds them up using a weighting factor to come up with a total number of fatality equivalents. Exploring operators' reports shows that the FWI was not commonly used, see Table 6-1. Still, it is beneficial to at least report on elements that are required for calculating the FWI.

Table 6-1: Some safety indicators used in operators' reports and publications

Safety indicator/HSR operator	1	2	3	4	5	6	7	8	9	10
Total number of fatalities and injuries due to rail way accidents	*	*			*					
Number of accidents at level crossings		*	*			*				
Number of train accidents		*								
Number of accidents to employees by type		*								
Number of employee accidents resulting in lost work time	*	*								
Number of accidents resulting in injuries or fatalities on board	*									
Number of railway accidents by type	*		*		*	*		*		
Number of railway accidents with casualties on platforms			*							
Total annual number of fatalities on the passenger rail network				*						
Number of transport disruptions and failures reflecting on the cause	*	*	*							
Number of properties damaged due to railway accidents	*	*	*							
Number of employees killed due to significant accidents					*		*	*		
Number of employees seriously injured due to significant accidents					*					
Number of passengers killed due to significant accidents					*	*			*	
Number of passengers seriously injured due to significant accidents					*	*			*	
Number of third parties killed due to significant accidents					*				*	
Number of third parties seriously injured due to significant accidents					*					
Number of accidents at work by gender					*					
Fatality weighted index/injuries FWI					*			*		
Workplace accident frequency rate (%)					*	*		*		*
Number of work days lost due to accidents in the workplace (per 1000,000 hours)						*	*			
Number of days of absence						*		*		
Absenteeism rate due to accidents at work								*		
Safety and risk index					*			*		*
Occurrence of human errors per million km	*	*	*							*

Source: author's elaboration on (DB, 2017; FS-Italiane, 2017; JR-Central, 2019d; JR-Central, 2018; JR-East, 2018b; KORAIL, 2017; NRB, 2019; Renfe, 2015; Renfe, 2017; SNCF, 2017a; SNCF, 2019d; THSR, 2017)

The UIC database publishes annual safety reports focusing on two indicators: the number of accidents by type, and the number of passengers, employees, and others who are killed or injured due to railway accidents (UIC, 2016b; UIC, 2017; UIC, 2018c). Also, the European Union Agency for Railways (EAR) discloses safety information using the same indicators (EAR, 2017). Finally, the GRI safety guidelines suggest disclosing information about the number of staff who are killed or injured in the workplace (GRI, 2018b).

By matching the operators' reporting interests presented in Table 6-1 with the UIC, EAR, and GRI publications, the sustainability framework proposes the following parameters for reporting and benchmarking purposes:

- SO-1-1: the total number of significant rail accidents
- SO-1-2: the number of staff killed, seriously/minorly injured in the workplace
- SO-1-3: the number of passengers killed, seriously/minorly injured due to railway accidents
- SO-1-4: the number of third-party people killed, seriously/minorly injured due to railway accidents

Regarding the level of targeted injuries, indicators SO-1-1, SO-1-2, and SO-1-3 consider both serious and minor injuries, and it is optimum to distinguish between them when reporting on safety. The total number of significant accidents includes train collisions, derailments, level crossing accidents, fires on locomotives, and other accidents.

Reporting and benchmarking exercise

Figure 6-2 compares the operators' total number of railway accidents for 3 years. Data for the benchmarking exercise were retrieved from different sources, including the UIC database. JR Central and Renfe accident figures were available in the operator's native language via websites, which were translated by the author for extracting comparable data. It is worth

mentioning that data were available for each type of accident including derailments, collisions with trains, level crossing accidents, rolling stock fires, and other accidents. These were combined and normalised to the total route km operated by each company. The accident data presented relates to all rail activities managed by each operator, as data that relate exclusively to HSR were not available. The comparison shows that Renfe followed by SNCF had the safest railway operations in all years, while JR East witnessed the significantly highest number of rail accidents. For instance, in 2016, the number of rail accidents for JR East was around 21 accidents per 1000 route km, compared to only four and five accidents per 1000 route km for Renfe and SNCF respectively. The safety performance of JR Central showed remarkable variation among different years, especially when compared with other operators, which showed a more consistent performance. The number of accidents reported by JR Central grew from almost 4.6 accidents per 1000 route km in 2016 to around 9 accidents per 1000 route km in 2017 and decreased again to 6.6 accidents per 1000 route km in 2018.

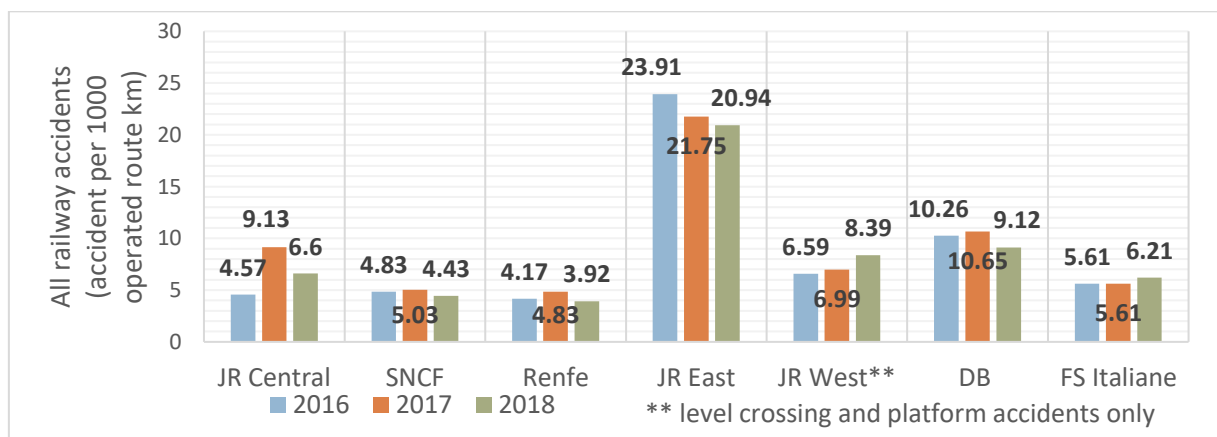


Figure 6-2: Comparison of the total number of significant railway accidents by HSR operator

Source: author's elaboration on (INdE, 2019; JR-Central, 2019d; UIC, 2019c)

Figure 6-3 looks at the number of passengers, employees, and third parties killed and injured between 2012 and 2015. The comparison considers four rail systems in four European countries, after applying the appropriate normalisation. Again, the safety data presented relate

to all rail services and were collected from the Eurostat database and SNCF's open data website. The comparison shows that number of third parties who were killed and injured was significantly higher than the number of passengers and staff killed and injured. During the 4 years, Spain showed the lowest number of fatalities and injuries, with around 197 and 134 people killed and injured respectively, considering the fatal HSR accidents of 2013 which killed 79 passengers. In contrast, Germany showed the highest numbers, with 629 and 550 people killed and injured respectively. Normalising the number of fatalities and injuries to the total route km for each country shows that France featured the safest railway operations, with around 9.2 and 6.9 people killed and injured per 1000 route km respectively, while Germany had the highest number of fatalities and injuries, with almost 19 and 17 people killed and injured per 1000 route km respectively. Notably, the number of third-party people killed in each country is higher than numbers of third-party people injured. This might be related to two reasons; first, a railway accident is likely to cause death rather than in injury; second, numbers of third-party people killed include those who committed suicide on tracks plus those who lost their lives in level-crossing and junction accidents.

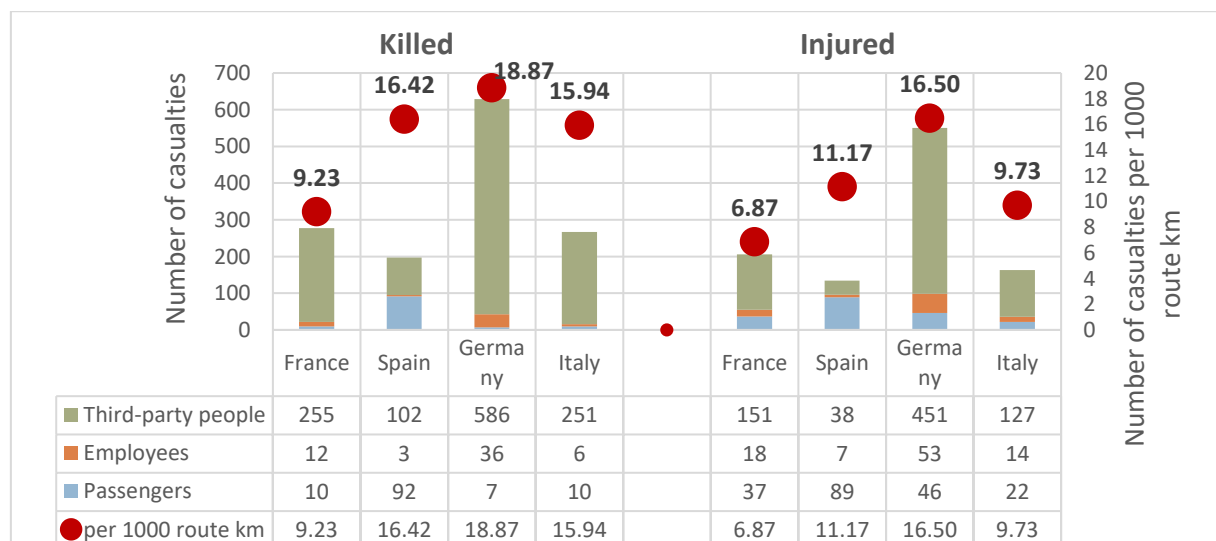


Figure 6-3: Comparing the number of casualties by type between 2012 and 2015

Source: author's elaboration on (Eurostat, 2019; SNCF, 2019d)

6.2 Door-to-door travel time

The annual and sustainability reports of some HSR operators contain mixed quality information about DTD solutions. These mostly reflect on integrated ticketing systems, shared cycling schemes, and collaborations with other transport operators (JR-East, 2018b; Renfe, 2017; SNCF, 2017a). However, the current disclosure practices focus on specific topics while ignoring many more points that could be covered in reports. Moreover, the current reporting mechanism does not provide a standardised parameter that allows direct benchmarking exercises. Both Chen and Wei (2013) and Leboeuf (2018) suggested DTD travel time as a performance parameter which could be used for benchmarking purposes.

The sustainability framework suggests two indicators for reporting on the DTD journey factor:

- SO-2-1: the overall door-to-door travel time between two points
- SO-2-2: a qualitative explanation of operators' efforts and solutions for providing a seamless door-to-door journey

When calculating SO-2-1, the two points refer to famous attractions in the origin/destination cities, and these could include hospitals, tourist attractions, universities, and city centers. The SO-2-1 indicator allows two different comparisons to be conducted. First, it benchmarks HSR corridors against each other. Second, it benchmarks HSR against other transport modes that operate along the same corridor. The outputs of the second comparison are essential since they are often used in transport demand management studies which calculate generalised costs associated with travellers' mode choice (Wardman and Toner, 2018).

SO-2-1 can be calculated according to the following formula (Chen and Wei, 2013; Leboeuf, 2018)

$$SO - 2 - 1 = \frac{T1 + T2 + T3 + T4 + T5 + T6 + T7}{\text{The total distance}}$$

- T1: time spent from the starting location to the connecting transport mode's stop, including waiting time;
- T2: transfer time spent in the connecting mode to the departure HSR station;
- T3: time spent within the departure HSR station for collecting tickets, security checks, finding the platform, and other potential tasks;
- T4: in-train travel time between two HSR stations;
- T5: time spent within the arrival HSR station for collecting luggage, finding exits, and connecting transport modes;
- T6: transfer time spent in the connecting mode from the arrival HSR station to the final destination's nearest stop;
- T7: time spent from the connecting mode's final stop to the final destination.

After considering the topics that are covered in operators' reports plus the UIC's recommendations, the qualitative reporting on the SO-2-2 indicator could cover the following points (DB, 2017; FS-Italiane, 2017; JR-East, 2018b; Leboeuf, 2018; Renfe, 2017; SNCF, 2017a; UIC, 2019a):

- Innovative solutions and interventions in the areas of: providing regular and straightforward mobility service connections; enhancing transport facilities and associated ergonomics; travel information provision; smart and integrated ticketing; tracking; and building travel planning apps that support multimodal bookings;
- Solutions might consider both personal and shared mobility. Personal mobility comprises walking, cycling, and driving. Shared mobility includes 1) scheduled, 2) semi-continuous, and 3) on-demand mobility. Scheduled mobility incorporates metros, trams, buses, coaches,

and bus rapid transit. Semi-continuous mobility encompasses cable cars, public lifts and escalators, and automated movers. Finally, on-demand mobility covers shuttles, taxis, bike-sharing schemes, carpooling and vanpooling, micro-transit and bus responsive networks, e-hails, car and van sharing, and moped sharing;

- HSR operator collaborations with transport operators plus station and infrastructure managers.

Reporting and benchmarking exercise

Table 6-2 presents the calculations for the SO-2-1 indicator along the selected HSR corridors. Three scenarios were considered in the comparison, and all calculations were made under the following assumptions:

- All trips under different scenarios start at 8 am from a residential address in the origin city;
- The connecting transport mode's average waiting time is 5 minutes;
- Only public transport modes and walking are used in the legs of the journey.

Table 6-2: Calculating the door-to-door journey times and distances of different scenarios

Scenario (1): from a residential address in the origin city to a main hospital in the destination city									
		T1	T2	T3	T4	T5	T6	T7	T
Tokyo to	Time (minutes)	21	24	8	150	4	17	10	234
Osaka	Distance (km)	1.1	11.4	0	552.6	0	5.4	0.7	571.2
Paris to Lyon	Time	21	38	10	117	4	23	5	218
	Distance	1.1	11.4	0	425	0	3.3	0.3	441.1
Madrid to	Time	21	31	10	152	3	15	6	238
Seville	Distance	1.1	7.1	0	471	0	3.9	0.55	483.65
Beijing to	Time	21	34	20	270	6	13	21	385
Shanghai	Distance	1.1	11.4	0	1318.3	0	8.4	1.1	1340.3
Scenario (2): from a residential address in the origin city to a main university in the destination city									
		T1	T2	T3	T4	T5	T6	T7	T
Tokyo to	Time (minutes)	21	24	8	150	4	40	2	249
Osaka	Distance (km)	1.1	11.4	0	552.6	0	11.8	0.1	577
Paris to Lyon	Time	21	38	10	117	4	13	14	217
	Distance	1.1	11.4	0	425	0	2.6	1.2	441.3
Madrid to	Time	21	31	10	152	3	19	13	249
Seville	Distance	1.1	7.1	0	471	0	2.7	1	482.9
Beijing to	Time	21	34	20	270	6	91	2	444
Shanghai	Distance	1.1	11.4	0	1318.3	0	25.2	0.2	1356.2
Scenario (3): from a residential address in the origin city to a city centre attraction in the destination city									
		T1	T2	T3	T4	T5	T6	T7	T
Tokyo to	Time (minutes)	21	24	8	150	4	9	5	221
Osaka	Distance (km)	1.1	11.4	0	552.6	0	4	0.3	569.4
Paris to Lyon	Time	21	38	10	117	4	13	13	216
	Distance	1.1	11.4	0	425	0	2.25	0.95	440.7
Madrid to	Time	21	31	10	152	3	25	5	247
Seville	Distance	1.1	7.1	0	471	0	1.7	0.5	481.4
Beijing to	Time	21	34	20	270	6	30	4	385
Shanghai	Distance	1.1	11.4	0	1318.3	0	15.4	0.2	1346.4

Source: author's elaboration on Google Maps, Baidu Maps, Moovit travel planning app, and operators' commercial websites

Figure 6-4 summarises the calculations of Table 6-2 and benchmarks the DTD travel time per km of selected HSR corridors under different scenarios. Applying normalisation – by calculating the travel time per distance – allows direct comparison between different corridors. Data for the benchmarking exercise were obtained from travel planning, commercial, and map websites. The comparison shows that the Asian corridors facilitated the fastest DTD journeys under all scenarios, when compared with the European corridors. Also, the Beijing–Shanghai corridor featured the significantly fastest DTD journeys among all corridors and under all scenarios. For instance, travelling from a residential address in Beijing to a hospital in Shanghai required less than 0.3 minutes/km, whereas similar journeys required more than 0.4, 0.5, and 0.5 minutes/km in Japan, France, and Spain respectively. This is because the Beijing–Shanghai corridor feature significantly the longest distance travelled by HSR. DTD travel times for the European corridors were remarkably close to each other, and the average time was around 0.5 minutes/km.

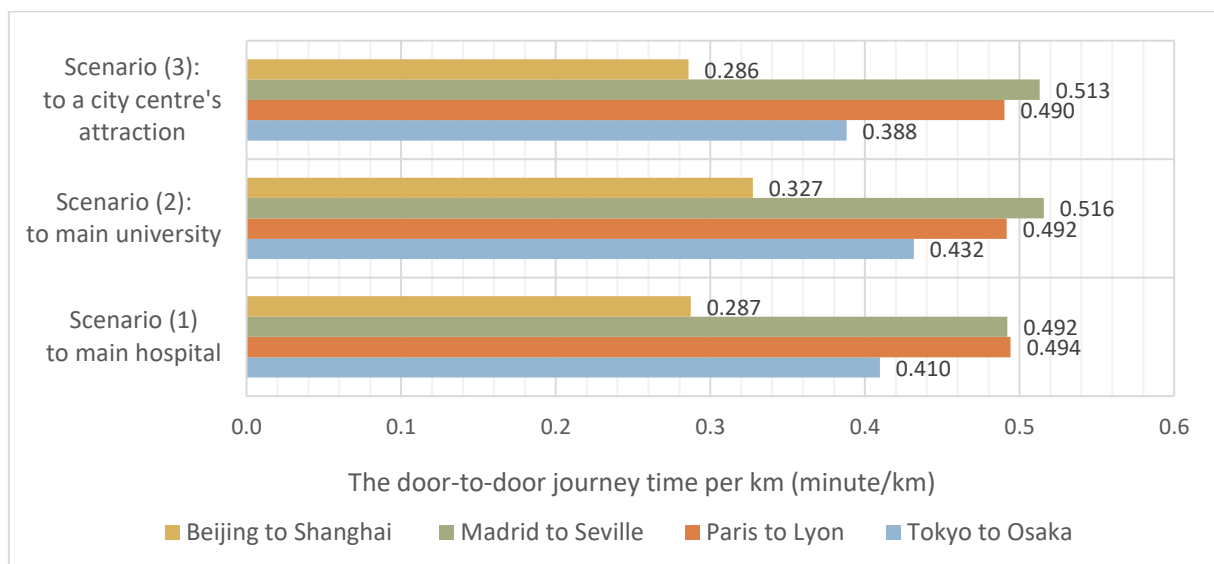


Figure 6-4: Comparing the door-to-door travel time of selected HSR corridors

Source: author's elaboration on Google Maps, Baidu Maps, Moovit travel planning app, and operators' commercial websites

6.3 Rapid expropriation

The rapid expropriation factor relates to land and property acquired during the planning and construction stages of HSR lines. In their reports and websites, HSR companies discuss this factor focusing on two main scopes: the expected acquisition of land and property that will occur along the HSR project; and the compensation that will be provided to land and property owners (CHSR, 2017b; HS2, 2019; NHSRC, 2017; NHSRC, 2015). Also, these two scopes are usually tackled by feasibility studies and the articles of independent scholars, economic centres, and online articles (Arcadis, 2018; Gabbatiss, 2018 ; Hongtong, 2019). The first scope tackles the number and location of properties that will be acquired by the HSR company, including farms, residential buildings, businesses, and community facilities. These could be located within a distance from the track that ranges between 100 and 500m depending on the land use policy of each country. For expressing the first scope, a quantitative indicator is proposed:

- SO-4-1: the total number of homes that will be demolished per route km

A home refers to the residence of one family. In addition to the total number of homes, companies could report on the number of other properties, including businesses, workshops, religious buildings, schools, and farms.

The second scope focuses on compensation offered to land and property owners. The following proposed qualitative indicators could represent the second scope:

- SO-4-2: a qualitative explanation of how the HSR company is willing to compensate land and property owners

The SO-4-2 indicator constitutes the compensation code of each HSR company, and it can be used to discuss and report on four topics (GRI, 2016b; Prkimeter, 2018; SNCF, 2017b; Tribuna, 2019):

1. Monetary compensation to be provided for property owners plus details regarding their rates, dates, and the claim procedure;
2. Housing relocation schemes that are offered by the HSR company;
3. Rehabilitation and resettlement programmes to help those who have been displaced from their property in adapting to their new life.
4. The legal advice and consultation available to help owners in claiming their rights.

The third point of the SO-4-2 indicator is important. Farmers and owners of local businesses are more likely to have their homes – and their only source of income – destroyed, and financial compensation alone might not be enough. These specific groups are accustomed to the rural lifestyle and basic economic activities and displacing them to a new urban setting might constitute a severe disadvantage. For this reason, rehabilitation programmes are vital in developing countries to assist farmers and those with a minimum level of literacy in starting a new life and business. Compensation and land acquisition programs should distinguish between different affected groups and should monitor variations in local conditions of different classes. Surveys that explore current conditions, expectations, worries, and plans of land and property owners could be utilised as a monitoring tool.

Reporting and benchmarking exercise

Figure 6-5 illustrates a benchmarking exercise presenting the SO-4-1 indicator for four HSR projects, namely, HS2 in the UK; CHSR in the USA; the Eastern Economic Corridor (EEC) HSR in Thailand; and the National HSR (NHSR) project in India. All these projects are

currently in their planning and construction stages. Data were retrieved from different sources, including company reports and feasibility studies.

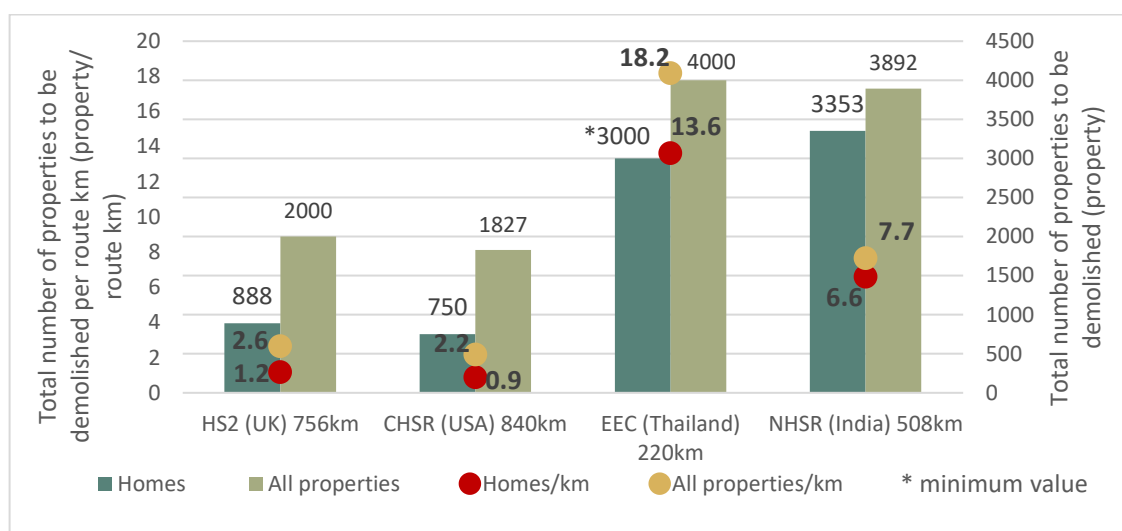


Figure 6-5: Number of properties which will be demolished along HSR corridors

Source: author's elaboration on (Arcadis, 2018; CHSR, 2017b; EEC, 2019; Gabbatiss, 2018 ; Hongtong, 2019; HS2, 2019; NHR, 2015)

Figure 6-5 shows that the Thailand EEC had the highest demolition rate when compared with other HSR projects. Despite the total numbers of homes and properties to be demolished along the EEC being close to their counterparts in the NHR project, the per route km comparison shows that the EEC's figures were double those for the NHR. For example, 13.6 homes per route km were demolished along the EEC, compared to 6.6 homes per route km along the NHR project. The effects of HS2 and CHSR seem to be close to each other at lower levels.

Table 6-3 shows how HSR companies cover the topics of the proposed SO-4-2 indicator in their reports and publications. Reporting variation is evident among HSR companies. HS2 and NHR provided comprehensive information regarding several points of the proposed SO-4-2 indicator, whereas the EEC company offered little information about the compensation code. All companies disclosed information about monetary compensation available to land and

property owners. However, only HS2 reported on the availability of legal advice regarding compensation matters, while NHSR was the only company to report on the availability of rehabilitation programs.

Table 6-3: Availability of topics of the SO-4-2 indicator in reports, websites, and online materials

Topics within the SO-4-2 indicator	HS2	CHSR	EEC	NHSR
Monetary compensation and claim process	*	*	*	*
Housing relocation schemes	*	*		*
Rehabilitation and resettlement programmes				*
Legal advice and consultation available	*			

Source: author's elaboration on (CHSR, 2017b; EEC, 2019; HS2, 2019; NHSRC, 2017; NHSRC, 2015)

6.4 Engaging with local communities

Railways as a transportation system have strong ties and are closely connected with local communities. To express this factor, the GRI reporting guidelines suggest as an indicator the percentage of operations with local community engagement implemented (GRI, 2016c). However, HSR operators do not use this specific indicator. Instead, in their reports they generally explain their engagement efforts with local communities qualitatively. The monetary value of investing in communities and associated total expenditure could also be used as a quantitative parameter for both reporting and benchmarking purposes; however, only Renfe has used this indicator in their reports (Renfe, 2015; Renfe, 2017). It is worth mentioning that the level of engagement with local communities is influenced by; the societal culture within the railway company; and, expectations of local communities.

The sustainability framework suggests a qualitative indicator to express the engagement with local communities factor:

- SO-6: a qualitative explanation of how the operator is engaging and working with local communities

The SO-6 indicator could cover a wide range of topics. After thoroughly examining the topics that are presented in operators' publications, this study has identified the following 14 points among those on which HSR could disclose information (DB, 2017; FS-Italiane, 2017; JR-Central, 2017; JR-East, 2018b; KORAIL, 2017; Renfe, 2017; SNCF, 2017a; THSR, 2017):

1. Operating local facilities such as healthcare institutions and museums;
2. Promoting local businesses, goods, and products of local agriculture and industries and selling these on trains and in stations;
3. Engagement in activities to enhance arts, culture, learning, and sports plus organising competitions;
4. Conducting school visits and spreading sustainable mobility culture plus promoting issues such as safety and fighting sexual harassment;
5. Commitment to local environmental initiatives and programmes of recycling, tree plantation, and rubbish collection;
6. Addressing practical tools to boost tourism and the attractiveness of local attractions such as running special trains and buses, providing tourist passes, and an integrated ticketing system;
7. Communicating with locals through ballots, meetings, and focus groups plus considering their feedback and recommendations;
8. Assisting people in hardship such as jobless and homeless people;

9. Growing local economies through local hiring, local sourcing, supporting innovations, and providing grants for business starters;
10. Commitment to programmes devoted to assisting children and people with disabilities;
11. Engagement in urban and town development plans such as building residential units for workers;
12. Solutions to enhance the comfort and accessibility to local stations by installing multi-functional toilets, elevators, and help points plus utilising modern technology such as robots for this purpose;
13. Operating websites, festivals, and campaigns to increase the attractiveness of local communities while using these as platforms for further communication;
14. The monetary value of the investment in and expenditure on engaging with local communities.

Reporting and benchmarking exercise

Table 6-4 shows the topics from the proposed SO-6 indicator in which selected HSR operators were involved in 2017, according to their publications and external websites. The comparison shows variation among operators in terms of their involvement with local communities. Each operator was engaged in at least half the 14 topics identified. Renfe followed by SNCF covered the majority of engagement topics, with 11 and 10 topics respectively, while the Asian operators showed a lower engagement level in their reports, covering around half the engagement themes identified. Topics such as enhancing station accessibility, engaging in cultural activities, assisting disabled people, and operating facilities were covered by all operators, whereas topics like conducting school visits and local hiring were generally not covered.

Table 6-4: Reporting on topics of the proposed SO-6 indicator

SO-6 topics	JR Central	SNCF	Renfe	CRSBG	CRBBG	Total
Operating facilities	*	*	*	*	*	5
Promoting local businesses	*	*	*			3
Engaging in art, culture, and sports	*	*	*	*	*	5
Conducting school visits		*				1
Environmental programmes		*	*	*	*	4
Tools to boost local tourism	*		*	*	*	4
Communicating with locals			*			1
Helping people in hardship		*	*			2
Local hiring, sourcing, innovation		*				1
Assisting children and disabled	*	*	*	*	*	5
Urban development plans	*					1
Enhancing station accessibility	*	*	*	*	*	5
Running websites and campaigns	*	*	*	*	*	5
Monetary value of the investment			*			1
Total points covered (out of 14)	8	10	11	7	7	

Source: author's elaboration on (CR, 2018b; JR-Central, 2017; JR-Central, 2018; Renfe, 2017; Renfe, 2019c; SNCF, 2017a; SNCF, 2017d)

6.5 Customer satisfaction

The GRI reporting guidelines recommend the results of a survey that measures customer satisfaction as an indicator for expressing the customer satisfaction factor (GRI, 2016b). Also, the European Commission presents the Market Performance Indicator (MPI) as an index comprising topics and issues that measure the performance of rail services from the customer's perspective (EC, 2017). Railway operators conduct regular surveys to help them gain an understanding of how rail users assess their experience and satisfaction of using the rail service,

while in both trains and stations. Considering operators' reports and GRI recommendations plus the MPI, the sustainability framework proposes the following indicator:

- SO-7: the overall passenger satisfaction level of the HSR service (%)

HSR operators could extract the SO-7 indicator from the findings of customer satisfaction surveys which might cover the following points:

- The provision of travel information during both regular services and disruptions;
- The ease of obtaining travel information via websites, mobile apps, electric boards, and help points in stations;
- The ease of buying train tickets through different platforms;
- The availability of multiple travelling choices in terms of duration and pricing;
- The stability and reliability of the service;
- The comfort and convenience of the journey;
- The extent to which railway staff are helpful and welcoming;
- Quality of travellers' free time while on trains, activities on which they spend it plus additional services provided such as Wi-Fi and charging points;
- Quality of travellers' free time while in stations;
- The ease of travel for disabled people, the elderly, and children;
- The trust of customers and their expectations;
- The value for money of the selected service.

Reporting and benchmarking exercise

Figure 6-6 presents the overall passenger satisfaction levels for several HSR services. Data were mostly retrieved from operators' reports. It was found that the European operators provided very detailed quantitative information about the customer satisfaction levels of

different transport services, including HSR. In contrast, the Japanese operators qualitatively discussed efforts to enhance customer satisfaction without quantitatively reporting on satisfaction levels. Even in the case of JR East, the company disclosed the overall satisfaction level of all transport services without providing specific data about their Shinkansen services.

The comparison shows that FS Italiane's HSR service gained the highest customer satisfaction level, whereas DB and Renfe services achieved satisfaction levels below the average of 83.8 per cent. However, customer satisfaction with HSR services was relatively higher than their satisfaction with all rail services combined in Europe.

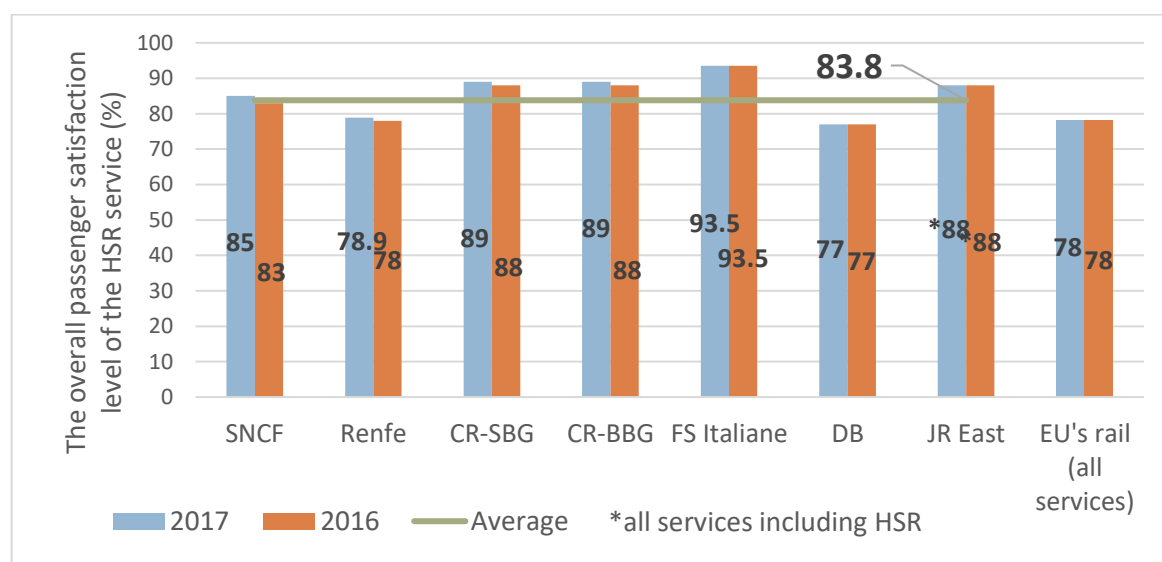


Figure 6-6: Benchmarking passenger satisfaction levels of HSR services

Source: author's elaboration on (DB, 2017; EC, 2017; FS-Italiane, 2017; JR-East, 2017; Renfe, 2017; SNCF, 2017a)

6.6 Employment

HSR operators use a wide range of parameters when reporting on employment, including but not limited to the total number of employees by age, gender, and contract type. These metrics are usually accompanied by quantitative and qualitative explanations of training, skills improvement schemes, and other benefits provided to employees (DB, 2017; JR-Central,

2018; Renfe, 2017; SNCF, 2017a). The GRI guidelines offer a rich list of indicators that could be used for disclosing employment information (GRI, 2016d).

After considering and matching topics from operator reports with GRI guidelines, the sustainability framework suggests the following six indicators for reporting on employment:

- SO-8-1: the total number of employees;
- SO-8-2: the percentage of women in the workforce;
- SO-8-3: total training hours provided per employee;
- SO-8-4: annual turnover rate of employees.

SO-8-4 can be calculated according to the following formula (Pavlou, 2018):

$$\text{Annual turnover rate \%} = \frac{\text{Number of employees who left}}{(\text{beginning} + \text{ending number of employees})/2} \times 100$$

These proposed quantitative parameters could be accompanied by a qualitative and quantitative explanation of the benefits that are provided to employees regarding life insurance, parental leave, salary, disability coverage, retirement compensation, stock ownership, healthcare, and others.

Reporting and benchmarking exercise

Table 6-5 presents key employment figures that express the proposed SO-8-1, SO-8-2, SO-8-3, and SO-8-4 indicators. SNCF reported the biggest number of employees in both 2016 and 2017, followed by CRBBG and CRSBG. JR Central reported the lowest turnover rate of only 1 per cent, which seems to be not credible. The highest level of female staff representation in the workforce was reported by CRBBG followed by CRSBG, where 36 per cent and 34 per cent of employees were females respectively.

Table 6-5: Key employment figures of different HSR operators in 2016 and 2017

	JR Central	SNCF	Renfe	CRSBG	CRBBG
Total number of employees (2017)	18116	270814	14581	160000	176000
Total number of employees (2016)	18054	270335	13955	154368	175000
Women in the workforce (2017) (%)	11	25	12.57	34	36
Women in the workforce (2016) (%)	10	25.3	10.91	34	36
Turnover rate (2017) (%)	1	8.2	5.86	2.4	3.7
Turnover rate (2016) (%)	1	7.17	4.91	2.6	4
Total training hours (2017)	652176	8630000	477167	5392000	6019200
Total training hours (2016)	649944	7569000	484801	5230500	6002500

Source: author's elaboration on (Baidu, 2019; CR-yearbook, 2016; CR-yearbook, 2017; JR-Central, 2018; LiaoningRailway, 2018; Lingui, 2017; Renfe, 2017; SNCF, 2017a)

Figure 6-7 benchmarks HSR operators in terms of the number of employees per route km in 2016 and 2017. Data were extracted from annual reports plus the China Railway Yearbooks of 2016 and 2017. All benchmarked HSR operators disclosed aggregate numbers of employees who work in the company without differentiating between different departments and services. In other words, HSR operators did not report on the number of staff who exclusively relate to HSR services. Apart from Renfe, all benchmarked operators are responsible for managing the rail infrastructure. So, to conduct a fair comparison, the number of employees of both Renfe and ADIF, the rail infrastructure manager in Spain were combined.

When normalising the total number of employees by the total route km in 2017, CRBBG reported the biggest number of employees, with around 20 staff per route km, whereas Renfe together with Adif had the lowest number with almost two staff per route km. Each of SNCF and JR Central reported around nine staff per route km. Finally, between 2016 and 2017, Renfe decreased their total number of staff, while all other operators recruited more employees.

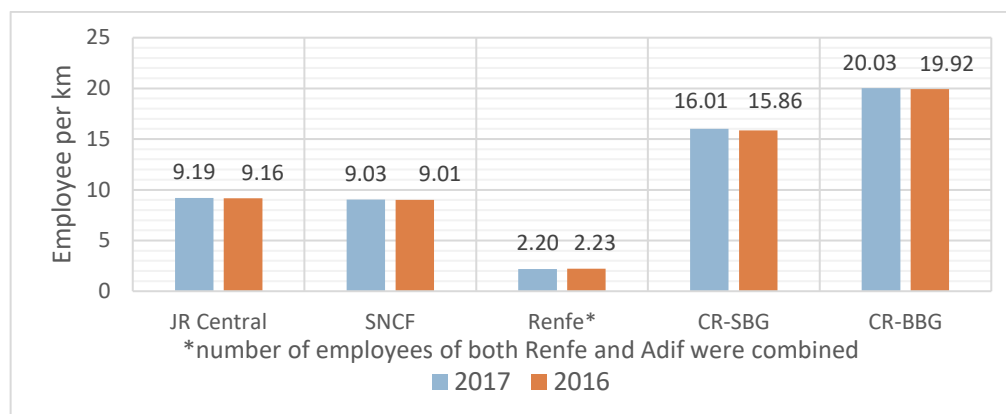


Figure 6-7: Comparing the number of employees per route km

Source: author's elaboration on (Adif, 2017; Adif, 2019b; Baidu, 2019; CR-yearbook, 2016; CR-yearbook, 2017; JR-Central, 2017; JR-Central, 2018; LiaoningRailway, 2018; Lingui, 2017; Renfe, 2017; SNCF, 2017a)

Figure 6-8 compares HSR operators in terms of training hours provided to employees in 2016 and 2017. JR Central reported the highest level in both 2016 and 2017, offering 36 training hours to each of their employees annually. Numbers of training hours offered to employees of all HSR operators were relatively close to each other, with an average of 34 training hours per person. The reported training was offered to staff of different departments within companies and not related to only HSR staff.

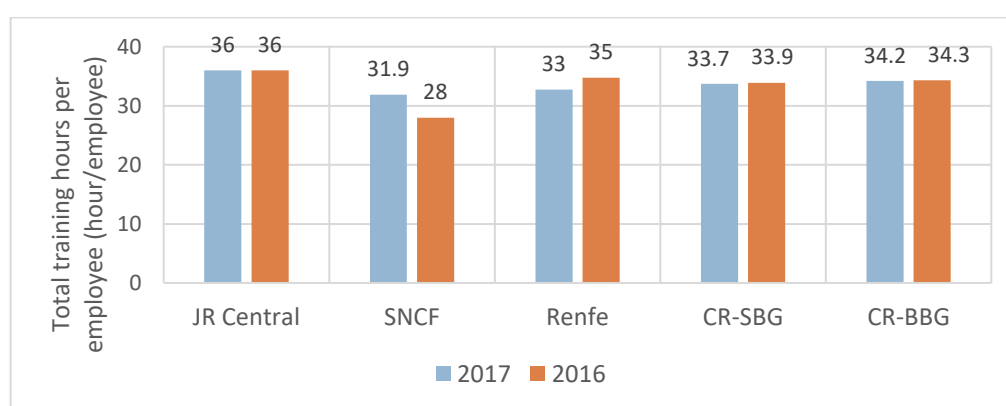


Figure 6-8: Benchmarking the total training hours per employee

Source: author's elaboration on (JR-Central, 2017; JR-Central, 2018; Renfe, 2017; SNCF, 2017a)

6.7 Affordability and operators' initiatives

Affordability looks at the monetary costs associated with purchasing HSR tickets in countries with different per capita incomes. Some HSR operators such as SNCF disclose in their reports information about offers and discounts available to specific groups in society (SNCF, 2017a). However, less attention is paid to reporting ticket prices across different lines, dates, and classes. The international reporting guidelines do not provide specific parameters for reporting on the affordability of transport services. The proposed framework suggests the following three indicators for benchmarking and reporting on the affordability of HSR services:

- SO-9-1: the fare for 100 km of HSR travel along different corridors
- SO-9-2: the fare for 100 km of HSR travel along different corridors, relative to the net average monthly income (%)
- SO-9-3: a qualitative explanation of discounts and offers available to students, senior citizens, the disabled, and disadvantaged groups

$$SO - 9 - 2 (\%) = \frac{\text{cheapest one - way fare} \times 10000}{\text{distance} \times \text{net monthly per capita income}}$$

Some operators increase ticket prices when these are being booked at a date close to the travel date. So, when reporting on the SO-9-1 and SO-9-2 parameters, different in-advance booking scenarios could be considered. Relating ticket costs to net monthly income provides a more robust comparison, showing how the population of each country will perceive the price and affordability of HSR tickets.

Reporting and benchmarking exercise

Figure 6-9 compares the cheapest one-way HSR fares along selected corridors. Data for the benchmarking exercises were retrieved from operators' commercial websites, and two

scenarios have been considered: one week in advance bookings and one day in advance bookings. In the case of one week in advance bookings, the Tokyo–Osaka ticket was significantly the most expensive, at around \$124, whereas the Paris–Lyon ticket was the cheapest, at almost \$18.50. Similarly, for 100 km of HSR travel, the Tokyo–Osaka ticket was the most expensive, while the Paris–Lyon ticket was the cheapest, at around \$22.40 and \$4.40 per 100 km respectively.

Prices of tickets which were booked one day in advance were identical to those booked one week in advance in the cases of Tokyo–Osaka, Paris–Lyon, and Beijing–Shanghai. However, late booking increased ticket prices in the cases of Madrid–Seville and Rome–Milan, and while the increment was around 10 per cent in the Madrid–Seville case, the ticket price almost doubled in the Rome–Milan case.

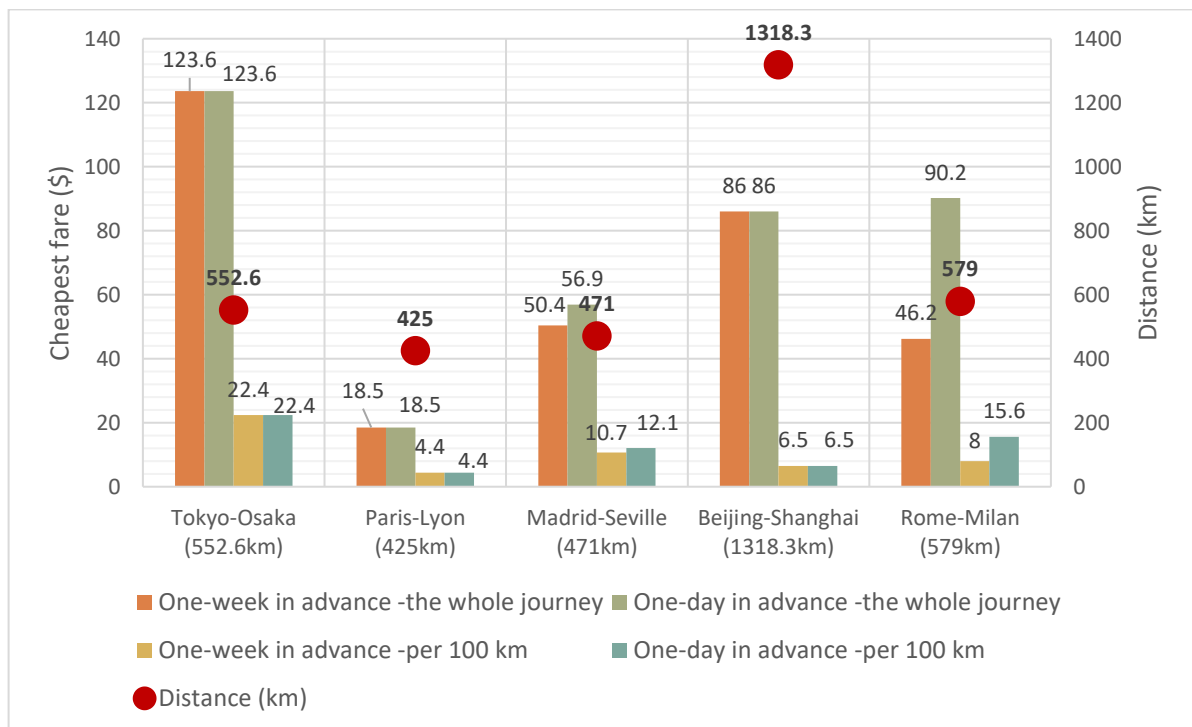


Figure 6-9: Comparing HSR fares along selected corridors

Source: author's elaboration on (Renfe, 2019a; SNCF, 2019a; JR-Central, 2019b; CH, 2019a; FS-Italiane, 2019)

Figure 6-10 presents HSR fares after relating them to the average net monthly per capita income of selected corridors. The comparison shows that for one week in advance bookings, the Paris–Lyon ticket was the cheapest, as its price constituted around 0.7 per cent of the net monthly income in France. In contrast, the Beijing–Shanghai ticket was the most expensive, as its price was almost 15.7 per cent of the net monthly income in China.

The Tokyo–Osaka ticket cost around 4.8 per cent of the average net monthly income in Japan, while Madrid–Seville and Rome–Milan tickets were relatively cheaper, costing approximately 2.6 per cent and 2.1 per cent of the average net monthly incomes of Spain and Italy respectively. The per 100 km HSR pricing showed similar trends, since the Beijing–Shanghai ticket was the least affordable, whereas the Paris–Lyon ticket was the most affordable.

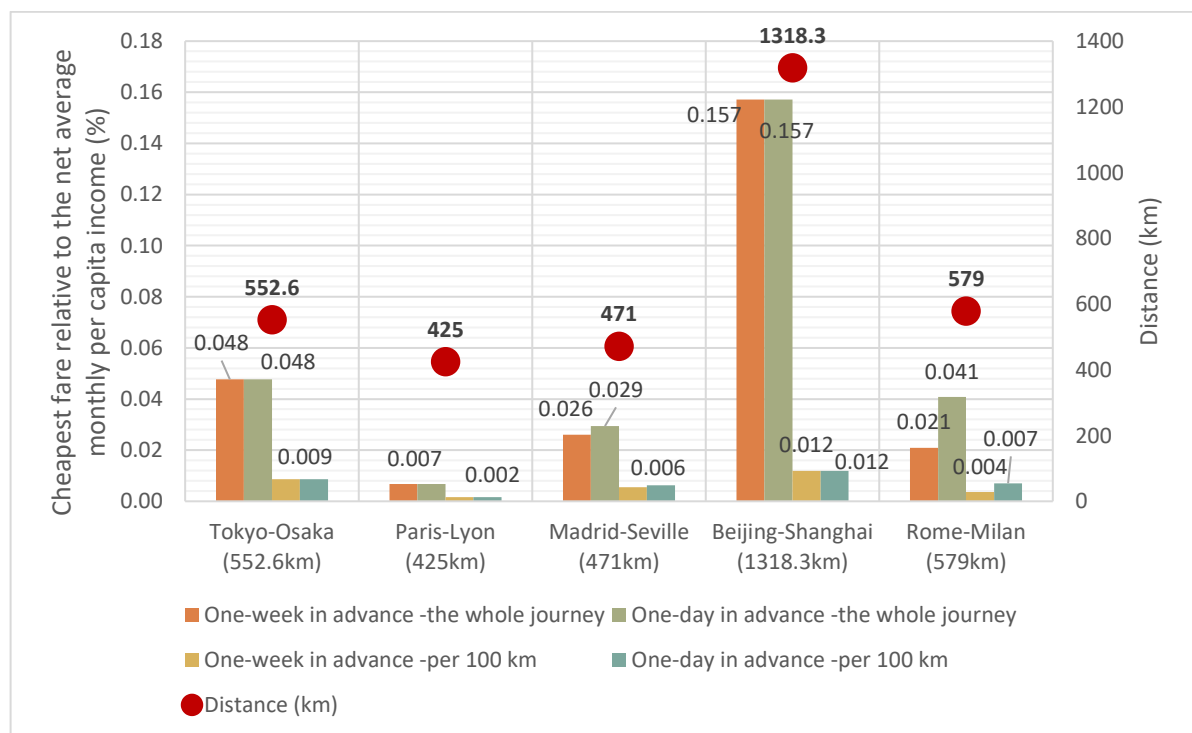


Figure 6-10: Comparing HSR fares along selected corridors after relating them to net monthly per capita income

Source: author's elaboration on (World-Bank, 2017a; Renfe, 2019a; SNCF, 2019a; JR-Central, 2019b; CH, 2019a; FS-Italiane, 2019)

6.8 Summary

This chapter has partly answered the third research question of this study, by suggesting indicators for expressing the social factors of the sustainability framework. The proposed indicators could be used for both reporting and benchmarking purposes. The applicability of some indicators and the availability of associated data were investigated through benchmarking exercises, which have offered insights into the social sustainability performance of HSR lines and companies. Data sources were referred to, and prominent benchmarking results were highlighted, revealing significant performance variations among the benchmarked entities. The results of the proposed indicators and benchmarking exercises are discussed in Chapter 8.

CHAPTER 7

REPORTING ON AND BENCHMARKING THE ENVIRONMENTAL SUSTAINABILITY OF HSR

The previous chapter proposes some indicators that can be used for expressing the selected social factors of the HSR sustainability framework. Similarly, this chapter proposes a variety of quantitative parameters and qualitative indicators for reporting on and benchmarking the selected environmental factors of the sustainability framework.

The usability of the proposed indicators and availability of associated data are tested with benchmarking exercises that tackle the environmental factors at company and corridor levels. A comprehensive explanation of topics and points that can be covered in qualitative environmental reporting is also provided. Figure 7-1 illustrates the step-by-step process of proposing indicators for each environmental factor.

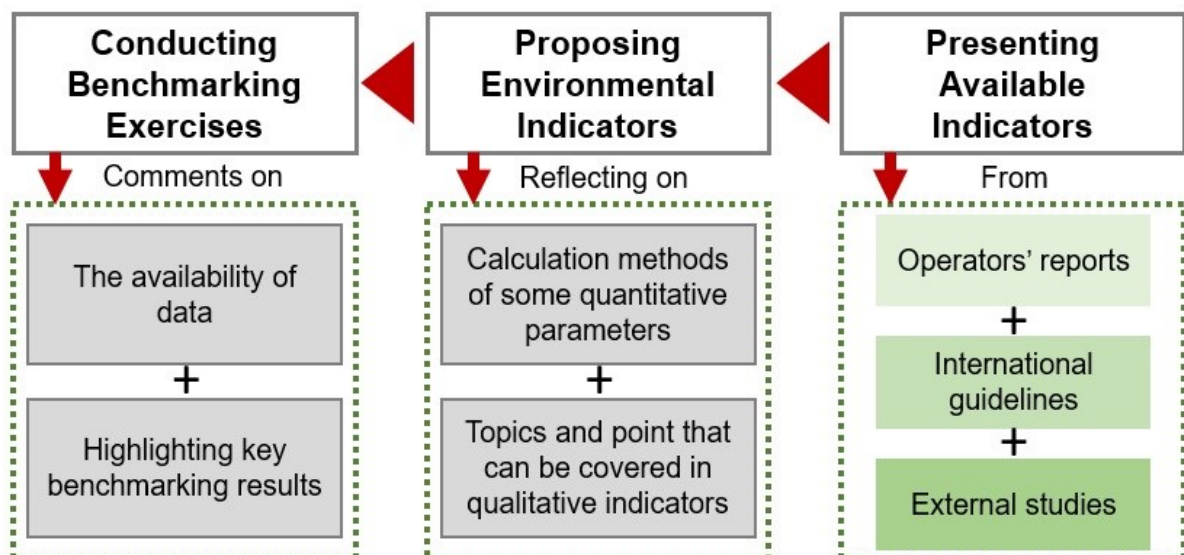


Figure 7-1: Step-by-step process of proposing indicators for each environmental factor

7.1 Carbon emissions, energy consumption, and sources

The carbon footprint of HSR projects is not limited to the operation stage; it spans the lifecycle of the whole project. The optimal reporting practice should disclose information about emissions associated with planning, construction, operation, and recycling stages of any HSR project. However, HSR operations might be the main contributor to total emissions among other stages. Lin et al. (2019) discussed that despite the enormous number of bridges and tunnels featured by the Beijing–Shanghai HSR corridor, operating the HSR service accounts for at least 70 per cent of the lifecycle emissions. The construction and maintenance of the corridor generate 20 per cent and 9 per cent of the emissions respectively. Considering Lin et al. (2019)’s findings plus time limitations, this study focuses on emissions related to the operation stage.

HSR operators often disclose aggregate emissions data, reflecting on the total amount of CO₂ generated from all transport and non-transport activities. Some operators distinguish between HSR and other services, offering emissions data that exclusively relate to HSR. For instance, DB reports very extensively and differentiates between emissions for different activities (DB, 2017). Also, some companies qualitatively discuss their efforts at adopting new technologies and solutions that aim to reduce emissions.

UIC leaflet No. 330 offers some railway-specific environmental performance parameters. For instance, the document proposes the per passenger.km equivalent CO₂e emissions, the per passenger.km final energy consumption, and the share of renewable electric energy in the total energy mix as potential indicators for reporting and benchmarking purposes (Bergendorff et al., 2008). The consultation with the UIC’s experts in February 2019 suggested using these parameters, while joint publications of the International Energy Agency (IEA) and

UIC use the same indicators (IEA, 2017; IEA, 2019; UIC-and-IEA, 2017). So, these indices will be used in the framework as follows:

- EN-1: the equivalent CO₂ emissions of operating HSR services (g CO₂e/p.km)
- EN-2-1: the final energy consumption of operating HSR services (kWh/p.km)
- EN-2-2: the share of renewable electric energy in the total energy consumption

The EN-1 indicator measures CO₂ and other Green House Gases (GHGs) that are emitted while generating traction electricity for carrying one passenger along 1 km. In this indicator, CO₂ is calculated as the most significant contributor, while other gases are estimated by adding 1 per cent of the CO₂ value (Brander, 2012). The EN-2-1 indicator expresses the amount of electricity that is used directly by electric traction units for moving one passenger along 1 km, including energy being used for air conditioning and heating, lighting, and on-board services (Bergendorff et al., 2008). The EN-1 and EN-2-1 indicators provide a clear idea about emissions and energy consumption for optimisation purposes, along with allowing benchmarking exercises considering both HSR and other transport modes.

When reporting on the EN-2-2 indicator, HSR operators could reflect on the energy mix used for generating traction electricity. This comprises disclosing the share of electricity generated by burning fossil fuels, nuclear power, hydropower, and solar power plants, biofuels, and wind power (Bergendorff et al., 2008).

Reporting and benchmarking exercise

Table 7-1 presents the calculations of the energy consumption and the CO₂e emissions of selected HSR operators for 3 years. All data presented are related exclusively to the operations of HSR services, with other transport and rail services are excluded. Data for the benchmarking exercise were extracted from different sources and were offered in different

units. So, all units have been standardised, and different calculation methods have been used for working out the per passenger. km values. The passenger. km figures of all operators were retrieved from one source – the UIC database – which supports a degree of consistency.

The Japanese operators disclosed information about total consumption and emission values (JR-East, 2016; JR-East, 2017; JR-East, 2018b; JR-West, 2018). In contrast, both SNCF and Renfe reported the per passenger. km emission figures (Oui-SNCF, 2018; Renfe-SNCF, 2015; SNCF, 2016a), from which the absolute emissions values were calculated. Moreover, the emission factors for both France and Spain were used for calculating the energy consumption rates of both operators. Data for CR were partly available through some of the latest joint publications of the IEA and UIC.

Table 7-1: Comparing final energy consumption and CO₂e emissions of selected HSR operators

Year	2015	2016	2017
Indicator	JR West		
HSR p.km (millions)	20449.379	20348.068	21023
Final energy consumption (GWh)	1417.012	1544.634	1551.461
Final energy consumption (kWh/p.km)	0.069	0.076	0.074
Equivalent CO ₂ emissions (million tonnes)	0.766	0.833	0.812
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	37.452	40.949	38.604
	JR East		
HSR p.km (millions)	22848	23176	23371
Final energy consumption (GWh)	1260	1330	1330
Final energy consumption (kWh/p.km)	0.055	0.057	0.057
Equivalent CO ₂ emissions (million tonnes)	0.5	0.52	0.53
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	21.884	22.437	22.678
	DB		
HSR p.km (millions)	25280	27213	28502
Final energy consumption (GWh)	2668.446	2948.074	2850.2
Final energy consumption (kWh/p.km)	0.106	0.108	0.1
Equivalent CO ₂ emissions (million tonnes)	0.49	0.52	0.52
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	19.383	19.109	18.244
	Renfe		
HSR p.km (millions)	14129	15059	15540
Final energy consumption (GWh)	770.673	828.245	854.7
Final energy consumption (kWh/p.km)	0.055	0.055	0.055
Equivalent CO ₂ emissions (million tonnes)	0.339	0.364	0.376
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	24	24.2	24.2
Emission factor	0.44	0.44	0.44
	SNCF		
HSR p.km (millions)	49980	53100	58280
Final energy consumption (GWh)	3017.66	3206.038	2639.094
Final energy consumption (kWh/p.km)	0.06	0.06	0.045
Equivalent CO ₂ emissions (million tonnes)	0.16	0.17	0.14
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	3.2	3.2	2.4
Emission factor	0.053	0.053	0.053
	China Railways		
HSR p.km (millions)	386306	464104	577635
Final energy consumption (GWh)	16111.1	19445.958	24116.261
Final energy consumption (kWh/p.km)	0.042	0.042	0.042
Equivalent CO ₂ emissions (million tonnes)	8.885	11.138	13.286
Equivalent CO ₂ emissions (g CO ₂ e/p.km)	23	24	23

Source: author's elaboration on (CovenantofMayors, 2017; DB, 2017; Hortelano, 2016; IEA, 2017; IEA, 2019; JR-East, 2016; JR-East, 2017; JR-East, 2018b; JR-West, 2018; Oui-SNCF, 2018; Renfe, 2017; Renfe-SNCF, 2015; SNCF, 2016a; SNCF, 2017a; statista, 2018; UIC-and-IEA, 2017; Wang et al., 2019)

Figure 7-2 and Figure 7-3 summarise the results of all calculations that are presented in Table 7-1. The comparison shows that the reported per passenger.km emissions of SNCF were the lowest in all years, with 2.4 g CO₂e/p.km in 2017. This reported figure is strikingly lower than figures of other operators, possibly because France depends on the nuclear power for generating electricity. In contrast, JR West had the highest emission values in all years, with around 38.6 g CO₂e/p.km in 2017. Emissions for CR, DB, Renfe, and JR East were relatively close to each other. Regarding energy consumption, CR showed the lowest consumption in all years, at almost 0.04 kWh/p.km in 2017, whereas DB had the highest consumption, of around 0.1 kWh/p.km, more than double the consumption of CR. The energy consumption of Renfe, JR East, and SNCF were relatively close to each other.

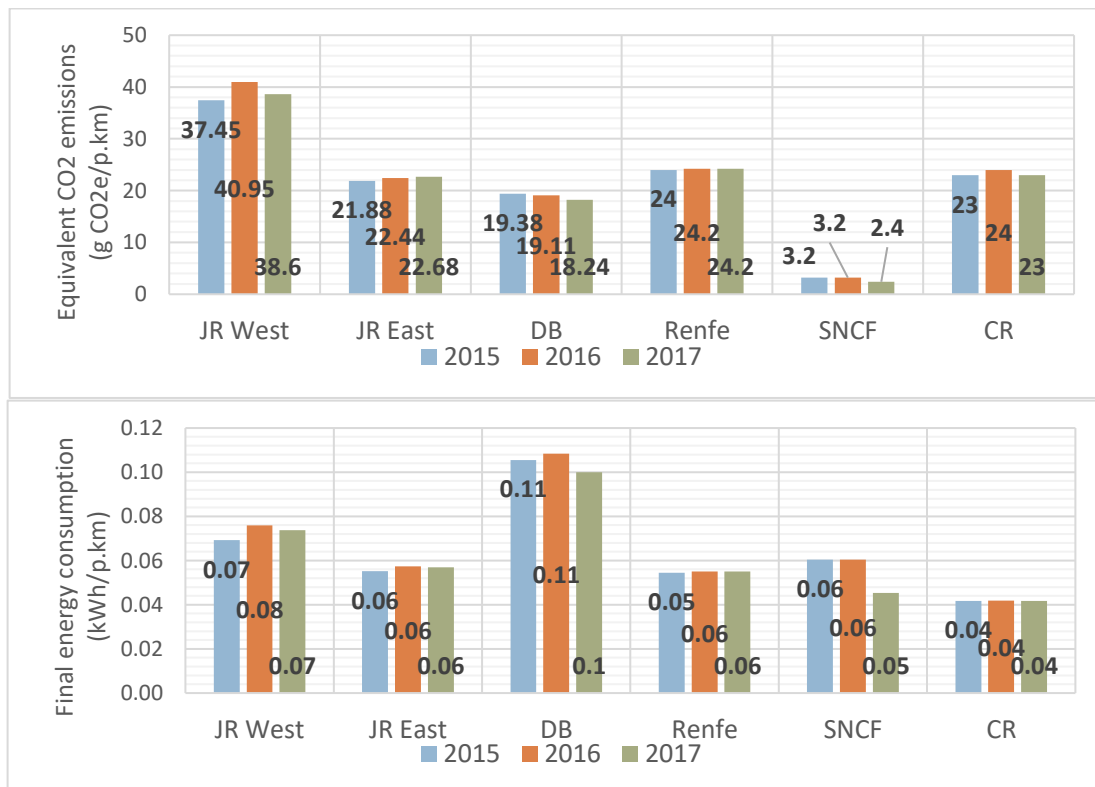


Figure 7-2: Energy consumption and carbon emissions of selected HSR operators

Source: author's elaboration on (CovenantofMayors, 2017; DB, 2017; Hortelano, 2016; IEA, 2017; IEA, 2019; JR-East, 2016; JR-East, 2017; JR-East, 2018b; JR-West, 2018; Oui-SNCF, 2018; Renfe, 2017; Renfe-SNCF, 2015; SNCF, 2016a; SNCF, 2017a; statista, 2018; UIC-and-IEA, 2017; Wang et al., 2019)

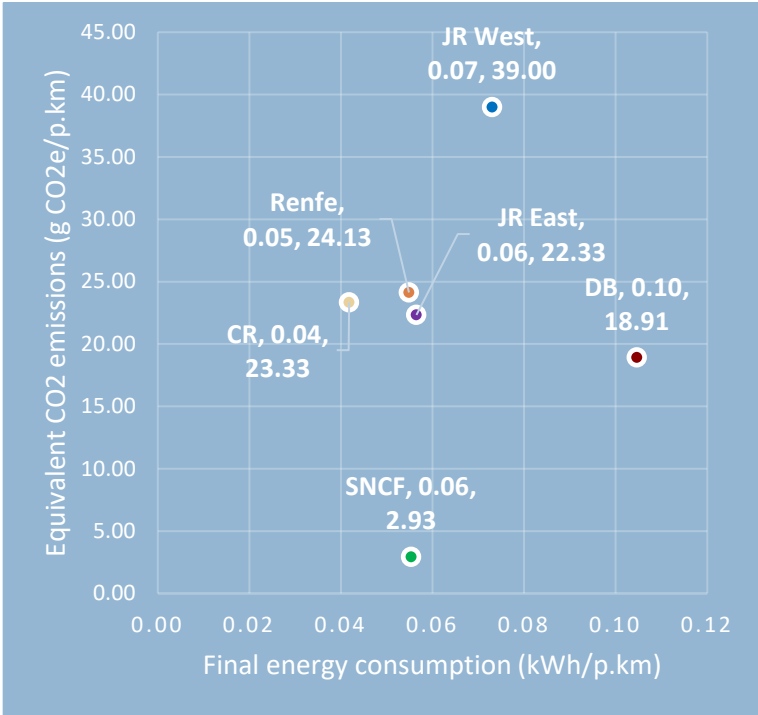


Figure 7-3: Energy consumption and carbon emissions of selected HSR operators – average of three years

Figure 7-4 illustrates the energy mix used for generating traction electricity for selected HSR operators in 2015. Both CR and JR East relied heavily on fossil fuels for generating electricity, whereas DB showed a more diversified energy mix.

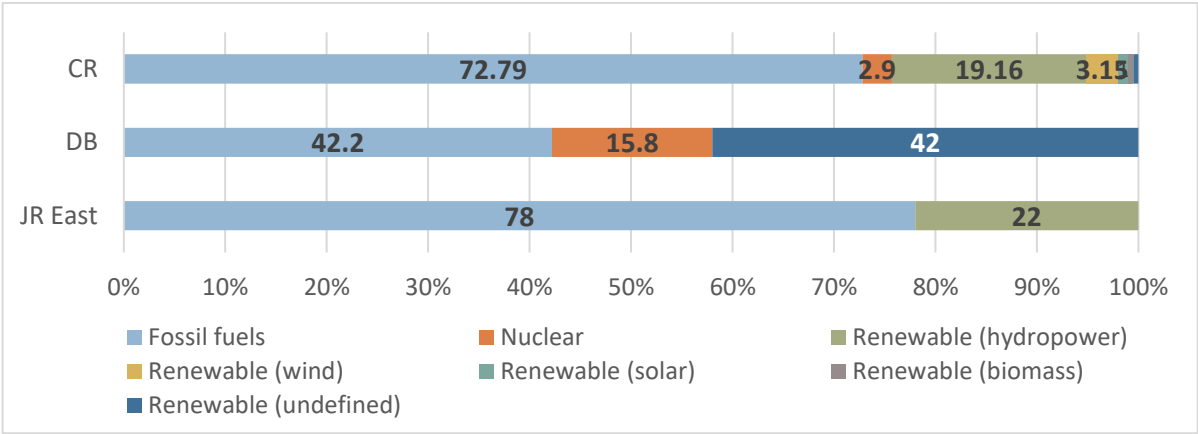


Figure 7-4: Comparing the energy mix of selected HSR operators in 2015

Source: author's elaboration on (JR-East, 2015; Wang et al., 2019)

Figure 7-5 illustrates a comparison of the CO₂e emissions that are generated from operating HSR services along selected corridors. Data for the benchmarking exercise were extracted and calculated from different sources. For instance, JR Central reported on the per seat.km emissions (JR-Central, 2018), which was converted into per passenger.km emissions. Also, emissions for the Paris–Lyon and Madrid–Seville corridors were provided by the Eco Passenger Carbon Footprint tool at occupancy rates of 85 per cent, from which emission values at other occupancy rates were worked out. Regarding the Beijing–Shanghai corridor, Lin et al. (2019) provided values for the total annual emissions, occupancy rate, and daily passenger figures, based on which the emissions calculations were made. Finally, the capacities of locomotives that run on the selected HSR lines were reported by the UIC (2019e).

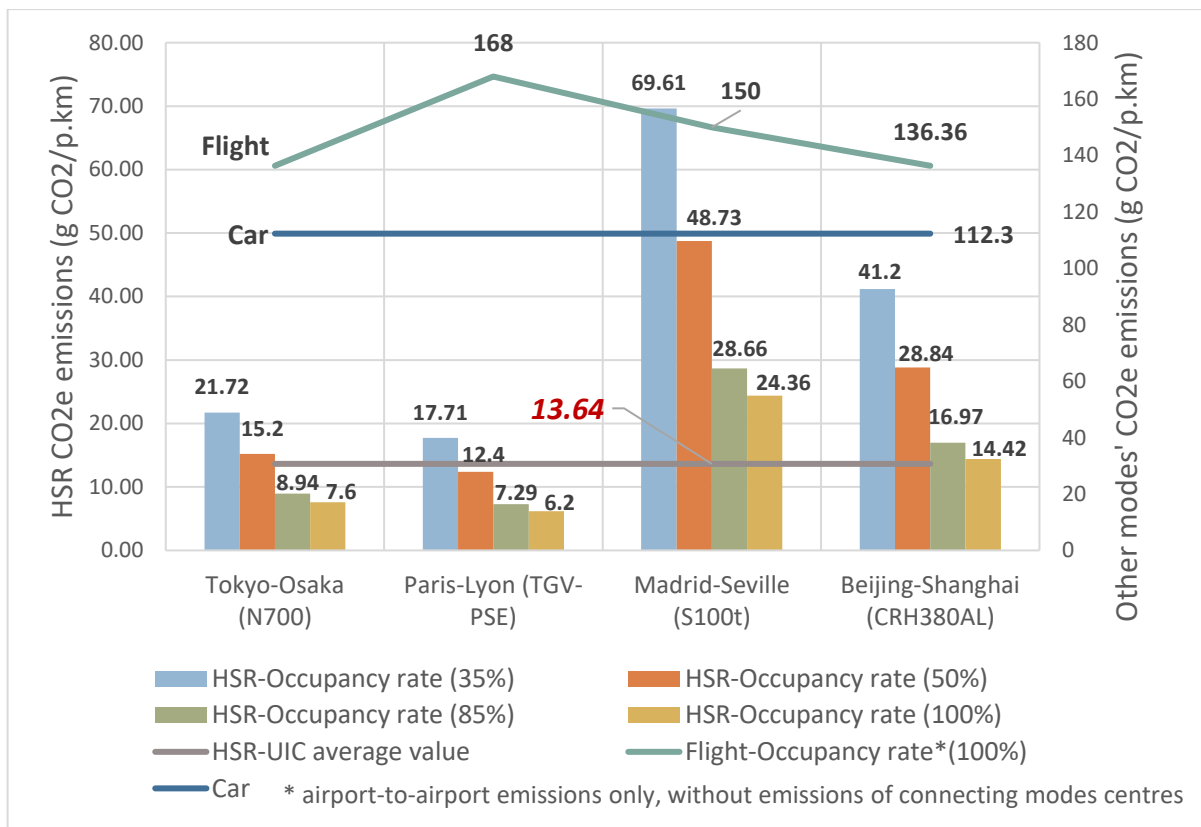


Figure 7-5: Operation carbon footprint comparison of selected HSR corridors

Source: author's elaboration on (CFC, 2019; EcoPassenger, 2019; Hüttermann and Knörr, 2016; JR-Central, 2018; Leboeuf, 2018; Lin et al., 2019; UIC, 2019e)

The proposed EN-1 indicator allowed two types of comparison: benchmarking the HSR of a specific corridor against the HSR of other corridors, and benchmarking HSR against other transport modes. Regarding the first comparison, Figure 7-5 shows that emissions associated with different corridors and occupancy rates vary significantly. At all occupancy rates, HSR on the Paris–Lyon corridor generated the least emissions followed by the Tokyo–Osaka HSR, whereas the Madrid–Seville HSR accounted for the highest emissions. For instance, at an occupancy rate of 85 per cent, the Paris–Lyon HSR generates around 7.3 g CO₂e/p.km, compared to around 8.9, 17, and 28.7 g CO₂e/p.km for Tokyo–Osaka, Beijing–Shanghai, and Madrid–Seville respectively. When trains were fully loaded, Madrid–Seville HSR emissions were almost four times higher than their counterparts for the Paris–Lyon HSR.

Regarding the second comparison, Figure 7-5 illustrates that even at the lowest occupancy rates, HSR emitted much lower emissions than cars and flights, across all selected corridors. For example, the HSR journey – where 35 per cent of the train was occupied – between Beijing and Shanghai emitted around 41.2 g CO₂e/p.km, whereas similar journeys by car and air transport generated around 112.3 and 136.4 g CO₂e/p.km respectively. Moreover, a flight from Paris to Lyon created around 168 g CO₂e/p.km, almost 10 times the emissions of a similar HSR journey, at an occupancy rate of 35 per cent. Notably, the Paris-Lyon corridor's emissions of 6.2 g CO₂e/p.km -at the highest occupancy rate- was higher than the carbon emissions of 3.2 g CO₂e/p.km as reported by SNCF in previous benchmarking exercises. Such finding draws the attention to variations in reporting and to different reporting routes.

7.2 Land use

The land use factor refers to the weed control and vegetation management along railway tracks. HSR operators and infrastructure managers rarely report on vegetation control and the

application of herbicides along tracks. Most of their reports discuss qualitatively efforts in managing environmental challenges, without providing in-depth information and quantitative data. For instance, JR East briefly mentions vegetation control in its sustainability report without presenting detailed information in this regard (JR-East, 2018b). One exception is ADIF, which consistently reports data about herbicide consumption in its sustainability reports. However, ADIF only discloses aggregate consumption data, without providing the per-track km consumption (Adif, 2015; Adif, 2017).

The UIC offers comprehensive guidelines for assessing railway weed control and management, suggesting two basic parameters (UIC, 2018b):

- EN-3-1: the amount of active substances – herbicides – used per track km
- EN-3-2: the cost of active substance – herbicides – used per track km

When reporting on these two indicators, HSR companies could also specify the areas treated with herbicides. These are categorised into three zones:

1. The track and all areas directly connected to it such as spaces between tracks;
2. Sealed areas which include sealed zones outside the track such as platforms, car parks, storage and loading areas, streets, and sealed pathways;
3. Unsealed areas which comprise embankments and all zones that are not directly linked with the track like meadows, forests, unsealed pathways, and areas around stations.

In addition, HSR companies could further enrich their land use disclosure by reporting on their efforts and measures to protect surrounding plants and soil from contamination plus solutions and techniques to limit the use of chemicals where possible.

Reporting and benchmarking exercise

Figure 7-6 presents a comparison of herbicide cost and consumption for different HSR operators and infrastructure managers in 2017. Most of the data were extracted from the UIC's HERBIE report. In their report, ADIF provided an aggregate figure for the total annual consumption, so this was divided by the overall track km operated by the company. The Japanese companies were absent from the comparison due to the lack of data available from both company reports and online publications. The comparison shows that ADIF had the significantly highest consumption of herbicides, at around 2.53 kg per track km, whereas the consumption of all other companies was relatively lower and close to the average consumption of 1 kg per track km in the EU. The cost of herbicides varied among HSR companies, and SNCF notably experienced the highest cost, at around €420 per track km.

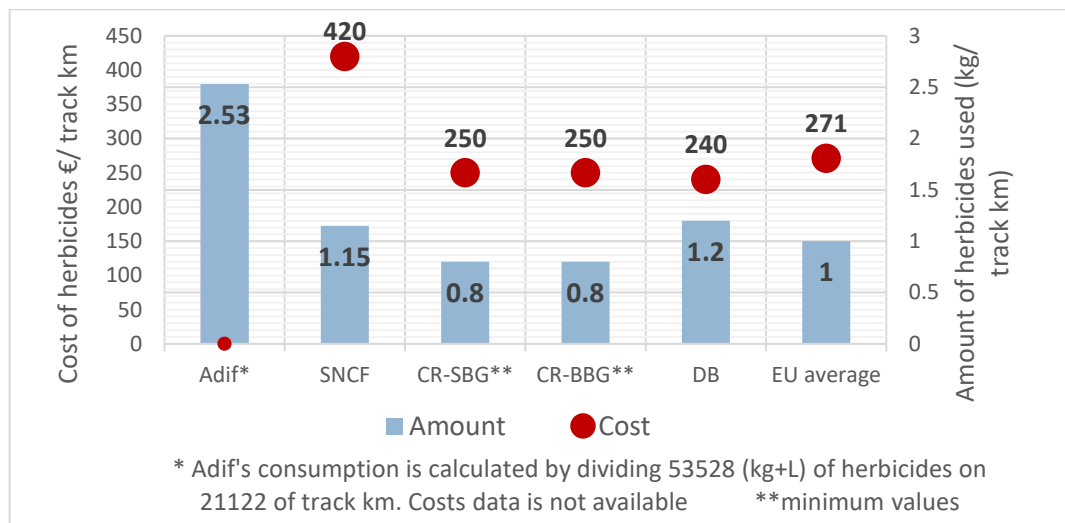


Figure 7-6: Herbicide cost and consumption by HSR operators and infrastructure managers in 2017

Source: author's elaboration on (UIC, 2018b; Qin, 2019; Adif, 2015)

Table 7-2 shows areas that were treated with herbicides by HSR operators and infrastructure managers. There was no accurate information regarding the share of the track that has been treated with herbicides by the Chinese operators. The comparison shows that DB had

the strictest herbicide application, as chemicals were applied to only tracks. In contrast, the Chinese operators used herbicides extensively on tracks and their surrounding areas.

Table 7-2: Areas treated with herbicides by different companies

Operator/infrastructure manager	Share of the network treated	Area treated		
		Track	Sealed	Unsealed
ADIF	95%			N/A
SNCF	97%			
CRSBG	N/A			
CRBBG	N/A			
DB	95%			
Colour code	Green: widely used, yellow: use restricted, red: forbidden			

Source: author's elaboration on UIC (2018b) and Adif (2015)

7.3 Resources and materials

HSR operators report information about their consumption of different renewable and non-renewable materials and supplies. These materials are usually consumed at different locations and for various purposes such as in-office use, printing tickets, washing locomotives, and performing maintenance tasks. For instance, JR Central, JR East, and JR West report on the amount of water and paper consumed annually (JR-Central, 2018; JR-East, 2018b; JR-West, 2018). Renfe adopts a broader scope, reporting on a wide range of materials consumed such as paints, water, oil, grease, and sand (Renfe, 2015; Renfe, 2017). SNCF communicates figures about the amounts of concrete, copper, metal, wood, paper, and water consumed (SNCF, 2017a). In general, most operators report on two primary materials: water and paper.

The GRI standards offer a comprehensive guideline for reporting on the consumption of materials and resources. These standards advise disclosing quantitative information about the weight and volume of renewable and non-renewable materials that are used by a firm (GRI, 2016c). Following the GRI's standards and reflecting on topics within operators' reports, the framework suggests the following indicator for reporting and benchmarking purposes:

- EN-4: the amount of water/sand/concrete/wood/metal/paper consumed per route km

Normalisation, by dividing the total amount of materials consumed by the total operated route kms will allow a fairer comparison between HSR operators.

Reporting and benchmarking exercise

Figure 7-7 illustrates a comparison of water consumption for different HSR operators in 2016 and 2017. The consumption is related to all activities managed by the operators, while data that relates to only HSR activities are not available. Since all benchmarked companies except Renfe perform operation and infrastructure management tasks, the consumption figures for ADIF were combined with Renfe's figures. Most of the data were extracted from annual and sustainability reports. The comparison shows that SNCF had the highest consumption of water in both 2016 and 2017. However, the per route km consumption tells a different story, showing that JR Central's per route km water consumption was significantly the highest, at around 1595 and 1687 m³ in 2017 and 2016 respectively.

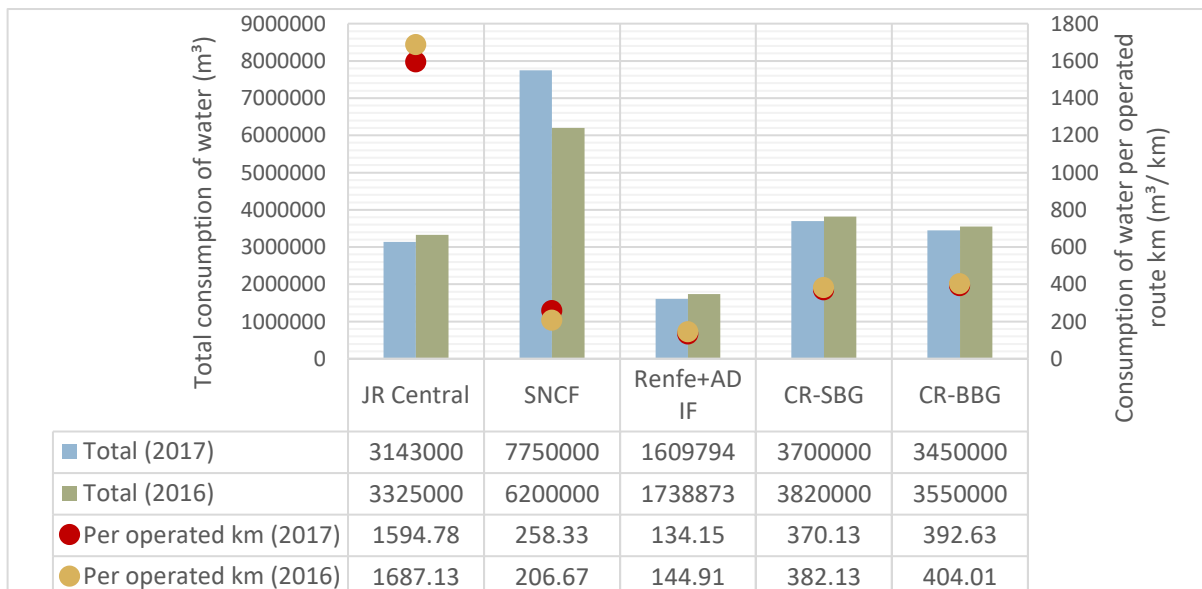


Figure 7-7: Comparing the water consumption of HSR companies

Source: author's elaboration on (Adif, 2017; JR-Central, 2017; JR-Central, 2018; Renfe, 2015; Renfe, 2017; SNCF, 2017a)

Figure 7-8 compares the paper consumption for different HSR operators in 2016 and 2017. All data were retrieved from annual and sustainability reports. However, while the European operators disclosed consumption figures in tonnes, some Japanese operators reported on the number of sheets of A4 paper that had been used. So, the latter were converted into tonnes to conduct the comparison.

Both total and per-route km consumption varied considerably among HSR companies. SNCF had the highest paper consumption in both 2016 and 2017, whereas Renfe -together with Adif- had the lowest consumption in both years. JR Central's per-route km consumption of paper was similar to SNCF, at around 330 and 337 kg per route km respectively. Renfe - combined with Adif- had a very significantly low consumption of paper, especially when compared with other operators, at around 6 and 6.8 kg per route km in 2017 and 2016 respectively.

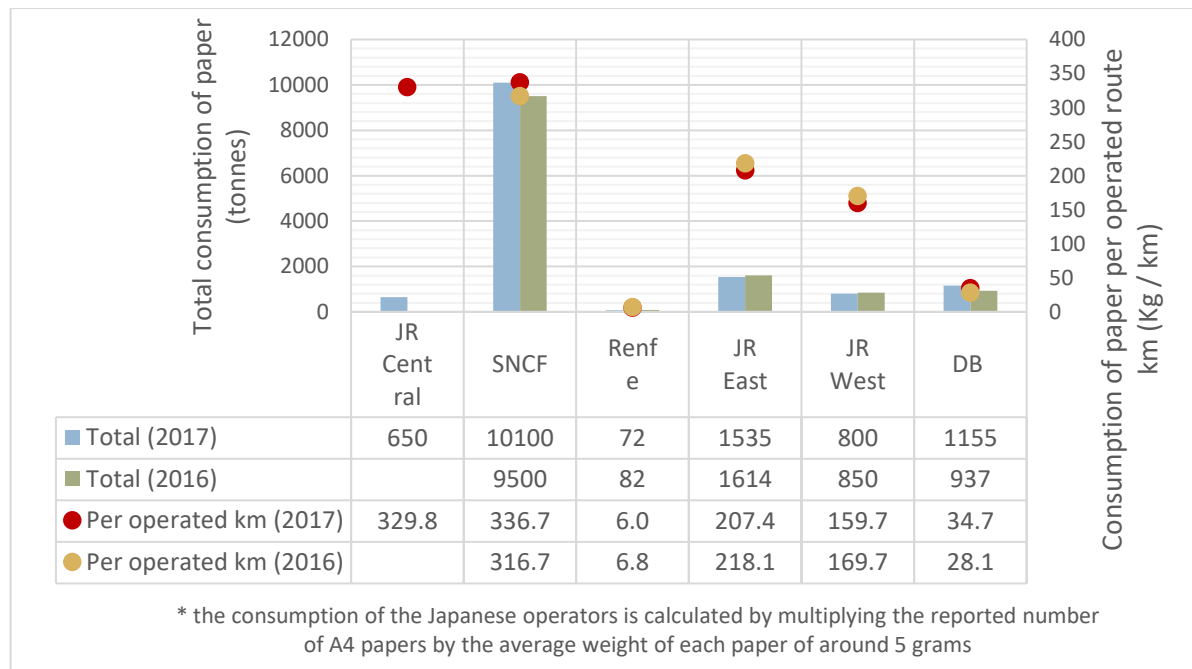


Figure 7-8: Comparing the paper consumption of HSR companies

Source: author's elaboration on (DB, 2016; DB, 2017; JR-Central, 2017; JR-Central, 2018; JR-East, 2017; JR-East, 2018b; JR-West, 2017; JR-West, 2018; Renfe, 2017; SNCF, 2017a)

7.4 Biodiversity

Most HSR operators discuss their efforts in protecting the natural habitat along railway corridors qualitatively. Some operators disclose information about their annual environmental expenditure (JR-Central, 2018). The GRI standards provide extensive biodiversity reporting guidelines. These encourage firms to disclose information around three topics: features and specification of natural areas, firms' activities and resultant impacts, and firms' solutions and efforts for alleviating the negative impact (GRI, 2016b).

The sustainability framework suggests two parameters for reporting on the biodiversity factor. The first indicator is influenced by the GRI's topic-specific indicators and has been modified and simplified to be used as follows:

- EN-5-1: A qualitative explanation of how the operator is protecting and promoting biodiversity

The EN-5-1 index reflects on three scopes:

1. **Scope 1**: providing information regarding locations, operation sites, and properties in or near zones of high biodiversity value and protected areas with a brief explanation about these zones and their importance, including:
 - The exact location of the activity: inside, adjacent, or containing the biodiversity zone;
 - Location and features of the protected zone;
 - Size, length, and dimensions of sites;
 - Type of properties: offices, tracks, and stations;
 - Type of activities: transporting goods, construction and running trains;

- The value of biodiversity characterised by the nature of the protected zone: freshwater, forest, terrestrial;
 - The status of the protected area such as a national park or UN-protected site.
2. **Scope 2:** explaining the adverse impacts of railway activities. These could include:
- Duration of impacts;
 - Type of impacts: positive or negative or both;
 - The attribute of the effect: reduction and increment;
 - Species affected: plants and animals including their numbers;
 - Changes in ecological processes such as salinity and freshwater levels.
3. **Scope 3:** explaining efforts and initiatives to restore and protect natural habitats, looking at:
- Location, size, and quantity of restored or protected areas;
 - Confirmation of the success of protection and restoration measures, preferably approved by an external auditor;
 - Collaboration with other parties and stakeholders in the process;
 - Financial efforts and conservation costs in monetary value.

The second proposed indicator with its quantitative nature allows direct benchmarking, and has been developed after considering the figures on which operators report:

- EN-5-2: The environmental expenditure per operated route km

$$EN - 5 - 1 = \frac{\text{Total annual environmental expenditure}}{\text{Total operated route km}}$$

The total environmental expenditure includes but is not limited to: provisions for environmental risks; countermeasures for noise and vibration; proper management of

environmental load materials; and other costs associated with conserving the environment along rail lines (JR-East, 2018a; Renfe, 2017; SNCF, 2017a).

Reporting and benchmarking exercise

Figure 7-9 illustrates a comparison of HSR operators' environmental expenditure in 2016 and 2017. Most values were extracted from annual and sustainability publications. In their annual report, JR Central distinguishes between two values, namely, environmental expenditure and environmental investment. However, only environmental expenditure was considered since other operators did not report environmental investment figures.

The comparison shows a remarkable variation in the environmental expenditure of HSR companies. SNCF's per-route km expenditure was the highest in both 2016 and 2017, followed by JR Central's expenditure. In contrast, Renfe -together with Adif- spent the least amount of money on the environmental conversation, at around €1417 per route km. Also, the comparison reveals that all companies reduced their environmental expenditure between 2016 and 2017.

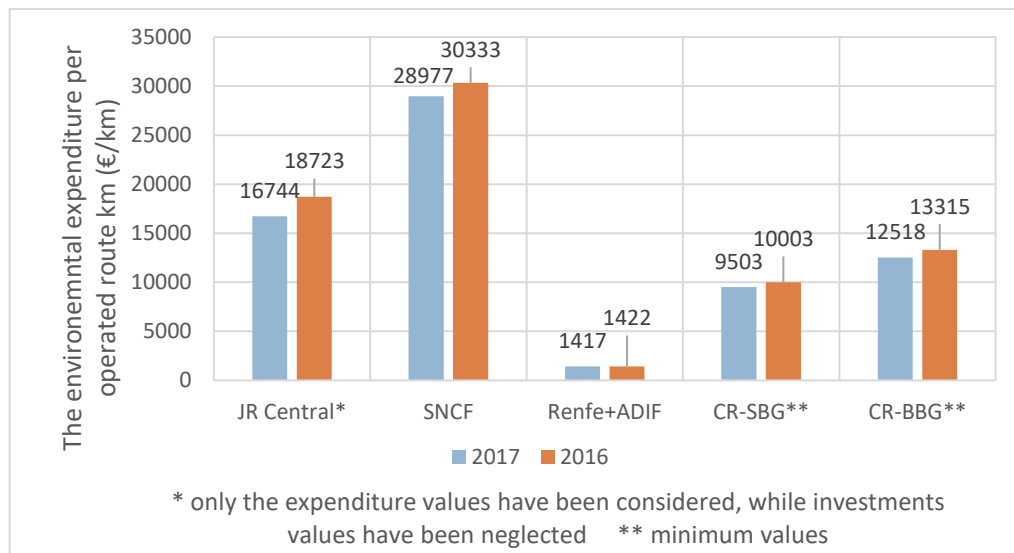


Figure 7-9: Benchmarking the environmental expenditure of selected HSR operators

Source: author's elaboration on (Adif, 2017; JR-Central, 2017; JR-Central, 2018; Renfe, 2017; SNCF, 2017a)

The following section shows how HSR operators report qualitative biodiversity information, reflecting on the three identified scopes of the proposed EN-5-1 indicator. JR Central, Renfe, and SNCF report biodiversity information in their annual and sustainability reports, while the Chinese operator has reported such information via its website.

- **JR Central (JR-Central, 2018)**

A soil survey was conducted at a previous corporate housing location in Kaiya. Some hazardous materials were found exceeding their standard values, resulting in contamination of the soil around the railway activity. The company invested and spent around €112 million and €33 million respectively on measures to conserve the environment surrounding railway lines, including implementing and modifying walls to block noise and properly managing environmental load substances. Moreover, JR Central collaborated with other stakeholders and ecological agencies to tackle issues such as soil contamination.

- **SNCF (SNCF, 2017a)**

Due to the vast expansion of its network, the company interacts with the ecosystem at several locations. For instance, SNCF maintains a biodiversity protection area around one of its technical centres. The protected area accommodates over 120 types of rare invertebrates and arachnids. SNCF had a positive impact on the site since it trims and controls invasive plants by trimming vegetation, allowing sunlight to reach the soil. To conserve and protect biodiversity, the company made partnerships with institutions such as Oree to preserve biodiversity. Also, SNCF used green bonds to fund some of its engineering works.

Moreover, the company took several actions to limit its water consumption such as using rain and recycled water to wash vehicles. To protect plants, SNCF purchased around 67.2 tonnes of plant protection products while training almost 500 employees on environmental protection.

Several studies focusing on the ecological continuity were launched to identify the maximum potential of the network without affecting the environmental system. Finally, around €869.3 million was provided to control environmental risks.

- **Renfe (Renfe, 2017)**

Renfe's interaction with biodiversity happens in or near natural areas through operating trains, managing facilities, and transporting hazardous materials. Renfe operates 12 material storage and maintenance workshops plus 55 stations in or near these protected areas of high biodiversity. Renfe's facilities occupy a space of almost 0.26 km². The contamination of both water resources and soil was found as a result of Renfe's activities. Renfe spent around €41,000 to prevent soil and water contamination plus €231,000 for treating and managing hazardous waste. Moreover, Renfe prepared an action plan to control contaminated and uncontaminated soil while working closely with other stakeholders and environmental authorities in this regard.

- **China Railway Guangzhou Bureau Group (CR, 2018a)**

The group interacts with biodiversity at several locations. For instance, it operates the HSR line connecting Shenzhen and Maoming, which is just 800 m away from Birds Paradise, a well-known nationwide natural habitat covering around 10,000 m² in Tianma Village, Jiangmen City, Guangdong Province. The natural spot accommodates more than 30,000 birds featuring different species such as night herons and cattle egrets plus other plants and ancient banyan trees. Originally, noise levels generated by the operation of HSR could threaten the existence of these species, but the intervention of the operator curbed such a negative impact. In collaboration with research institutes, CRGBG tested and implemented a fully enclosed arched noise barrier to reduce noise generated by HSR in Birds Paradise. The arched barrier spans around 2 km featuring design and materials that reduce noise to minimum levels below

50 dBA at Birds Paradise, which does not affect living conditions of birds and other species. Moreover, the unique shape respects the iconic scenery of the site while the cost of the barrier is almost €11.5 million/km.

All operators have managed to cover some of the points identified within the proposed EN-5-1 qualitative indicators. However, most reporting practices focused on scope 3 of the parameter, while less information was provided regarding scopes 1 and 2.

7.5 Recycling

The recycling factor reflects the refuse and waste generated by HSR operators and the extent to which these are being recycled and reused. Some annual and sustainability reports disclose quantitative information about the amount of waste produced in trains, stations, and offices, plus construction and rolling stock waste. This quantitative information is often followed by a qualitative explanation of how HSR operators utilise recycling for recreating value from the waste produced. Some operators such as SNCF report on the revenues generated from the reclamation of end-of-life materials (SNCF, 2017a), while others discuss the internal reuse of junk and scrap (JR-Central, 2018; JR-East, 2018b). The GRI guidelines offer several parameters for expressing the recycling factors; these include the percentage of reclaimed products, the percentage of recycled input materials, and the recycling rate (GRI, 2016c). The sustainability framework suggests the recycling rate as an indicator, which could be calculated according to the following formula:

- EN-6: the annual recycling rate (%)

$$EN - 6 (\%) = \frac{\text{Total waste recycled (in thousand tonnes)}}{\text{Total waste produced (in thousand tonnes)}}$$

Recycled waste includes both the refuse that is reused by the operator and materials that are sold for generating external revenue.

Reporting and benchmarking exercise

Figure 7-10 presents a benchmarking exercise comparing the recycling rates of selected HSR operators. Most of the data were extracted from annual and sustainability reports. However, some operators disclosed their recycling rate while others reported on aggregate amounts of generated and recycled wastes, based on which recycling rates were calculated. The comparison shows that apart from JR Central's rate, the recycling rates of all benchmarked operators were relatively close to each other. DB reported the highest recycling rates in both 2016 and 2017, with rates of 97 and 98 per cent respectively. In contrast, JR Central's recycling rates were significantly lower than the rates of other operators, at 58 and 52 per cent of waste being recycled in 2016 and 2017 respectively. Most HSR operators increased their recycling activities between 2016 and 2017.

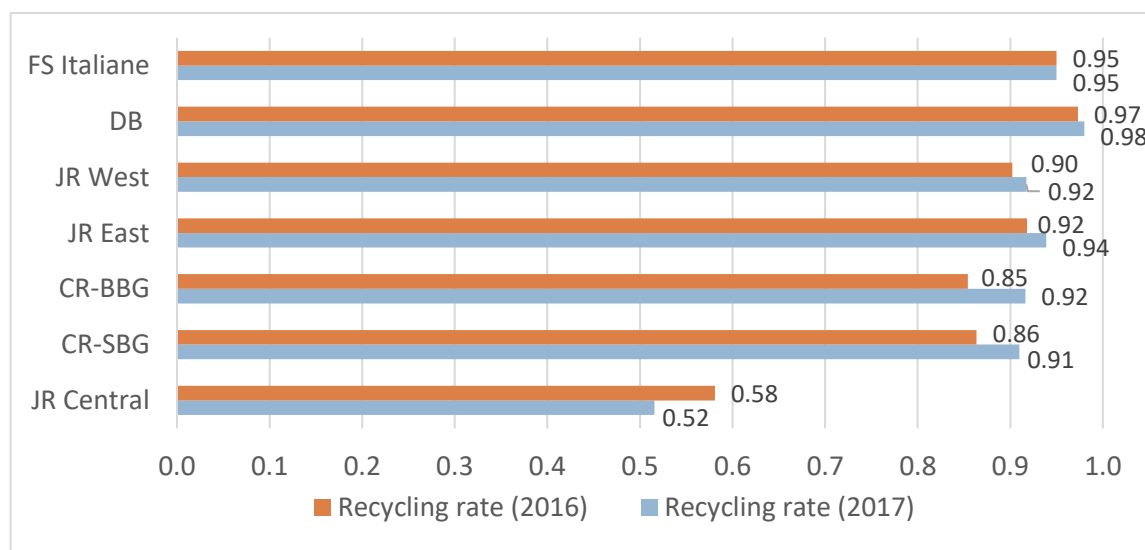


Figure 7-10: Comparing the recycling rate of selected HSR operators

Source: author's elaboration on (DB, 2016; DB, 2017; FS-Italiane, 2017; JR-Central, 2017; JR-Central, 2018; JR-West, 2017; JR-West, 2018)

7.6 Noise

EC Regulation 1304/2014 on the technical specification for interoperability (TSI) on noise suggests measuring pass-by sounds at a height of 3.5 m above the rail for trains with speeds equal to or higher than 250 km/h (EURLEX, 2014). Also, Ivanov et al. (2017) conducted a study that looked at noise levels of HSR, obtaining data from Japan, China, Korea, and Europe. The study used linear regression and found a relationship between noise levels and train speed and length. The findings of the study suggested a formula to calculate noise levels for HSR, and this formula complies with the EU TSI regulations and recommendations. So, the formula will be adopted in the sustainability framework as follows (Ivanov et al., 2017):

- EN-7-1: sound level (dBA) at a height of 3.5 m and a distance of 25 m from the rail axis

The EN-7-1 indicator can be calculated according to the following equation:

$$EN-7-1 = 54.6 \log V - 10 \log [\arctan (l / 50)] - 10 \log (T / T200) - 42.8$$

- V: speed of the HST (km/h);
- l: length of the HST;
- T: passage time of the HST passing an observation point;
- T200: passage time of a reference train with a length of 200 m passing an observation point.

HSR manufacturers and operators adopt different solutions to reduce train noise levels. These include modifying the shape of the train's body, modifying the track, and installing noise barriers. The effectiveness and costs of these solutions vary significantly (Vos, 2016). The framework proposes another qualitative indicator:

- EN-7-2: a qualitative explanation of operators' solutions to reduce noise levels

HSR operators could use EN-7-2 to report on their efforts in tackling HSR noise reflecting on the nature of the resolution, its cost, and effectiveness.

Reporting and benchmarking exercise

Figure 7-11 compares the noise levels of HSTs that operate along selected corridors. All sound levels were calculated using the EN-7-1 formula plus the technical specifications and operating speeds of the locomotives that run on the selected lines. The benchmarking exercise considered different scenarios; this is because even along the same corridor, operators run different train sets and at different speeds. The comparison shows that higher operating speeds and longer trains are associated with higher sound levels. Also, linear changes in speed are accompanied by much stronger linear changes in noise levels. Operating trains at 300 km/h generated noise levels of around 91.2 dBA, which can highly annoy around 70 per cent of residents, while operating trains at 350 km/h generated at least 94.9 dBA, which can highly annoy almost all residents in the vicinity of the track, see Figure 2-8.

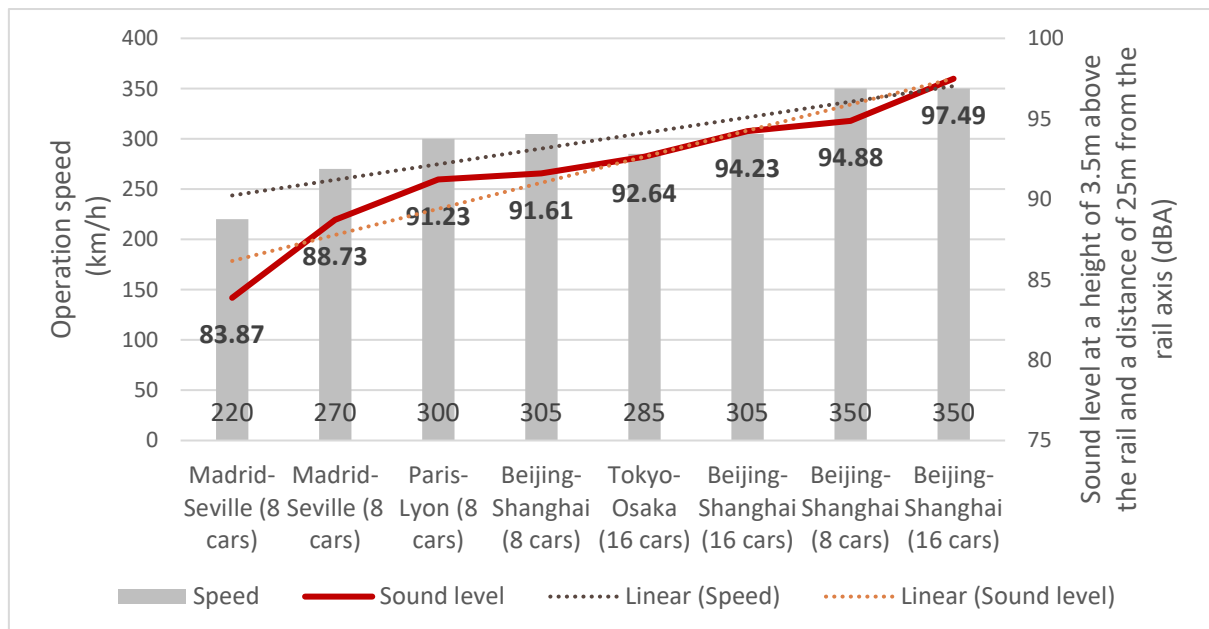


Figure 7-11: Benchmarking noise levels of HSTs which run in selected corridors

Source: author's elaboration on (Ivanov et al., 2017; UIC, 2018a; UIC, 2019e)

Table 7-3 presents several solutions and modifications on which HSR operators report in their publications. Most operators disclosed qualitative information about noise reduction measures without necessarily commenting on its effectiveness in terms of the reduction in noise levels. So, some dBA reduction values were estimated using external studies. According to Table 7-3, arched noise-blocking walls are significantly the most effective solution, as they have the capability to reduce sound levels by around 45 dBA. Also, DB's solution of equipping homes with noise-absorbing windows is effective, with reported noise reduction ranging between 15 and 33 dBA.

Table 7-3: HSR operators' noise reduction solutions and their effectiveness

Operator	Solution	Reduction (dBA)
JR Central	Implementing noise-blocking walls	10*
JR Central	Modifying the shape of the train nose for better aerodynamics	1–2
SNCF	Implementing advanced braking systems	10
Renfe	Implementing advanced braking systems	10
China Rail	Implementing arched noise-blocking walls	~ 45
JR East	Modifying the shape of the pantograph for better aerodynamics	1–10
JR East	Modifying the shape of brake disks	1–3
DB	Equipping homes with noise-blocking windows	15–33
DB	Implementing noise-blocking walls	10*
FS Italiane	Enclosing the noisy machinery of trains	1–10
FS Italiane	Implementing noise-blocking walls	10*
* The effectiveness of noise-blocking walls depends on their height		

Source: author's elaboration on (CR, 2018a; DB, 2017; FS-Italiane, 2017; Ivanov et al., 2017; JR-Central, 2018; JR-East, 2017; Renfe, 2017; SNCF, 2017a; Vos, 2016)

Figure 7-12 shows that only two operators reported on the length of sound barriers erected for 3 years. The comparison shows that the noise barriers erected by FS Italiane were significantly longer than those reported by DB.

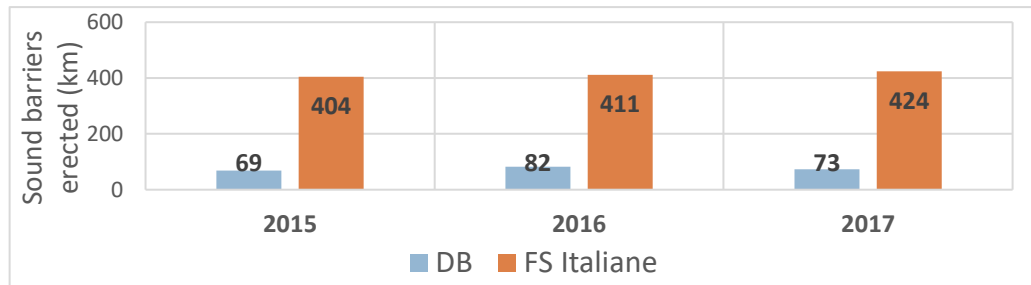


Figure 7-12: Sound barriers erected by two HSR operators

Source: author's elaboration on DB (2017) and FS-Italiane (2017)

7.7 Summary

This chapter has partly answered the third research question of this study, by proposing quantitative and qualitative indicators for expressing the environmental factors of the sustainability framework. The suggested indicators could be used for both reporting and benchmarking purposes. The usability of indicators and availability of data were tested through benchmarking exercises, which have provided insights into the actual environmental sustainability performance of HSR operators and corridors. Benchmarking data sources were mentioned, and key comparison findings were highlighted, revealing significant performance variations among benchmarked companies and corridors. However, these results and variations were not discussed as this is the topic of Chapter 8.

This chapter and the previous two chapters have proposed a variety of quantitative and qualitative indicators for expressing the 26 sustainability factors of the framework. These indicators answer the third research question of this study. All proposed economic, social, and environmental indicators can be found in Appendix C.

CHAPTER 8

TWOFOLD DISCUSSION

The previous three chapters propose some indicators for expressing the 26 sustainability factors and offer a variety of benchmarking exercises at operator and corridor levels. The benchmarking exercises have provided some insights into the economic, social, and environmental sustainability performance of HSR operators and corridors.

This chapter presents a discussion that can be divided into two parts. The first part discusses the sustainability performance of HSR operators and corridors as revealed through benchmarking exercises, referring to the reasons that drive the performance and potential causes behind variations among benchmarked entities. This part shows how the performance for specific factors correlates with performance for other factors.

The second part offers a more general discussion reflecting on the importance of the sustainability framework and the role, effectiveness, and robustness of the proposed indicators. Also, the second part discusses obstacles to benchmarking exercises and limitations, while suggesting potential improvements and areas for further research.

8.1 Discussing the sustainability performance of operators and corridors

This section discusses potential reasons behind variations in the economic, social, and environmental performance revealed by benchmarking exercises, referring to causes that drive the performance. Also, this section shows how performance for different factors is correlated.

Benchmarking HSR punctuality showed that DB's services were the least punctual. DB relates delays to the fact that most HSR services depart from the top 10 most congested stations, which impacts the whole network (DB, 2017). However, Chinese and Japanese HSR services depart from stations that are far more congested than German stations (UIC, 2019c) and hence DB's justification might not be fully valid. Connolly (2016) suggested that the main reason behind train delays in Germany is the chronic lack of investment in rail infrastructure, which has witnessed years of underfunding. Connolly (2018) points out that the per capita spending on rail infrastructure of around €70 in Germany lags far behind that in the UK and Switzerland of €165 and €362 respectively. Ageing tracks, stations, bridges, and platforms and, most importantly, the 19th-century signalling systems negatively impact the punctuality of rail services and there is a need to upgrade the infrastructure currently used (Connolly, 2016). Another explanation could be that HSTs in Germany run on mixed-use tracks, whereas in Asia, for example, most HSTs run on HSR-dedicated tracks.

Benchmarking of costs has looked at two aspects: the per km construction costs and TACs. The per km construction cost of the Beijing–Shanghai line was significantly higher than the construction costs of the Tokyo–Osaka, Paris–Lyon, and Madrid–Seville lines. Ollivier et al. (2014) claimed that the cost of building HSR in China is a third lower than costs in other countries, and the per km construction cost in China is around \$17–21 million, compared to almost \$25–39 million in Europe. The findings of the benchmarking exercise contradict Ollivier

et al. (2014)' results possibly due to the fact that around 80 per cent of the Beijing–Shanghai line is built on bridges, imposing significant additional costs (Lin et al., 2019).

In terms of revenue, the superior performance of JR Central might be explained by the significantly high annual ridership of the Tokaido Shinkansen accompanied by the relatively expensive tickets, plus the operator's involvement in a wide range of transportation and non-transportation domestic and international businesses. These revenues and associated net profits allow the company to pay its debts regularly and invest in new technologies like maglev besides making significant environmental investments and expenditures. Also, the high income enables JR Central to fund initiatives to engage with local communities. The employment benchmarking exercises showed that JR Central offers their employees the highest number of training hours. The company regularly conducts theoretical and practical training to enhance the safety culture within the organisation and to be able to swiftly respond to disasters, accidents, and extraordinary circumstances (JR-Central, 2018). Benchmarking punctuality revealed superior performance for JR Central, which it suggests is related to the provision of regular training and skill enhancement programmes (JR-Central, 2018).

SNCF's revenues and profits could be attributed to many factors, such as the diverse transport and non-transport businesses managed by the company and, most importantly, its strong international presence. The operator derives around a third of its total revenue from international activities (SNCF, 2017a). Also, the company generates additional income from the reclamation of end-of-life components and materials. Benchmarking exercises revealed that SNCF has a relatively balanced sustainability performance; the company invests its economic gains in social and economic activities. SNCF had the highest per route km environmental expenditure and is involved in a variety of initiatives and activities with local communities, in addition to offering the most affordable HSR service (OUIGO).

Renfe's revenues and profits were significantly lower than their counterparts for JR Central and SNCF. Between 2008 and 2014, the financial crisis was accompanied by fluctuation in the annual ridership figures, resulting in several financial losses. After that, increments in the annual ridership have helped increase Renfe's total revenues. Still, the company has made hardly any net profits (Barrow, 2019; EuropaPress, 2019). This might be related to the fact that Renfe's activities are centred around managing domestic transportation services, while being less involved in non-transport businesses (Barrow, 2019; Renfe, 2017). Also, the current representation of Renfe in international markets does not contribute significant external revenue. Compared to other HSR operators, the company could consider expanding its activities to include domestic and international transport and other activities. In 2019, Renfe started planning to advance its internationalisation, with the aim to generate around €220 million and €550 million from international activities in 2023 and 2028 respectively (Barrow, 2019). The relatively weak economic performance of Renfe might explain the lowest environmental expenditure, lowest consumption of materials, and reductions in the number of staff.

Benchmarking revenues showed that the net-to-total profits ratio of CR was significantly the lowest, and net profits constituted only around 4 per cent of EBITDA. Jian and Hongchang (2018) pointed out that CR is facing a financial crisis. The company depends heavily on governmental subsidies, and while debts are growing, the net operating profits are incapable of repaying the cumulative interest on debts. Surprisingly enough, despite the debt crisis, the company continues to expand its network, arguing that income from the most profitable lines will cover the losses from other lines (Mitchell and Liu, 2018). The continuous expansion of the Chinese HSR network could be related to the support of the Chinese government, which has adopted an expansion vision and hence backs CR financially. Also, the expansion might be encouraged by the construction loans offered by the World Bank. A senior

infrastructure specialist at the World Bank argues that taking into consideration the growth in ridership, China's HSR network should be capable of covering its costs in the long term, as long as the company regularly increases ticket prices to compensate for inflation rates (Ollivier, 2018). However, the author believes that increasing ticket prices on a regular basis might not be the most sustainable or sensible solution, economically or socially. Benchmarking affordability showed that the Beijing–Shanghai fare – at its current rate – is relatively the most expensive and least affordable, when compared with the fares for other corridors, constituting around 15 per cent of the per capita net monthly income in China. Similarly, Chen and Wei (2013) pointed out that HSR services in China are not affordable for the majority of the Chinese population, drawing attention to social equity concerns. Enhancing economic sustainability would therefore be done at the expense of hindering social sustainability.

To generate additional revenues, CR could consider diversifying the businesses in which it is involved nationally and internationally. Moreover, the company could temporarily put on hold plans for building new lines, especially those that are not expected to attract enough ridership. The Paris–Lyon corridor had the cheapest HSR service among all corridors, and yet SNCF can generate revenues and profits. SNCF's OUIGO service offers HSR tickets at relatively low prices that are often cheaper than the conventional TGV service by around 70 per cent. OUIGO trains feature high capacity with around 25 per cent more seats than TGV trains (Delaplace and Dobruszkes, 2015). The main aim of launching the OUIGO service is to attract additional passengers to the HSR service, especially considering the strong competition between HSR and LCC in France (Demarthon, 2019).

In terms of integration with other transport modes, the Shanghai Hongqiao hub showed a good performance. Building the hub outside Shanghai city centre allowed the combination of the international airport and HSR station in one megastructure (Chen and Wei, 2013) that is

connected with other parts of the city through several in-station metro and bus lines. When benchmarked against other corridors under three scenarios, the Beijing–Shanghai corridor facilitated the fastest DTD journeys and the shortest per km travel times. Such findings are partly correlated with the proper integration of HSR with other modes in Shanghai Hongqiao station, which allows a significant number of bus and metro stations that are distributed across different parts of the city to be reached directly without transfers.

The Tokyo–Osaka, Paris–Lyon, and Madrid–Seville corridors are 552.6, 425, and 471 km long respectively, and benchmarking the competition with air travel showed that the market share of HSR in the HSR–flight market exceeded 85 per cent in all these corridors. This finding matches those of Leboeuf (2018) and Chen and Wei (2013) that when journey distances ranges between 200 and 600 km, HSR constitutes the most favourable mode in the HSR–flight competition. This distance provides an important indication, referring to the great potential for replacing short- and medium-haul flights with HSR. Such replacement brings substantial environmental advantages. Benchmarking carbon emissions at the corridor level showed that even at low occupancy rates, HSR feature the lowest per passenger.km CO₂ emissions, when compared with flights and cars. Leboeuf (2018) presented similar findings, asserting the environmental advantage of HSR against other transport modes especially for short- and medium-distance trips. However, according to the consultation with UIC experts, replacing short- and medium-haul flights with HSR remains a complicated topic that is greatly influenced by national and international politics. Leboeuf (2018) points out that when journey distances exceed 1000 km, the share of HSR in the HSR–flight market does not exceed 20 per cent. However, benchmarking the competition with air travel showed different results, where the HSR share along the 1318-km Beijing–Shanghai corridor equalled to almost 50 per cent, revealing that HSR can compete with airlines even at longer distances

Comparing emissions and energy consumption at operator level showed that SNCF's HSR services had the lowest per passenger.km CO₂e emissions, at around 2.4 g CO₂e/passenger.km. This is related to the fact that France depends heavily on nuclear energy for generating traction electricity, and this type of energy features a low emission factor especially when compared with fossil fuels (UIC, 2018a).

Benchmarking recycling rates showed that apart from JR Central, all HSR operators recycled at least 85 per cent of their refuse, whereas JR Central's recycling rate was close to 50 per cent in 2017. The author suggests that JR Central's reported recycling rate may be the most realistic, especially when it is relatively hard to recycle some components such as concrete ballast. Comparing sound levels of HSR along the benchmarked corridors showed that higher operating speeds and longer trains are associated with higher sound levels, which have the potential to seriously annoy residents along the track. However, benchmarking the effectiveness of selected noise-reduction solutions revealed that HSR operators can adopt a variety of methods to reduce sound levels, which vary significantly in terms of effectiveness and cost. While arched noise-blocking walls might be the most effective solution, their per km construction cost can reach as much as €11 million (CR, 2018a). So, HSR operators should choose solutions that match their economic capabilities appropriately.

The author believes that all 26 sustainability factors are important, and while some factors seem to be more critical than others, it is desirable that HSR operators have a balanced sustainability performance. In an optimum scenario, HSR companies would be able to generate sufficient income and be able to provide an affordable, safe, and punctual service besides investing in local communities and staff skills, while minimising negative impacts on the environment.

8.2 General discussion

This section reflects on the importance of the sustainability framework and discusses the effectiveness and robustness of its indicators. Moreover, it analyses obstacles and limitations of benchmarking exercises and offers some recommendations.

8.2.1 Importance of the framework and its proposed indicators

In the previous three chapters, the sustainability framework proposes a variety of quantitative and qualitative economic, social, and environmental indicators for expressing the 26 selected sustainability factors. The full list of proposed indicators can be found in Appendix C. The 26-factor framework and its suggested indicators constitute a genuine sustainability reporting mechanism that facilitates a minimum level of standardisation while tackling economic, social, and environmental factors that are representative of the sustainability performance of HSR. Some proposed indicators have been developed by operators and international reporting guidelines, while others have been created by the author to suit the purpose of this study and to facilitate future reporting practices. However, the proposed indicators are not exclusive and HSR operator can use additional parameters to fulfil their reporting requirements.

The role of the proposed indicators is not limited to providing HSR operators with a standardised sustainability reporting mechanism; they could be used for updating the reporting guidelines and publications of the railway sector plus international agencies like the UIC and GRI. In addition, the framework could offer an economic, societal, and environmental view of sustainability. The framework proposes several railway-specific parameters for facilitating disclosure on factors that are poorly covered in both operators' reports and the guidelines of the GRI and UIC. Updating international reporting guidelines and publicising them would

potentially improve the take-up and reporting practices of railway operators (Azizul Islam and Deegan, 2008).

Moreover, the framework could provide a minimum level of standardisation in studies and researches that look at factors like effects on tourism, CBA, and wider impacts. For example, the study proposes a change in international and domestic tourism demand as an indicator that has been used by several studies, and hence this indicator has the potential to be used in future researches. Also, benchmarking the BCR and WEIs has shown remarkable variation among studies in terms of the benefits and costs covered in each evaluation. Missing specific costs or benefits that are associated with HSR projects could weaken the creditability of feasibility study outcomes, resulting in inaccurate conclusions that might affect the decision-making process. The framework offers a comprehensive explanation of topics and points that should be covered in CBA studies.

It is worth mentioning that most of the proposed indicators are not limited to expressing the sustainability performance of HSR; rather, they could also be used for reporting on and benchmarking the sustainability performance of conventional railways. However, such an approach would require some modifications to the definition of indicators. For instance, while the percentage of trains that arrive within 5 minutes of the scheduled arrival time seems to be appropriate in the HSR case, the percentage of trains arriving within 10 to 15 minutes might be more suitable for conventional rail.

Also, some of the proposed indicators allow benchmarking of HSR against other transport modes in the areas of carbon emissions, energy consumption, and DTD travel time. Conducting such comparisons could help to highlight the social and environmental advantages associated with shifting to HSR.

The applicability and usability of some of the suggested parameters have been tested with real performance data and under different scenarios. The quantitative nature of indicators has allowed direct benchmarking exercises at corridor, operator, and project level. These exercises have revealed remarkable variations in performance among benchmarked entities and succeeded to some extent in providing insights into the actual performance of HSR companies, by revealing best practices and operators with different relative performance.

8.2.2 Discussing the effectiveness and robustness of the proposed indicators

As explained in section 3.3.4, the ORR suggested four-point criteria for testing the effectiveness and robustness of railway benchmarking indicators. The benchmarking exercises in this study used 41 quantitative indicators; Table 8-1 presents how these indicators met the ORR's four-point criteria.

Regarding the first criterion, all proposed indicators facilitate an acceptable level of comparability, taking into consideration significant differences between benchmarked corridors, operators, and projects. Normalisation has played an essential role in ensuring that benchmarked entities can reasonably be held accountable for the levels of performance revealed. Some indicators demonstrate advanced comparability of performance by further allowing the benchmarking of HSR against other transport modes.

In terms of the second criterion, calculations for almost all indicators are relatively clear and straightforward. The majority of indicators do not require complicated calculation methods and, in some cases, report figures were used directly as an indicator. Still, data were often standardised, and units of quantities were unified. Operators have sometimes reported on some factors using certain parameters that were different to the proposed indicators, but it was possible to convert operator parameters to the indicators proposed in this study.

Regarding the consistency criterion, 35 out of 41 parameters appear to correlate with other parameters in the framework. Such correlation is very important. In interviews, experts of the UIC underlined the importance of consistency, and the Head of the Sustainability Unit emphasised that in order to create a functional and reliable framework, performance indicators must correlate with each other. The correlations between proposed indicators exist within a specific sustainability pillar or link several pillars together. On the one hand, the emissions performance is directly associated with the performance for energy consumption and the energy mix. Also, the number of training hours is linked with the number of accidents, fatalities, and injuries, as more training enhances the safety culture and reduces the potential for accidents. On the other hand, the punctuality and reliability of HSR services is correlated with customer satisfaction; a punctual and reliable service enhances the satisfaction of clients. Also, higher net profits could allow investment in environmentally friendly technology while facilitating further engagement with local communities and more staff training.

Finally, in terms of the credibility criterion, each of the proposed indicators can be understood and related to one or more stakeholders. The suggested parameters concern different parties including passengers, employees, policy makers, planners, international collaborators, railway organisations, and environmental agencies.

The author has found that quantitative benchmarking does not always demonstrate causality. For instance, having a high share of the international market revenue in the total revenue does not reveal the international activities in which an operator is involved. For this purpose, and alongside the quantitative parameters, the framework suggests several qualitative indicators, using which operators can qualitatively explain the causes, solutions, and efforts that drive the actual performance and related improvements. The framework extensively defines the points and topics that can be covered within each proposed qualitative indicator. Qualitative

explanations could influence actions and help other operators to track the causes of weaknesses and equally enhance performance. To summarise, quantitative and qualitative indicators complement each other and both are necessary for a balanced and meaningful disclosure.

Table 8-1: Testing the robustness and effectiveness of indicators with ORR's four-point criteria

Symbol	Proposed indicators used in benchmarking exercises	Comparability	Ease of calculation	Consistency	Credibility
EC-1-1	The percentage of trains arriving within 5 minutes of the scheduled arrival time	**	**	*	*
EC-2-1	The construction cost of major/new HSR lines per km	*	*	*	**
EC-2-5	The track access charge per train-km of major lines	*	**	*	**
EC-3-1	Operating profits (EBITDA) per HSR route km	**	*	*	*
EC-3-2	Net operating profits per HSR route km	*	*	**	*
EC-3-3	Net operating profits of major HSR corridors per km	*	*	**	*
EC-4-1	Operating revenue per train-km (monetary unit/train-km)	**	*	*	**
EC-4-2	Operating cost per train-km (monetary unit/train-km)	**	*	*	**
EC-5	The enhanced benefits-to-costs ratio of new HSR projects	*	*	*	*
EC-7-1	Changes in domestic tourism demand in cities along HSR corridors	*	*		*
EC-7-2	Changes in international tourism demand in cities along HSR corridors	*	*		*
EC-8-1	The market share of HSR against airlines in major corridors	*	*	*	**
EC-8-2	The daily and annual ridership of HSR and airlines in major corridors	*	*	*	*
EC-8-3	HSR–airline pricing comparison in major corridors	**	*	*	**
EC-9-1	The number of metro and bus lines at the HSR station	*	**	*	*
EC-9-2	The number of metro stations and bus stops that can be reached directly from HSR stations without transfer	*	**	*	*
EC-9-3	The quality of the transfer between HSR services and other transport modes expressed in minutes	*	*	*	*
EC-9-4	The number – and cost – of parking spaces in and within 500 m of stations	*	*	*	*
EC-9-5	Time and monetary costs associated with transferring from the HSR to the nearest international airports	**	*	*	*
SO-1-1	The total number of significant rail accidents	*	*	*	**
SO-1-2	The number of staff killed, seriously/minorly injured in the workplace	*	*	*	**
SO-1-3	The number of passengers killed, seriously/minorly injured due to railway accidents	*	*	*	**
SO-1-4	The number of third-party people killed, seriously/minorly injured due to railway accidents	*	*	*	**
SO-2-1	The overall door-to-door travel time between two points	**	*	**	**
SO-4-1	The total number of homes that will be demolished per route km	*	*		*
SO-7	The overall passenger satisfaction level of the HSR service (%)	**	**	*	*
SO-8-1	The total number of employees	*	**	*	**
SO-8-2	The percentage of women in the workforce (%)	**	**		*
SO-8-3	Total training hours provided per employee (hours)	**	*	*	*
SO-8-4	The annual turnover rate of employees (%)	**	*	*	*
SO-9-1	The fare for 100 km of HSR travel along different corridors	*	*	*	*
SO-9-2	The fare for 100 km of HSR travel along different corridors, relative to the net average monthly income (%)	**	*	*	*
EN-1	The equivalent CO ₂ emissions of operating HSR services (g CO ₂ e/p.km)	**	*	**	**
EN-2-1	The final energy consumption of operating HSR services (kWh/p.km)	**	*	**	**
EN-2-2	The share of renewable electric energy in the total energy consumption (%)	**	*	*	*
EN-3-1	The amount of active substances – herbicides – used per track km	**	**	*	*
EN-3-2	The cost of active substances – herbicides – used per track km	**	**	*	*
EN-4	The amount of water/sand/concrete/wood/metal/paper consumed per route km	*	*	*	*
EN-5-2	The environmental expenditure per operated route km	*	*	*	**
EN-6	The annual recycling rate (%)	**	**	*	*
EN-7-1	Sound level (dBA) at a height of 3.5 m and a distance of 25 m from the rail axis	**	*		*
Key: * = applicable ** = very applicable no star = not applicable					

Source: author's evaluation based on the criteria offered by ORR (2017)

8.2.3 Obstacles and limitations of benchmarking exercises

The benchmarking exercises faced several obstacles, some of which were presented by Nash and Shires (2000), see section 2.3.3. For example, the diversity of rail and non-rail activities managed by each operator is demonstrated in the multiplicity of output data and associated abundant parameters provided in sustainability reports. This means that some of the 26 sustainability factors can be expressed by a variety of indicators. However, the study has, where possible, selected parameters on which several operators agree in their reporting practices and are equally important from the perspective of international reporting guidelines plus external studies.

Another obstacle is related to the quality of data. Input data for benchmarking exercises have been obtained from operators' publications plus the UIC's database and reports. These sources sometimes provide conflicting inputs, even regarding basic information like corridor length, daily and annual ridership, and annual train and passenger activity. Moreover, operators' own data are not completely identical through different publications; for instance, report information was slightly different from figures provided via company websites. Even though the UIC's data may be generally consistent, it is also a 'second hand' data and hence it might not be completely accurate. Furthermore, to fill data gaps, the study has occasionally used some independent online articles and newspapers. Data from these sources often express the publishers' own agenda and hence might be inaccurate and even biased. However, regardless of the source of data, all these sources were appropriately cited under each benchmarking exercise.

Considering these data issues, the results and findings of all benchmarking exercises are subject to the accuracy and validity of the data collected. The previously discussed data issues

impose serious problems that could challenge and even hinder the accuracy and creditability of any potential benchmarking exercise. So, it is desirable that HSR operators regularly provide key performance information related to the 26 sustainability factors and their proposed parameters. Operators' sustainability reports could be the central and most trustworthy platform that offers robust benchmarking data, allowing a minimum level of comparability.

Finally, in several cases, companies offer aggregate data regarding costs, revenues, safety, employment, emissions, and energy in their publications, without distinguishing between HSR and other transport and non-transport services. Aggregate information offers a general overview of company performance. However, if operators disclose performance information that exclusively relates to HSR services, then benchmarking exercises will generate a more meaningful and realistic output, which can help to influence more effective outcomes and decisions.

8.2.4 A gentle reminder to railway operators

HSR operators often point out specific indicators to highlight their superior performance for a specific sustainability aspect. For instance, JR Central uses the 'number of accidents that result in injuries or fatalities of passengers on board' as a safety indicator, to highlight the fact that the company has had zero accidents since operations commenced (JR-Central, 2018). Such specific indicators can only be used for benchmarking purposes when other operators also report on them. Also, highlighting a specific indicator without providing complementary performance data on a specific topic could be misleading. For example, highlighting zero fatalities due to railway operations during a specific period does not necessarily mean ultra-safe railway operations. Highlighting a particular parameter is not enough to claim superior safety performance; rather, it should be accompanied by a comprehensive safety disclosure that

reflects on fatalities and minor and serious injuries caused to passengers, staff, and third parties due to railway activities.

Hahn and Kühnen (2013) explained that some firms might avoid reporting on specific topics, especially those associated with weak performance. This study confirms Hahn and Kühnen (2013)'s point as it has found that some operators tend to avoid reporting on particular factors and related indicators such as net profits and the number of fatalities and injuries caused to different parties. This becomes a problem for serious benchmarking when third parties like the media disseminate information about losses or major accidents. These might be inaccurate and biased and hence have more negative effects than when they are published by the operator. For example, the author has examined several online articles and newspapers that discuss (in Spanish) Renfe's financial losses; these information sources provide data that vary scientifically. So, HSR operators are encouraged to disclose performance information in a balanced manner, reflecting on both positive and negative aspects of performance.

The framework does not suggest that operators should fake or manipulate their performance figures to fulfil the reporting requirements of the proposed indicators. Moreover, fulfilling reporting requirements should never be done at the expense of degrading the actual performance, and seeking good-looking figures does not justify hindering the quality of services. For instance, some trains skip some scheduled stations to improve punctuality figures. Such an act imposes serious risks; first, it artificially covers the real gap in the performance; second, it degrades the performance – and the data – of other indicators like customer satisfaction, revenues, cancellation, and ridership. Instead, the framework encourages operators to provide a truthful, transparent, and high-quality reporting, and because what is well measured is well managed, high-quality reporting will lead to high-quality performance. The punishment culture should be avoided, and a healthy reporting culture should be adopted where staff are

encouraged to report realistic performance data without manipulating figures or degrading the quality of services. Staff should believe that only truthful and realistic data can reveal performance gaps, then realistic solutions to solve problems should be sought.

8.2.5 What could have been done better?

Due to limitations of time and data availability, several benchmarking exercises focused on performance for 2 or 3 years. The proposed indicators could be used in the future for facilitating comparisons that consider performance over longer timeframes. This is specifically important because benchmarking exercises that are stripped of a longer-term context – particularly trend analysis – run the risk of being misleading.

Regarding normalisation, almost all proposed indicators have been normalised to values such as passenger and train activity expressed as passenger.km and train.km respectively, the total route km managed by operators, the total track km, and the per capita net monthly income. The normalisation process has generated more meaningful results, especially when benchmarking factors such as the affordability of HSR and DTD travel time. Normalising to the operated route km could have been replaced with normalising to track.km, passenger.km, and train.km, especially when discussing factors such as safety. However, the availability of reliable data often restrained such an approach. In developing any new guidelines, the UIC should encourage HSR operators to regularly report on key performance information that relates to passenger and train activity, annual and daily ridership, and total track kilometres. These will ease the calculation of different indicators for conducting benchmarking exercises.

CHAPTER 9

CASE STUDY: THE RELATIONSHIP BETWEEN HSR AND SOCIAL EXCLUSION IN CHINA

The previous chapters propose quantitative and qualitative indicators that can be used for expressing the selected economic, social, and environmental sustainability factors. However, no indicators have been proposed to express the social exclusion factor. In Chapter 2, social exclusion is defined and its types classified into seven categories. Moreover, some recent studies are presented that link HSR and social exclusion categories in Spain, Italy, and the UK.

This case study looks at the relationship between HSR and social exclusion categories in China. Specifically, it explores the obstacles that prevent specific groups from using HSR services, in accordance with the previously listed seven exclusion categories. Pagliara et al. (2017a) and Pagliara et al. (2017b) used stated and revealed preference surveys that collected responses from both HSR and non-HSR users. So, to express the social exclusion factor, the 26-factor sustainability framework suggests the following indicator:

- SO-5: Results of a stated and revealed preference survey that explores barriers to using HSR

9.1 Methodology

Using travel surveys to understand people's perceptions and preferences about HSR offers several advantages. First, it helps decision makers and planners to better understand travel demand alongside notifying them to consider applying necessary inclusion policies (Su et al., 2019). Second, travel surveys assist railway operators in enhancing the quality of the service both in stations and trains, plus supporting the application of adequate pricing models for attracting new customers while keeping current passengers (Xu et al., 2018; Zheng et al., 2019). This case study is based on collecting information about the obstacles that prevent specific users from using HSR services in China. For this purpose, an online questionnaire that encompasses stated and revealed preference questions was prepared. The questionnaire was created and launched on the WJX.CN website, which uses the Star Survey tool. The website is famous in China and is used by a variety of academic, financial, technological, and industrial institutions. These include universities in Shanghai Jiao Tong, Beijing, and Tsinghua. The website allows the survey to reach participants in different provinces and from different occupations, age groups, and education levels. All questions were written in Mandarin, the official language in China. Before its launch on the website, 17 native Mandarin speakers volunteered to test the questionnaire by answering its questions. Those volunteers included friends of the author, their friends, and relatives from different age groups. All volunteers expressed that they understood the questions of the survey easily without being confused. Testing the survey before its official launch confirmed its clarity and readiness to use.

The survey was officially available online in August 2019 for a period of 65 days. A total of 3655 responses were received. However, to ensure the robustness of data, 302 responses were set aside after carefully reviewing all responses. The neglected responses contained

misleading or suspicious information. For instance, responses of ‘speeders’ who spent a very little time – less than 10 second- on answering questions of the survey were deleted. Also, the IP address of the device from which some participants answered the survey did not match the province they stated they live in. After filtering responses, the final number of valid and useful responses was 3353. The author activated some features that were offered by the online platform, to prevent participants from submitting more than one response. This allowed the avoidance of duplication.

The first part of the questionnaire collected socioeconomic information from respondents including their age, education, job, salary, and nationality. Then, participants were asked about several topics including: whether they have ever used HSR; the most favourable factor for using HSR; and their favourite transport mode for long-distance trips of 150 km or more. After that, participants were asked to select the transport mode that they chose for their last long-distance trip of 150 km or more. The next part of the questionnaire asked participants about the strongest barrier that prevents them from using HSR services, and they could choose only one barrier. Barriers were classified into seven categories in accordance with the seven categories of social exclusion as presented in section 2.5.3 in Chapter 2 and as discussed by Church et al. (2000). Each category was supported by an example to help respondents in their selection. For example, the geographical exclusion category reflected on the difficulty of reaching the HSR station. The final part of the questionnaire presented a hypothetical scenario, which featured three HSR travelling options. These options showed a trade-off between time and money, and from which respondents could select only one option. The hypothetical scenario was used to understand the extent to which respondents are sensitive about time and money when using HSR. The survey questions, a participant information sheet, and an

electronic consent form are available in Appendix D, Appendix E, and Appendix F respectively. After collecting data, a cross-analysis was conducted that links the categories of social exclusion and the socioeconomic characteristics of non-HSR users. Also, a benchmarking exercise that compares the findings of the Chinese case with results of similar studies in other countries is presented. Table 9-1 shows the socioeconomic characteristics of respondents.

Table 9-1: Socioeconomic characteristics of the sample

Characteristic	Level	All users (n = 3353) %	Non-HSR users (n = 1060) %
Age	18–21	10.53	11.49
	22–30	29.35	29.62
	31–40	32.39	30.95
	41–50	20.49	20.53
	51–65	6.29	6.52
	66 or above	0.95	0.89
Gender	Male	48.88	48.2
	Female	51.12	51.8
Nationality	Chinese	94.51	94.5
	Other	5.49	5.5
Education	High school or below	25.95	29.5
	College	38.26	40.25
	Bachelor	29.67	24.73
	Master's degree	4.68	4.29
	PhD and above	1.43	1.23
Occupation	Full-time/part-time job	32.57	32.7
	Student	16.31	16.85
	Freelancer	35.61	33.52
	Unemployed	6.89	7.24
	Retired	4.32	4.59
	Other	4.29	5.1
Monthly income	¥2500 or below	30.96	36.22
	¥2500–5000	45.21	43.72
	¥5000–10000	19.98	16.72
	¥10000 and above	3.85	3.34
Travel type	Alone	23.71	27.69
	With a partner	32.36	30.35
	With a friend	26.57	23.7
	With colleagues	5.07	4.89
	With family	12.29	13.37
Trip purpose	Work	19.03	19.97
	Study	22.46	22.24
	Holiday	33.16	31.16
	Personal activities	25.35	26.63

9.2 Results and discussion

This section presents the survey's results and discusses potential reasons behind them.

9.2.1 HSR experience and preference

Figure 9-1 shows that around 70 per cent of the sample had previously used HSR services in China, compared to almost 30 per cent who had never used it. The number of female users was lower than the number of male users. This could be related to variations in social responsibilities between men and women, leaving women with less money and time to travel.

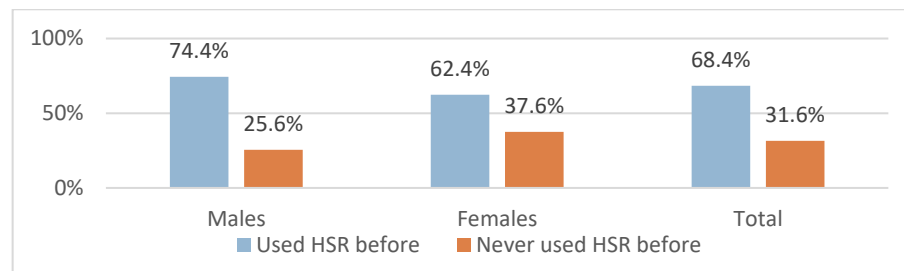


Figure 9-1: Experience of using HSR by gender

Figure 9-2 illustrates that the results for stated and revealed preferences were similar, suggesting that the normal train was the most favourable mode, followed by HSR and cars. More than half of non-HSR users used a normal train for their last journey of 150 km or more.

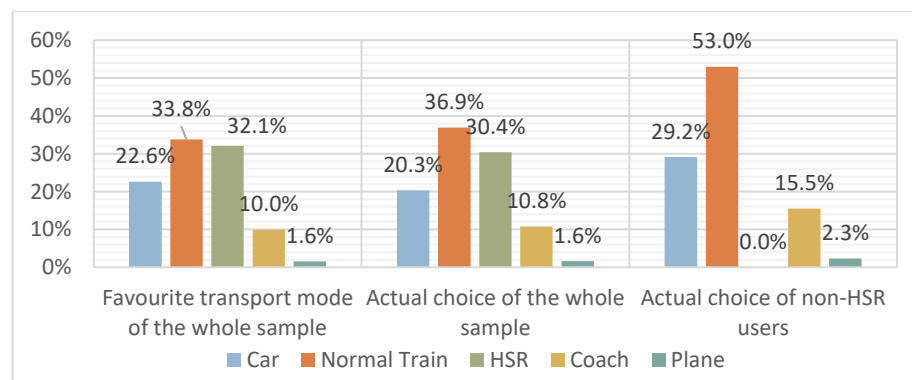


Figure 9-2: Stated favourite transport mode for a 150 km trip vs actual choice for non-HSR users

The popularity of normal trains over HSR could be linked to several factors. Normal trains are usually more frequent, and they offer more flexibility and options in terms of departure and arrival times while offering tickets at relatively lower prices when compared to HSR. Also, travellers who are less concerned about travel time can choose to travel by normal train at night, considering the availability of sleeper options. Moreover, normal train stations are typically located in the city centre in China, while the majority of HSR stations are in the suburbs and peripheral zones outside the city. This results in longer access/egress time to reach HSR stations (Chen, 2012; Chen and Wei, 2013; Diao et al., 2017).

Respondents were asked to select the most favourable factor for using HSR. Considering the whole sample, Figure 9-3 shows that comfort was significantly the most favourable factor, with around 28 per cent of the sample selecting it. Travel time, reliability, and cost were also favourable factors for using HSR, especially when compared with factors of safety, environmental impact, and seat availability, which were less important. Station facilities and management were barely considered as a favourable factor for using HSR.

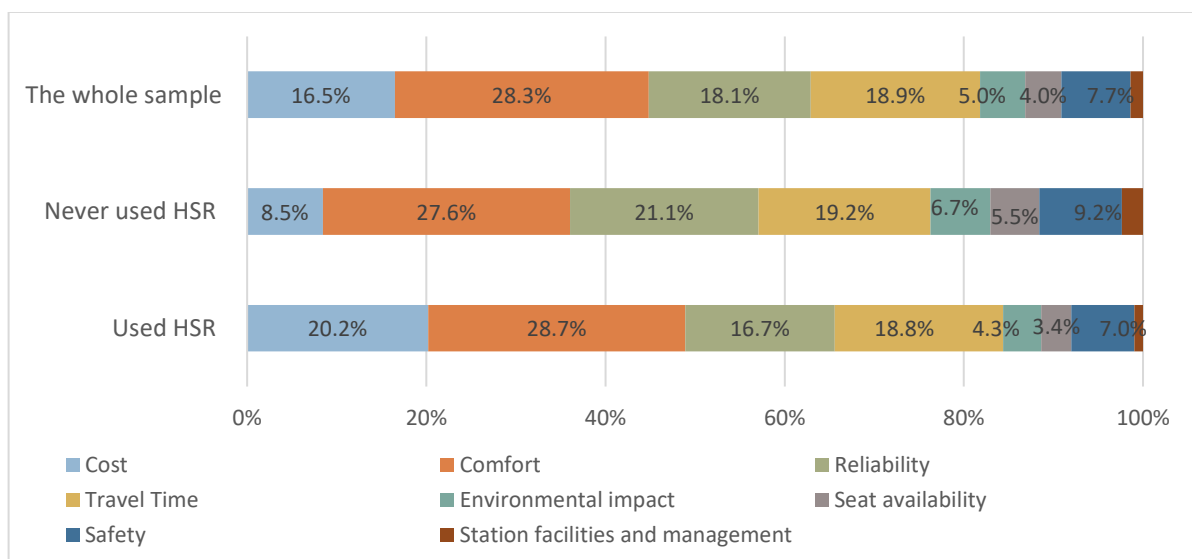


Figure 9-3: Favourable factors for using HSR

Selecting comfort as the most favourable factor for using HSR is surprising, especially when several studies found that travel time constitutes the most favourable factor. For instance, Leboeuf (2018) conducted a travel survey in Spain, the UK, and France and found that travel time followed by cost is the most important factor that encourage choosing HSR. Also, Pagliara et al. (2017b) found that travel time is selected as the most favourable factor for using HSR in the UK. The findings of the Chinese case suggest that comfort can join travel time and cost as the most favourable factors for using HSR.

Selecting comfort could be related to the fact that HSR stations constitute the modern face of China, with futuristic architectural design and technological advances, while featuring order, tidiness, massive waiting halls, clean facilities and toilets (Chen and Wei, 2013). Other forms of comfort are facilitated in HSR trains: comfortable seats, air-conditioned locomotives, plenty of legroom, and a variety of food and drink services (Jacobs, 2019). In contrast, normal train stations are considered as a symbol of chaos where huge numbers of workers from rural areas gather in small halls that are less tidy and clean (Chen and Wei, 2013).

Figure 9-3 also distinguishes between HSR and non-HSR users, and a clear distinction existed between these two groups. Around 20 per cent of HSR users selected the cost factor as the most favourable factor for using HSR, compared to only around 9 per cent of those who never used HSR before. This finding suggests that HSR passengers are relatively more satisfied with the monetary costs associated with travelling by HSR, while non-HSR users might be holding the perception that HSR is an expensive service, hypothetically preferring it for factors of comfort, travel time, and reliability.

9.2.2 Barriers to using HSR services

Table 9-2 presents the seven social exclusion categories among both HSR and non-HSR users. Economic exclusion and geographical exclusion constituted the top two categories for both groups. However, there was a clear distinction between the two groups. Economic exclusion was more relevant in the case of non-HSR users, while geographical exclusion was dominant in the case of HSR users. Also, the exclusion values of non-HSR users showed more significant variations than those of HSR users, which were relatively closer to each other. Physical exclusion ranked third for both groups. There were no significant differences between males' and females' perceptions since their percentages were relatively similar.

Table 9-2: Church's categories of social exclusion by gender

Exclusion type	Males n = 1639		Females n = 1714		Total n = 3353	
	HSR users n = 1219	Non- HSR users n = 420	HSR users n = 1074	Non- HSR users n = 640	HSR users n = 2293	Non- HSR users n = 1060
Economic exclusion	10.59%	20.02%	9.80%	17.62%	20.39%	37.63%
Geographical exclusion	15.20%	13.76%	13.63%	13.59%	28.82%	27.35%
Physical exclusion	8.14%	5.96%	7.55%	6.86%	15.69%	12.82%
Fear-based exclusion	6.76%	3.30%	5.98%	3.90%	12.75%	7.20%
Time-based exclusion	7.16%	3.04%	8.33%	5.74%	15.49%	8.79%
Space exclusion	1.67%	1.16%	2.45%	2.49%	4.12%	3.64%
Exclusion from facilities	0.98%	0.94%	1.76%	1.63%	2.75%	2.57%
Total	50.49%	48.18%	49.51%	51.82%	100%	100%

A cross-analysis was conducted to explore the relationship between types of social exclusion and socioeconomic features of non-HSR users reflecting on their salary, age, and occupation besides other mobility-related choices such as the purpose of the trip.

Figure 9-4 shows the relationship between social exclusion categories and the salary of non-HSR users. Across the sample, economic exclusion was predominant, with around 38 per cent of participants seeing themselves excluded from using HSR on economic grounds. The economic exclusion values decreased significantly with higher incomes, to be substituted by geographical and physical exclusion whose values increased steadily.

Low- and low-medium income groups perceived the strongest levels of economic exclusion, with around 47 per cent and 37 per cent of respondents being economically excluded respectively. In contrast, different types of exclusion dominated other income groups; geographical exclusion was dominant in the medium-high income group. The highest income group perceived the highest levels of physical and fear-based exclusions. Su et al. (2019) pointed out that Chinese businesspeople and rich passengers are highly concerned about their safety and convenience in stations. It might be that the richest group fear for their personal safety in HSR stations due to crowding or the lack of in-station VIP waiting halls.

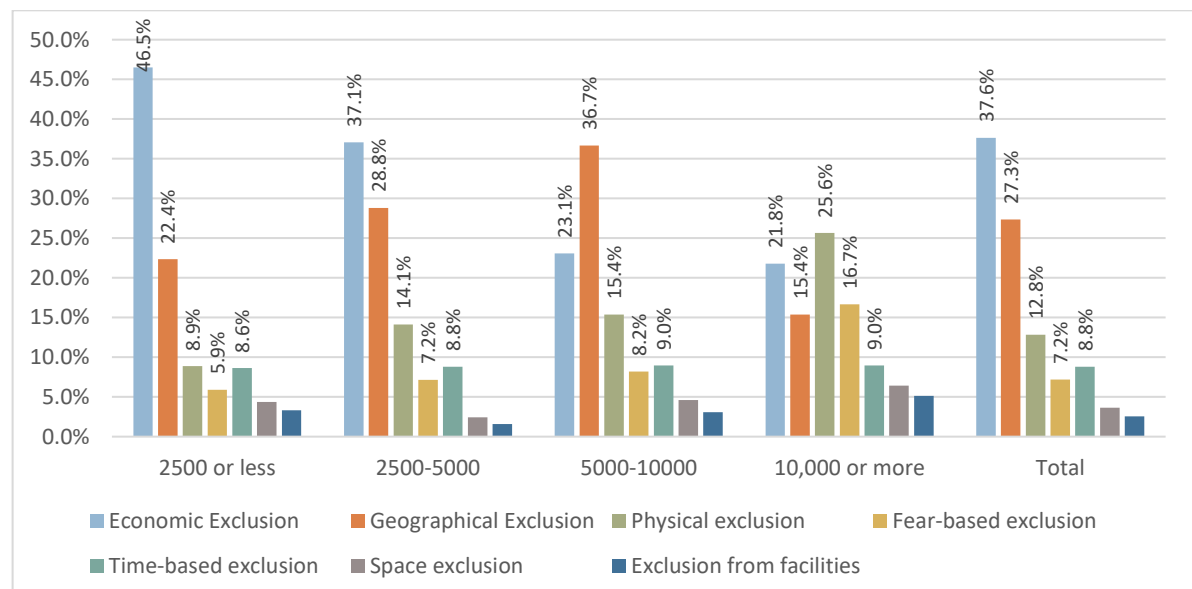


Figure 9-4: Social exclusion type vs monthly income for non-HSR users

Figure 9-5 illustrates the relationship between social exclusion categories and the age of non-HSR passengers. Except for the middle-aged group, all other groups were dominated by economic exclusion, followed by geographical and physical exclusion respectively. People from the middle-aged group usually have stable jobs and salaries and hence the monetary costs associated with travelling are more affordable to them. Significantly, the 51–65 age group perceived the strongest level of economic exclusion when compared with other groups. This could be related to the fact that people from this age group travel less frequently and choose to save or spend money on other activities.

Remarkably, the oldest group perceived the strongest level of physical exclusion and 25 per cent of people aged 66 or above saw themselves as physically excluded. This finding is very important since it might refer to two points: (1) the lack of disability and accessibility facilities – in trains and stations – that meet the special requirements of the elderly; (2) the lack of disability and accessibility facilities in subway stations and other connecting transport modes, which prevent passengers from reaching HSR stations.

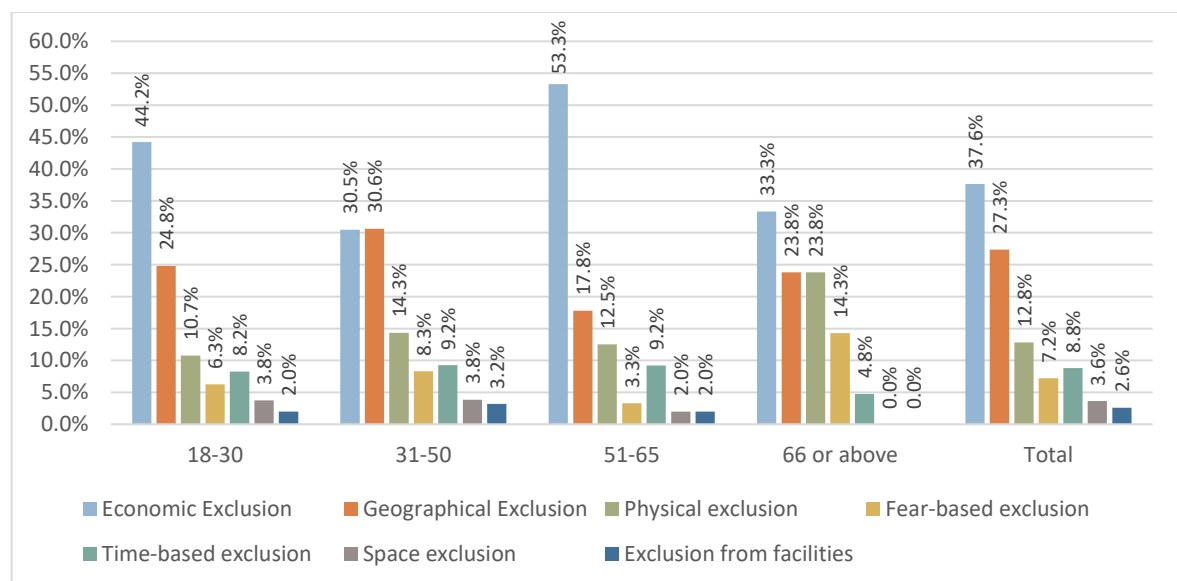


Figure 9-5: Social exclusion type vs age for non-HSR users

Figure 9-6 links the purpose of the trip and social exclusion categories. The economic barrier was perceived as the strongest barrier by respondents who travelled for work, holiday, and personal activities. People who travel for work usually have tight schedules and have to book their tickets for specific dates and from/to specific destinations. This could present HSR as an expensive option for work travellers. Respondents who travelled for study perceived the strongest level of geographical exclusion among other groups. Students in China enjoy discounted HSR tickets and hence they are less excluded for economic reasons (ChinaRailway, 2019). However, they are geographically excluded since they might be living in remote and rural areas where it is hard to reach HSR stations.

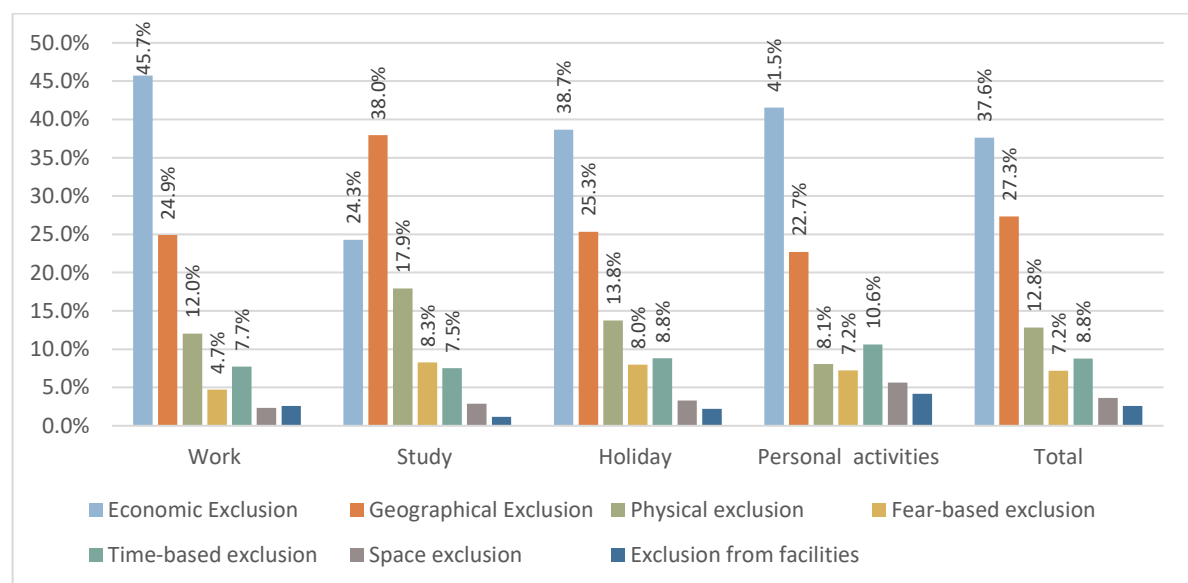


Figure 9-6: Social exclusion type vs trip purpose for non-HSR users

Figure 9-7 illustrates the relationship between social exclusion categories and the occupation of non-HSR users. Generally, economic exclusion followed by geographical exclusion was dominant across all occupations. Full-time and part-time workers perceived the strongest level of economic exclusion, with more than half of respondents in this category seeing themselves as excluded from using HSR for economic reasons. This could be related to

the low salaries of this category besides their tight schedule which forces them to travel on specific routes, dates, and services that are more expensive. Economic exclusion remarkably dominated other forms of exclusions in the retired group. This could be related to the fact that the income of this group is not enough to support travelling by HSR. Another explanation is that retired people are reluctant to spend money on travelling and are willing to spend it on other activities.

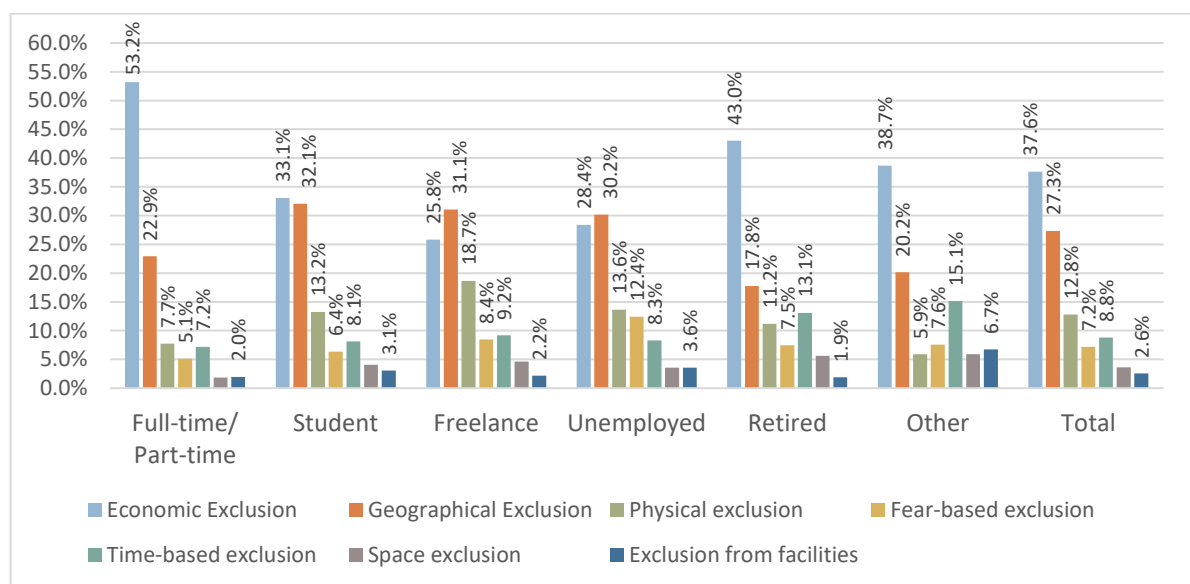


Figure 9-7: Social exclusion type vs occupation for non-HSR users

Finally, Figure 9-8 shows the relationship between social exclusion categories and the chosen transport mode. Economic exclusion followed by geographical exclusion dominated for car, normal train, and coach users, whereas geographical exclusion was dominant in the case of plane users. This is justifiable since travelling by car, normal train, and coach might be cheaper than travelling by HSR in China. In contrast, travelling by plane could be more expensive than travelling by HSR. Since plane users are less concerned with the monetary cost of travel, they are more concerned with geographical and time-based exclusions. It might be that plane users

find that reaching an airport is easier and more convenient than reaching an HSR station. Also, planes are the fastest travel option, especially for long-distance trips.

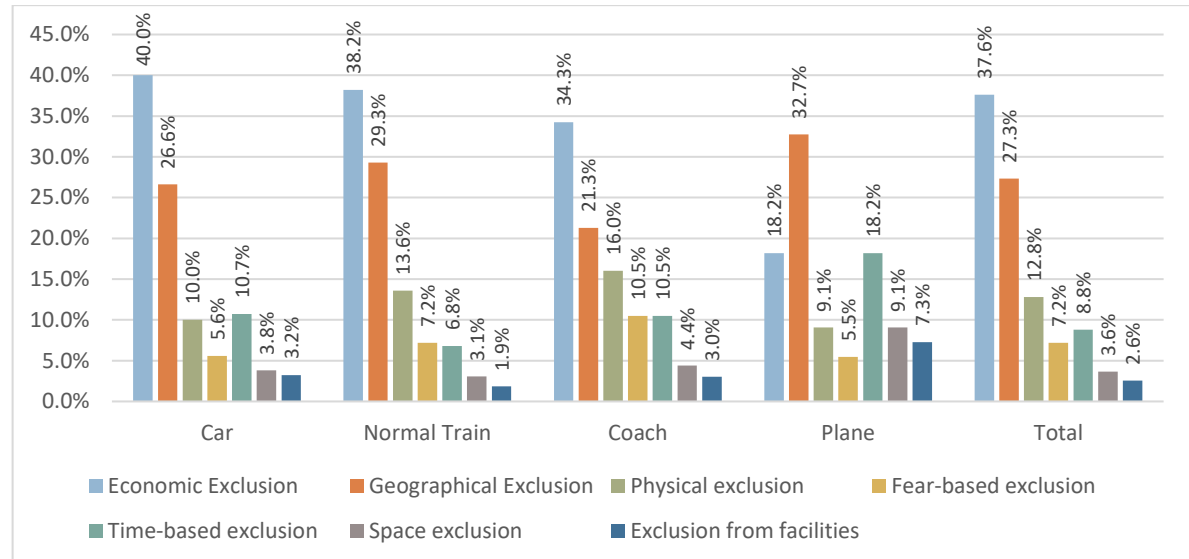


Figure 9-8: Social exclusion type vs transport mode for non-HSR users

9.2.3 Benchmarking exercise

Pagliara et al. (2017a) examined the relationship between the categories of social exclusion and HSR in three European countries: Spain, the UK, and Italy. Figure 9-9 presents a benchmarking exercise that compares the findings of Pagliara et al. (2017a) with the results obtained from the Chinese case. Except for Italy, economic exclusion followed by geographical exclusion was predominant in all countries. In the UK, respondents perceived the strongest level of economic exclusion when compared to respondents of other countries. Geographical exclusion was significantly dominant in Italy, with around 60 per cent of respondents seeing themselves as excluded from using the HSR service due to geographical obstacles. In Spain and China, the values for economic exclusion were somewhat close to each other, and the same trend appeared for geographical exclusion.

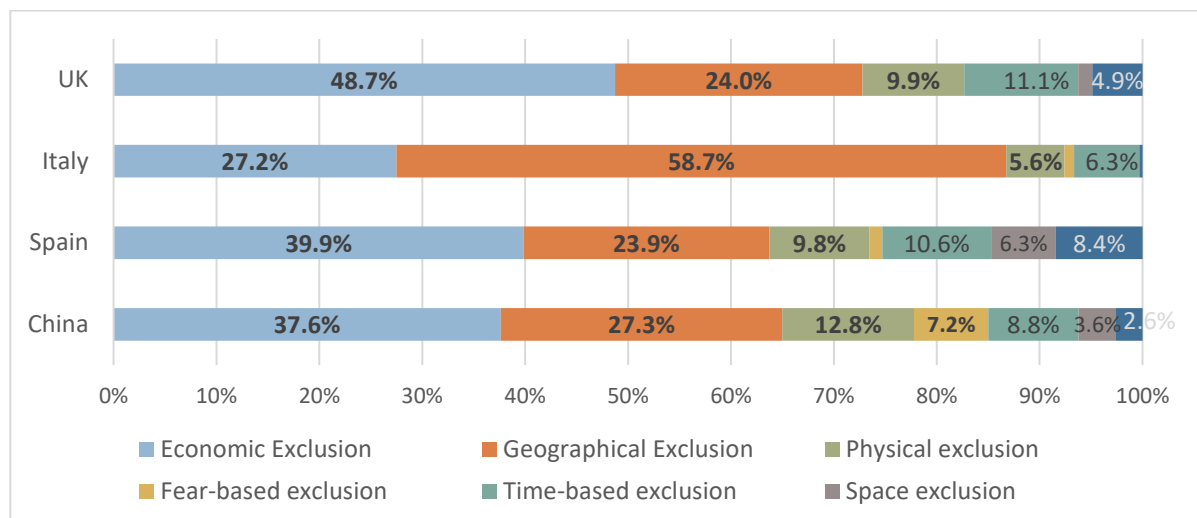


Figure 9-9: Social exclusion type comparison for non-HSR users in four countries

Source: author's findings, with findings of the UK, Spain, and Italy extracted from Pagliara et al. (2017a)

Also, the comparison shows that the Chinese case found the highest level of physical exclusion, with almost 13 per cent of non-HSR users seeing themselves as physically excluded from using the HSR service, whereas respondents of the same category in other countries did not exceed 10 per cent of the whole sample. This might indicate that the special needs of some groups such as the elderly and disabled are not being properly met and catered for in trains, stations, and connecting modes. Another important finding that distinguishes the Chinese case is that non-HSR users in China perceived the highest level of fear-based exclusion; around 7 per cent of respondents saw themselves as excluded due to fear-based reasons, while figures for this category were close to zero in other countries. The high levels of crowding in some Chinese HSR stations might explain the perception of fear-based exclusion. In massive crowds, some people fear for their personal safety and belongings. HSR stations like Beijing South and Shanghai Hongqiao handle a crowd of up to 4.8 million users during the Spring Festival (Chen and Lin, 2016; Xinhua, 2019).

There is a need to address major safety and security issues in HSR stations, to enhance the safety perception of both HSR and non-HSR users and to reduce their fears. Through travel surveys, Hickman et al. (2015) examined passengers' expectations and experience of facilities in three major Chinese HSR stations. The study found that specific zones inside the three stations experienced severe congestion and long queues, which decreased the feeling of being safe and secure and reduced the passengers' personal space. Furthermore, the needs and expectations of the disabled and elderly were not seen as being adequately catered for.

9.2.4 Hypothetical scenario

Figure 9-10 and Figure 9-11 show a hypothetical scenario that examines how all respondents – both HSR and non-HSR users – trade off between money and time. In the scenario, respondents were asked to select one of three alternative options of travelling by HSR, for a 600 km journey that typically costs ¥200 and takes 2 hours. Each option featured a further 17 per cent reduction in travelling time accompanied by a 20 per cent increase in ticket cost.

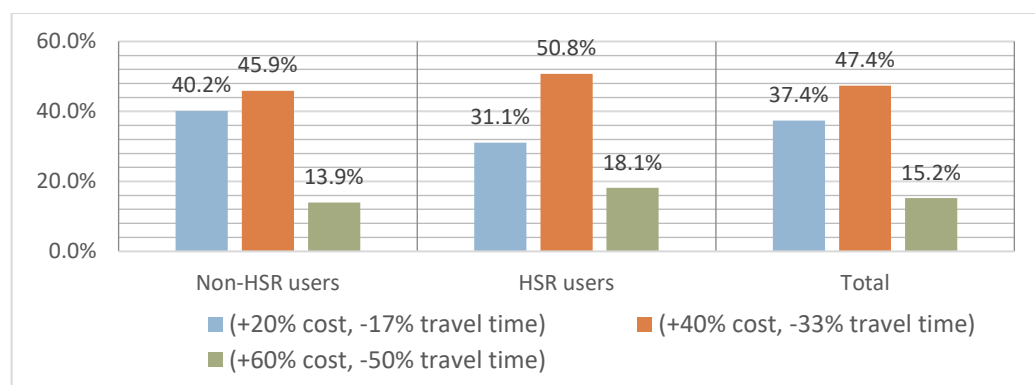


Figure 9-10: Hypothetical scenario: trading off between time and money

Figure 9-10 illustrates that around half the respondents preferred the second travelling option, followed by the cheapest option, whereas the fastest option was the least popular. This finding indicates that travellers in China are relatively more concerned about travel time than

monetary cost. Zhao et al. (2015) pointed out that Chinese HSR travellers find the departure/arrival time more important than the duration of the journey. Another finding of the hypothetical scenario is that non-HSR users are more concerned about the cost and less concerned about travel time when compared with HSR users, affirming the stronger level of economic exclusion perceived by non-HSR users.

Figure 9-11 shows a cross-analysis of the sample, considering both the hypothetical scenario and salary. There was a clear correlation between monthly income and sensitivity to the cost and travel time: the higher the income of respondents, the faster the travel option they preferred. This could be explained by the fact that the value of travel time (VTT) varies significantly among occupations and related salaries. For example, the VTT in the UK ranges between around £6/hour and £30/hour (DfT, 2015b). Similarly, the VTT varies among travellers of different occupations in China (Zhao et al., 2015). Managers and executives who earn higher incomes prefer the fastest travel option, whereas those with lower incomes like workers prefer cheaper options.

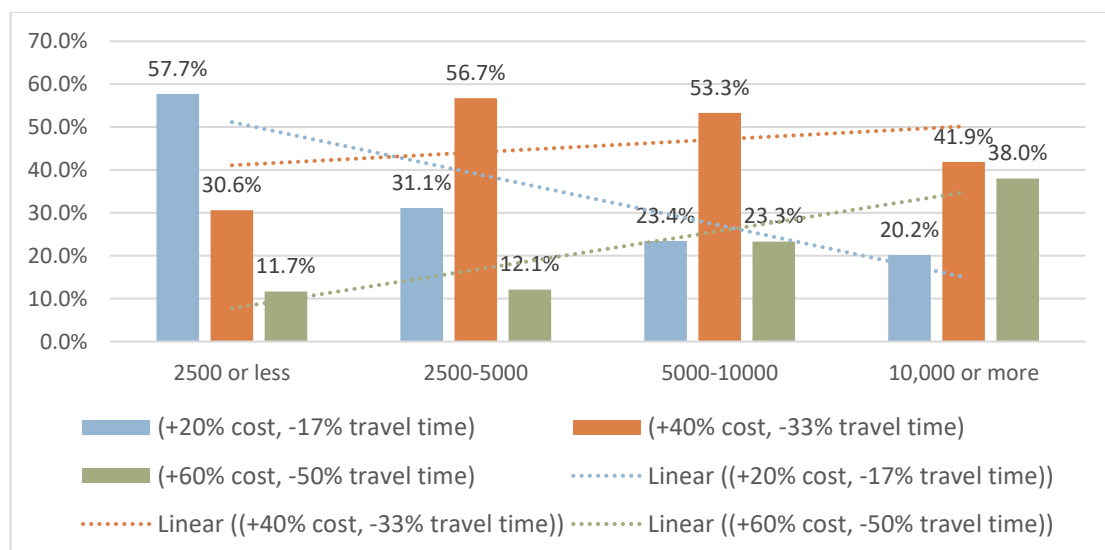


Figure 9-11: Hypothetical scenario: trading off between time and money vs monthly income

9.3 Potential solutions and interventions

A variety of solutions and interventions can tackle different forms of social exclusion. Geographical exclusion could be reduced by adopting DTD mobility solutions. For example, HSR operators could arrange coaches and minibuses that operate regularly between HSR stations and rural areas, remote villages, and peripheral zones. This would enhance access to HSR stations and simultaneously allow those who live in remote areas to access opportunities in the job market. Optimum modal coordination is required for providing seamless and hassle-free travel, and integrated ticketing, mobile apps, and communication technologies play an important role in this regard (Leboeuf, 2018).

The availability of appropriate accessibility facilities and adequate ergonomic design is essential for alleviating physical exclusion. Such facilities should be available during the whole journey: in trains, stations, and connecting modes. Some operators install guiding blocks to help disabled travellers and deploy ramps and elevators to eliminate uneven ground (JR-Central, 2018). JR East uses information robots to assist disabled travellers and those who are not fully accustomed to the rail system (JR-East, 2018b). The optimum utilisation of mobile apps and e-watches could ease access to travel updates and timetable information. Finally, DTD solutions could grant the elderly and disabled people hassle-free journeys.

To mitigate economic exclusion, discounted tickets could be offered to senior citizens, retired people, and others who are excluded for economic reasons. A more effective solution is to adopt a new business model that introduces cheaper HSR services. For instance, the French OUIGO which features a hybrid HSR service – between normal HSR and LCC – offers tickets at competitive prices, spreading the culture of HSR and allowing more people to use them.

Finally, HSR stations could provide some services that are available in airports. VIP waiting halls and high-quality lounges could meet the expectations of business and high-income travellers, and hence reduce space management- and fear-based exclusions. Such improvements could create a modal shift by encouraging air transport users to use HSR.

9.4 Conclusion

This study looked at the relationship between HSR and categories of social exclusion in China. A stated and revealed preference survey was launched online, and 3353 useful responses were collected.

In terms of findings, comfort was proven to be the most favourable factor for using HSR services, followed by travel time and reliability. Regarding barriers, economic exclusion ranked first and was dominant across different age, occupation, and monthly-income groups of non-HSR users. In other words, non-HSR users saw themselves as excluded from using HSR mainly due to the high monetary costs associated with travelling by HSR. Geographical exclusion ranked second; non-HSR users found it hard to reach the departure/arrival HSR station, possibly due to living in remote areas and peripheral zones. Physical and fear-based exclusions were also significant as they were perceived by a number of respondents and so cannot be underestimated. Specifically, the elderly perceived the strongest levels of physical exclusion, possibly due to the lack of facilities that meet their special mobility needs.

The benchmarking exercise showed that China is similar to the UK, Spain, and Italy: economic and geographical exclusion were the strongest among other exclusion categories. However, physical and fear-based exclusion were more noticeable in the Chinese case.

The hypothetical scenario showed that respondents were relatively more sensitive to the cost of the travel than travel time. Still, this trend changed with higher salaries where respondents with higher incomes preferred faster options.

To create a modal shift from other modes, and to allow more people to access HSR services, HSR should be competitive in terms of accessibility and affordability. Even though this study did not look in detail at policy responses to the results, some obvious interventions could be explored and considered by policy makers and HSR operators. For example, DTD mobility solutions could tackle both geographical and physical exclusion. Introducing cheaper HSR services and offering tickets to specific groups could alleviate economic exclusion. Appropriate ergonomic design and the availability of technologies and facilities that meet the special needs of the elderly and disabled people are required to reduce physical exclusion. Finally, the availability of VIP and business waiting halls could tackle fear-based exclusion.

The study was based on respondents' answers; hence results might be subjective and biased, and it is hard to verify the truthfulness and validity of responses. Also, the author did not use any statistical analysis tool, which could have created more robust and trustworthy findings. Moreover, the study did not distinguish between different provinces in China. The monthly income in Beijing and Shanghai might be higher than the income of other provinces. Another limitation is that the design of the survey allowed respondents to select only the strongest factor that prevents them from using HSR. However, travel decisions are usually not based on one single factor; rather, travellers take into consideration a combination of factors before selecting or rejecting a transport mode. Those who perceived a strong level of economic exclusion might also be subject to other forms of exclusion and might be excluded because of geographical, physical, and fear-based reasons. While almost 37 per cent of respondents stated

that they are excluded from using HSR because of economic obstacles, the actual percentage might be much higher, and the same limitation can apply to all exclusion categories. In summary, findings of the study revealed minimum exclusion values while the actual values might be higher.

Still, the study features a remarkable number of responses – 3353 – especially when compared with similar studies, which enhances the robustness and validity of results. Also, the study was inclusive as it collected responses from different age, occupation, education, and monthly-income groups. Therefore, the study offers, to some extent, realistic insights into the relationship between HSR and social exclusion in China. **The findings of the case study in China answer the fourth research question of this project.**

CHAPTER 10

CONCLUSION

10.1 Summary of findings

This study aimed to create a sustainability reporting and benchmarking framework which comprises key economic, social, and environmental factors that are representative of HSR sustainability performance. Primary and secondary data were obtained from a wide range of sources, focusing on HSR operators' sustainability publications. A variety of methods, including face-to-face interviews, visual observation, and surveys were used.

The study fulfilled its aim and accordingly responded to the four research questions identified in section 1.3. In response to the first research question, this study identified ten economic, nine social, and seven environmental factors that are representative of the HSR sustainability performance. The economic factors are punctuality and reliability, costs, revenues, BCR, WEIs, effects of tourism, competition with air transport, integration with other modes, and international involvement. The social factors comprise safety, DTD travel time, social segregation, rapid expropriation, social exclusion, engaging with local communities, customer satisfaction, employment, affordability and operator initiatives. Finally, environmental factors include carbon emissions, energy consumption and sources, land use, resources and materials, biodiversity, recycling, and noise. All 26 factors were selected after thoroughly exploring the literature that links sustainability with HSR. The selection of factors was conducted through consultation with experts from the UIC.

Regarding the second research question, the study looked at how the selected sustainability factors are covered in companies' publications and revealed remarkable reporting

variations at different levels. At the sustainability pillar level, the environmental pillar had the most vigorous representation in sustainability reports, followed by the economic pillar, while the social pillar had the relatively weakest representation. At factor level, costs, revenues, safety, employment, emissions, and energy had good reporting performance. Factors with average reporting performance included international involvement, customer satisfaction, noise and biodiversity. The weakest reporting performance was obtained for competition with air transport, social exclusion, social segregation, affordability, and land use. At company level, some HSR operators such as SNCF, Renfe, and FS Italiane had relatively higher reporting performance than others like JR West, JR East, JR Central, and DB. CR did not offer sustainability reports and hence was excluded from the comparison. Finally, at the indicator level, most factors showed a balance in the use of both quantitative and qualitative indicators. Most importantly, the study discovered opportunities for improving the sustainability disclosure at all levels and suggested some potential improvements.

In reply to the third research question, the study selected a variety of quantitative parameters and qualitative indicators for expressing the selected sustainability factors; a full list of these indicators can be found in Appendix C. Most indicators were selected after considering – where possible – their availability in operators’ publications, international reporting guidelines, and external studies. Still, since there were no specific indicators for expressing some factors, the study proposes brand new indicators for facilitating future reporting practices on these factors. The applicability and usability of most selected indicators were tested by benchmarking exercises, for which performance data were obtained from different sources. The proposed quantitative parameters, through benchmarking examples, revealed notable variations in the sustainability performance of the benchmarked HSR operators and corridors. Besides quantitative parameters, the study presents some qualitative indicators, through which operators

explain their efforts and the underlying causes that drive actual performance. Such qualitative explanations complement the quantitative disclosure.

The fourth research question, responses to the stated and revealed preference survey, showed that economic exclusion followed by geographical exclusion is dominant across different genders, ages, occupations, and income groups in China. In other words, Chinese non-HSR users perceive the ticket price, followed by poor accessibility to the departure/arrival station as the strongest obstacles that prevent them from using the HSR service.

10.2 Stepping away: a holistic view

Topics, issues, and challenges that link HSR and sustainability are fragmented in a variety of journal articles, books, operators' publications, and reporting guidelines. This study combines these topics and factors under the umbrella of sustainability by forming an original, unique, and genuine 26-factor framework that, to the best of the author's knowledge, has not been proposed by other authors or studies.

The sustainability framework can serve many purposes. First and foremost, it could constitute the backbone of HSR operators' future sustainability reports and publications. The framework offers a ready-to-use sustainability template that encompasses factors that are necessary from the operators' perspective plus those that are tackled in the most recent literature. Also, the framework comprises various sustainability factors that might concern different parties. So, HSR operators could use it as a communication tool with a wide range of stakeholders, including investors, the public, passengers, governmental and non-governmental organisations, policymakers, environmental agencies, railway organisations, and independent scholars.

On the basis of the author's analysis, the framework has been shown to be capable of providing insights into the actual performance of HSR operators and corridors by showing how different sustainability factors correlate with each other. Thus, HSR operators could employ the framework as an instrument for managing and tracking their sustainability performance throughout reporting periods.

Also, the framework offers a potential minimum level of reporting standardisation, which is desirable for facilitating benchmarking exercises. The quantitative nature of the framework's parameters allows direct comparisons, while qualitative indicators explain the causes that drive performance. Together, quantitative metrics and qualitative indicators can show how the sustainability performance of different corridors and operators compare to each other. In other words, the framework presents a platform for benchmarking, sharing experience, and spreading good practice.

The framework could be used to update the publications and reporting guidelines of international organisations like the UIC and GRI, to include additional sustainability factors in their reports, such as effects on tourism, international involvement, and affordability.

The framework offers railway-specific reporting guidelines that can be used for disclosing sustainability information related to the performance of both HSR and conventional railways. Also, several proposed indicators can be used for benchmarking railways against other transportation modes, like cars and air transport.

The author believes that the effects of HSR reach far beyond improvements in the capacity and travel time, and judging HSR projects solely by these two components is a sketchy appraisal which can result in misleading conclusions. The 26 factors offer a set of topics that could be considered when conducting HSR appraisal studies. Similarly, the framework could

be used for enhancing the publicity of new HSR projects. Promoters often limit the benefits of HSR projects by focusing on improvements in the capacity and travel time, while other advantages might not be visible to the public and stakeholders. So, promoters could diversify and expand the benefits when publicising HSR projects by reflecting on the 26 factors.

The 26 sustainability factors underpin several of the United Nations' SDGs. In the longer run, the framework could perform as a sustainability management tool in the field of railways, by addressing the SDGs and equally contributing to the sustainability of the built environment. Integrating the framework and its indicators in railway sustainability reports could help this purpose.

Finally, while serving all previous purposes, the framework features a balance between the three pillars of sustainability by paying almost equal attention to the economic, social, and environmental factors respectively. The author found that the economic and environmental aspects of sustainability have been addressed in many studies, publications, policy documents, and regulations, and considerable efforts are being invested in this regard. In contrast, social issues and topics have gained much less attention, and this trend seems to be prevalent not only in the railway sector but also in the transportation field in general. The focus on the economic pillar might be explained by the continuous need for appraisal studies that are necessary for justifying transport projects plus economic constraints. Focusing on the environmental pillar might be related to efforts in reaching environmental goals at local, regional, and international levels. However, a balanced approach to the three sustainability pillars would, in the author's opinion, strengthen the case for, and the public understanding of, investing in HSR.

10.3 General recommendations

HSR operators are encouraged to adopt the 26-factor framework in their sustainability publications, as this could help drive both internal and external benefits. Such adoption will be encouraged if international organisations like the UIC and GRI adopt the framework within their agenda and publications.

In addition to aggregate performance data, railway operators could distinguish between HSR and other transport and non-transport activities when reporting on factors like costs, revenues, safety, employment, emissions, and energy consumption. Also, some key performance information such as annual and daily ridership, passenger and train activity expressed as passenger.km and train.km could be regularly presented, as these allow the calculation of a wide range of indicators. Moreover, besides highlighting the indicators of superior performance, railway companies should consider disclosing information about areas of average and even weak performance.

Finally, in the author's opinion, there should always be a balance between the three pillars of sustainability, and such a balance should be featured in both theory and practice. For example, academic studies on the sustainability of HSR could pay more attention to topics of social exclusion, social segregation, affordability, and rapid expropriation. In practice, economic and environmental improvements should not be considered at the expense of the affordability and accessibility of HSR services.

10.4 Summary of limitations

The limitations of this study can be summarised in three main points. The first limitation is that visual observation was used for examining the availability of sustainability factors in

operators' reports, and hence the results of the search process might be slightly biased and subjective. However, to eliminate potential impacts of subjectivity and bias on the results and to increase the legitimacy and credibility of the findings and recommendations, operators' publications have been thoroughly checked at least twice. Also, the search process considered different parts of each publication including the main body, highlights, factsheets, and even letters from chairpersons. The second limitation is related to the quality and reliability of the data used in benchmarking exercises. Data for comparisons were collected from different sources including online articles and newspapers, which might be inaccurate and biased. So, the findings of the benchmarking exercises are subject to the accuracy and validity of the data collected. The third limitation is related to the fact that the social exclusion case study used a preference survey for collecting responses. It is hard to verify the truthfulness of respondents and the validity of their responses, which might be biased and subjective. Still, the study – especially when compared with similar researches – featured a remarkable number of 3353 responses, which enhances the validity of the findings.

10.5 Areas for further research

Based on the findings of this thesis, follow-up studies could look at the following points:

- Developing brand new indicators for enhancing disclosure on the sustainability factors that are poorly represented in operators' publications, including social exclusion, social segregation, effects on tourism, and affordability;
- Conducting benchmarking exercises after considering different methods for normalisation and reliable data sources. HSR operators could be contacted to obtain reliable and robust data sets;

- This study focused on the sustainability publications of specific HSR companies, most of which were published between 2015 and 2017. Future studies could analyse the sustainability disclosure of other HSR operators in Russia, Taiwan, South Korea, and Turkey. Also, publications that date to before 2015 could be considered.

Also, further research in the HSR field could consider the following topics:

- Exploring the purposes for which HSR operators usually get involved in international projects and examining the conditions under which such involvement occurs;
- Conducting in-depth studies that explore the possibility of launching low-cost HSR services in Asia and Europe that are on a par with the French OUIGO;
- Examining solutions and policy interventions that could alleviate forms of social exclusion, to deliver more inclusive HSR services.

10.6 Pathways to impact

During the consultation with the UIC experts, the Head of the Sustainability Unit expressed an interest in adopting the 26-factor framework, which could lead to updating of the UIC's publications and agendas and hence dissemination of the findings to the railway operators. The World Congress on High-Speed Rail that will be organised by the UIC constitutes an opportunity for communicating the results to the broader railway community, including academics, operators, and policymakers. The Congress will be held in Beijing in 2020, and the author has submitted the key research results in a conference paper. Also, the author has submitted the key findings of this thesis to the Cambridge University Press Redux Conference's Sustainability Award Committee.

Moreover, some key findings of this study have been already published in high-impact journals in the fields of sustainability management, railways, and transport policy, as shown in the list below. Finally, the author will continue to explore the correlation between HSR and aspects of sustainability by pursuing post-doctoral studies during the following years.

10.7 Key publications

1) Azzouz, L. & Jack, A. 2020. Benchmarking the sustainability reporting of high-speed railways (HSRs): Towards a state-of-the-art benchmarking and reporting framework for HSRs. *Journal of Cleaner Production*, 250, 119505.

2) Blumenfeld, M., Wemakor, W., Azzouz, L. & Roberts, C. 2019. Developing a New Technical Strategy for Rail Infrastructure in Low-Income Countries in Sub-Saharan Africa and South Asia. *Sustainability*, 11, 4319.

3) Azzouz, L. & Jack, A. 2020. High-speed railways and the environmental sustainability: Realising the potential. *International Journal of Environmental Sciences & Natural Resources*, 24, 1, 13-15.

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Appendices

Appendix A -Assessing the Availability of the 26 factors in companies’ publications

	Company	JR Central	JR East	JR East	JR East	JR West	DB	Renfe	FS Italiane	FS Italiane	FS Italiane	SNCF	SNCF	SNCF	SNCF	Guangsh en Railway	CHSR	HS2	HS2	HS2	Total Maxim um of 30
	Country	Japan	Japan	Japan	Japan	Japan	Germany	Spain	Italy	Italy	Italy	France	France	France	France	China	USA	UK	UK	UK	
	Document type	AR	AR	SR	Final*	AR	IR	CSRR	AR	SR	Final*	AFR	CSER	RBR	Final*	ASRR	SR	AR	SS	Final*	
	Year	2018	2018	2018	Final*	2018	2017	2015	2018	2017	Final*	2018	2017	2017	Final*	2017	2017	2018	2016	Final*	
Symbol	Reference	(JR- Central, 2018)	(JR-East, 2018a)	(JR-East, 2018b)	Final*	(JR- West, 2018)	(DB, 2017)	(Renfe, 2015)	(FSItalia ne, 2018)	(FS- Italiane, 2017)	Final*	(SNCF, 2018a)	(SNCF, 2017a)	(SNCF, 2017c)	Final*	(Guangsh en, 2018)	(CHSR, 2017a)	(HS2, 2018)	(Temple- RSK, 2016)	Final*	
EC-1	Punctuality and reliability	3	1	2	2	1	3	3	0	3	3	1	3	1	3	3	0	0	0	0	21
EC-2	Costs	2	3	1	3	3	3	3	2	2	2	2	2	2	2	2	1	2	0	2	23
EC-3	Revenues	3	3	3	3	3	3	3	3	3	3	3	3	0	3	2	0	0	0	0	23
EC-4	Efficiency	2	1	1	1	2	2	2	0	2	2	1	2	2	2	2	2	0	2	2	19
EC-5	Benefits-to-costs ratio	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
EC-6	Wider economic impacts	1	1	1	1	1	2	1	0	2	2	2	1	2	2	1	3**	0	2	2	13
EC-7	Effects on tourism	2	2	2	2	2	1	2	0	2	2	0	0	1	1	0	0	0	0	0	12
EC-8	Competition with air transport	3	0	1	1	1	2	1	0	0	0	0	1	0	1	0	2	0	1	1	12
EC-9	Integration with other modes	1	1	2	2	1	1	2	0	3	3	1	1	0	1	0	1	0	2	2	14
EC-10	International involvement	2	3	3	3	0	2	3	1	3	3	2	3	1	3	1	0	0	0	0	17
SO-1	Safety	3	3	3	3	3	2	3	0	3	3	2	3	3	3	2	3	2	1	2	27
SO-2	Door-to-door travel time	0	0	1	1	1	1	0	0	2	2	2	2	1	2	0	0	1	0	1	8
SO-3	Social segregation	0	0	0	0	0	2	0	0	2	2	0	0	2	2	0	0	0	0	0	6
SO-4	Rapid expropriation	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3
SO-5	Social exclusion	0	0	1	1	0	0	1	0	1	1	0	2	1	2	0	0	2	2	2	7
SO-6	Engaging with local communities	3	2	3	3	2	0	3	0	2	2	1	3	3	3	3	2	3	2	3	24
SO-7	Customer satisfaction	1	1	2	2	2	3	3	0	3	3	1	3	1	3	1	0	0	0	0	18
SO-8	Employment	2	2	3	3	3	3	3	0	3	3	2	3	3	3	3	3	2	1	2	28
SO-9	Affordability and operators’ initiatives	2	0	0	0	0	0	1	0	0	0	0	3	0	3	0	0	0	0	0	6
EN-1	Carbon emissions	3	1	3	3	3	3	3	0	3	3	1	3	2	3	3	3	2	3	3	30
EN-2	Energy consumption and sources	2	2	3	3	2	3	3	0	3	3	1	3	3	3	2	2	1	1	1	24
EN-3	Land use	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0	2	2	6
EN-4	Resources and materials	2	0	2	2	3	2	3	0	3	3	1	2	1	2	2	3	1	2	2	24
EN-5	Biodiversity	0	0	2	2	1	1	3	0	1	1	1	3	2	3	0	2	0	3	3	16
EN-6	Recycling	3	0	2	2	2	3	3	0	3	3	1	3	2	3	1	3	0	1	1	24
EN-7	Noise	1	0	2	2	0	2	2	0	2	2	0	2	1	2	0	0	1	3	3	14
	Total (maximum of 78)	43	26	43	45	36	45	51	6	52	52	25	51	34	55	28	29	19	30	36	
AR= annual report SR=sustainability report IR= integrated report CSRR=corporate social responsibility report AFR= annual financial report CSER=corporate social engagement report RBR= responsible business report ASRR=annual social responsibility report SS= sustainability statement *the higher value in all documents for a specific operator is adopted ** the value is obtained from the (Inverting in California Economy Report) available via the operator’s website																					
0 = no meaningful information is presented regarding the specific factor 1 = patchy information is presented without providing enough clarification and with limited use of charts and visuals 2 = good information regarding the factor is presented. Good use of charts and visuals. However, not all areas of the factor are well covered and addressed. 3 = the reporting provides full information regarding the factor; a mix of quantitative and qualitative indicators is presented with an extensive use of charts and examples comparing the performance of different years																					

Appendix B -Assessing the Availability of indicators in companies’ publications

	Company	JR Central	JR East	JR East	JR West	DB	Renfe	FS Italiane	FS Italiane	SNCF	SNCF	SNCF	Guangshen Railway	CHSR	HS2	HS2	Total Maximum of 15																	
	Country	Japan	Japan	Japan	Japan	Germany	Spain	Italy	Italy	France	France	France	China	USA	UK	UK																		
	Document type	AR	AR	SR	AR	IR	CSRR	AR	SR	AFR	CSER	RBR	ASRR	SR	AR	SS																		
	Year	2018	2018	2018	2018	2017	2015	2018	2017	2018	2017	2017	2017	2017	2018	2016																		
	Reference	(JR-Central, 2018)	(JR-East, 2018a)	(JR-East, 2018b)	(JR-West, 2018)	(DB, 2017)	(Renfe, 2015)	(FSItaliane, 2018)	(FS-Italiane, 2017)	(SNCF, 2018a)	(SNCF, 2017a)	(SNCF, 2017c)	(Guangshen, 2018)	(CHSR, 2017a)	(HS2, 2018)	(Temple-RSK, 2016)																		
Symbol	Type and availability of indicators	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	N	L	
EC-1	Punctuality and reliability	●	*	●		●	*	●		●	*	●	*			●	*			●	*	●		●	*								10	7
EC-2	Costs	●	*	●	*		*	●	*	●	*	●	*	●	*	●	*	●	*	●	*	●	*	●	*			●	*				12	13
EC-3	Revenues	●	*	●	*	●	*	●	*	●	*	●	*	●	*	●	*	●	*	●	*			●	*								11	11
EC-4	Efficiency	●	*						*	●	*		*			●	*			●	*	●	*	●	*	●	*				*		7	10
EC-5	Benefits-to-costs ratio																															0	0	
EC-6	Wider economic impacts	●	*	●		●	*	●	*	●	*	●				●	*	●	*	●		●	*			●	*			●	*		12	9
EC-7	Effects on tourism		*		*		*	●	*	●			*			●	*																3	6
EC-8	Competition with air transport	●	*			●			*	●	*	●								●						●	*						6	4
EC-9	Integration with other modes		*		*	●	*				*		*			●	*																2	6
EC-10	International involvement		*	●	*	●	*				*	●	*	●		●	*	●	*	●	*												7	8
SO-1	Safety	●	*	●	*	●	*	●	*	●	*	●	*			●	*		*	●	*	●	*	●	*	●	*	●	*				12	13
SO-2	Door-to-door travel time						*										*		*	●	*		*									1	5	
SO-3	Social segregation									●	*					●	*						*										2	3
SO-4	Rapid expropriation																											*	●	*			1	2
SO-5	Social exclusion											●	*				*			●	*						●	*		*		3	5	
SO-6	Engaging with local communities	●	*		*	●	*		*			●	*			●	*			●	*	●	*	●	*	●	*	*	●	*			8	11
SO-7	Customer satisfaction					●	*		*	●	*	●	*			●	*			●	*	●										6	6	
SO-8	Employment	●	*	●	*	●	*	●	*	●	*	●	*			●	*	●	*	●	*	●	*	●	*	●	*	●	*				13	13
SO-9	Affordability and operators’ initiatives	●	*																	●	*											2	2	
EN-1	Carbon emissions	●	*			●	*	●	*	●	*	●	*			●	*	●		●	*	●	*	●	*	●	*	●	*	●	*		13	12
EN-2	Energy consumption and sources	●	*		*	●	*	●	*	●	*	●	*			●	*	●		●	*	●	*	●	*	●	*		*				11	12
EN-3	Land use		*														*									*			●	*		1	4	
EN-4	Resources and materials	●	*			●	*	●		●	*	●	*			●	*	●	*	●	*	●		●	*	●	*	●		●	*		13	10
EN-5	Biodiversity					●	*					●	*							●	*		*			*			●	*		4	6	
EN-6	Recycling	●	*			●	*	●		●	*	●	*			●	*	●	*	●	*	●				●	*						10	8
EN-7	Noise	●				●	*			●	*	●	*			●	*			●	*	●	*					*	●	*		8	8	
	Total (maximum of 26)	15	18	7	9	16	18	11	12	16	17	17	18	3	2	18	21	9	9	20	18	13	12	10	10	9	12	7	9	7	9			
AR= annual report SR=sustainability report IR= integrated report CSRR=corporate social responsibility report AFR= annual financial report CSER=corporate social engagement report RBR= responsible business report ASRR=annual social responsibility report SS= sustainability statement N= quantitative indicators L= qualitative indicators ● Existence of quantitative indicators * existence of qualitative indicators																																		

Appendix C -A list of all proposed indicators for the framework

59 quantitative and qualitative indicators for expressing the 26 sustainability factors			
Symbol	Economic Indicators	Symbol	Social Indicators
EC-1-1	The percentage of trains arriving within 5 minutes of the scheduled arrival time	SO-1-1	The total number of significant rail accidents
EC-1-2	A qualitative explanation of the reasons behind major delays, expected future delays	SO-1-2	The number of staff killed, seriously/minorly injured in the workplace
EC-2-1	The construction cost of major/new HSR lines per km	SO-1-3	The number of passengers killed, seriously/minorly injured due to railway accidents
EC-2-2	The operating cost of major/new HSR lines per km	SO-1-4	The number of third-party people killed, seriously/minorly injured due to railway accidents
EC-2-3	The maintenance cost of major/new HSR lines per km	SO-2-1	The overall door-to-door travel time between two points
EC-2-4	The recycling cost of major/new HSR line per km	SO-2-2	a qualitative explanation of operators' solutions for providing a seamless DTD journey
EC-2-5	The track access charge per train-km of major lines	SO-3	Results of a stated and revealed preference survey that explores barriers to using HSR
EC-3-1	Operating profits (EBITDA) per HSR route km	SO-4-1	The total number of homes that will be demolished per route km
EC-3-2	Net operating profits per HSR route km	SO-4-2	A qualitative explanation of how the company is willing to compensate land & property owners
EC-3-3	Net operating profits of major HSR corridors per km	SO-5	Results of a stated and revealed preference survey that explores barriers to using HSR
EC-4-1	Operating revenue per train-km (monetary unit/train-km)	SO-6	A qualitative explanation of how the operator is engaging and working with local communities
EC-4-2	Operating cost per train-km (monetary unit/train-km)	SO-7	The overall passenger satisfaction level of the HSR service (%)
EC-5	The enhanced benefits-to-costs ratio of new HSR projects	SO-8-1	The total number of employees
EC-6	A quantitative and qualitative explanation of the projected WEIs associated with new HSR projects	SO-8-2	The percentage of women in the workforce (%)
EC-7-1	Changes in domestic tourism demand in cities along HSR corridors	SO-8-3	Total training hours provided per employee (hours)
EC-7-2	Changes in international tourism demand in cities along HSR corridors	SO-8-4	The annual turnover rate of employees (%)
EC-7-3	A qualitative explanation of operators' efforts and solutions to promote tourism	SO-9-1	Fare for 100 km of HSR travel along different corridors
EC-8-1	The market share of HSR against airlines in major corridors	SO-9-2	Fare for 100 km of HSR travel along different corridors, relative to the net average monthly income (%)
EC-8-2	The daily and annual ridership of HSR and airlines in major corridors	SO-9-3	A qualitative explanation of discounts and offers available to students/senior citizens/and others
EC-8-3	HSR–airline pricing comparison in major corridors		
EC-9-1	The number of metro and bus lines at the HSR station	Symbol	Environmental Indicators
EC-9-2	The number of metro stations and bus stops that can be reached directly from HSS without transfer	EN-1	The equivalent CO ₂ emissions of operating HSR services (g CO ₂ e/p.km)
EC-9-3	The quality of the transfer between HSR services and other transport modes expressed in minutes	EN-2-1	The final energy consumption of operating HSR services (kWh/p.km)
EC-9-4	The number – and cost – of parking spaces in and within 500 m of stations	EN-2-2	The share of renewable electric energy in the total energy consumption (%)
EC-9-5	Time and monetary costs associated with transferring from the HSS to nearest international airports	EN-3-1	The amount of active substances – herbicides – used per track km
EC-9-6	The number of parking spaces available for bikes and motorbikes	EN-3-2	The cost of active substances – herbicides – used per track km
EC-9-7	A qualitative explanation of operators' efforts to improve integration with other modes	EN-4	The amount of water/sand/concrete/wood/metal/paper consumed per route km
EC-10-1	A qualitative and quantitative explanation of how operators are involved in the international market	EN-5-1	A qualitative explanation of how the operator is protecting and promoting biodiversity
EC-10-2	The share of the international market revenue in the total annual revenue as a monetary value	EN-5-2	The environmental expenditure per operated route km
		EN-6	The annual recycling rate (%)
		EN-7-1	Sound level (dBA) at a height of 3.5 m and a distance of 25 m from the rail axis
		EN-7-2	A qualitative explanation of operators' solutions to reduce noise levels

Appendix D -Travel survey: questions of the survey

1. What is your age?
 - 18-21
 - 22-30
 - 31-40
 - 41-50
 - 51-65
 - 66 or above
2. What is your gender?
 - Male
 - Female
 - Other
3. What is your nationality?
 - Chinese
 - Other
4. What is your education level?
 - High school and below
 - College
 - Bachelor
 - master's degree
 - Ph.D. and above
5. What is your current occupation?
 - Full-time/part-time work
 - Student
 - Freelancers
 - Unemployed
 - Retired
 - Other
6. What is your monthly income?
 - ¥ 2500 or less
 - ¥ 2500-5000
 - ¥ 5000-10000
 - ¥ 10,000 or more
7. How do you often travel?

- Alone
 - With a partner
 - With friends
 - With colleagues
 - With family members
8. On a trip of 150 km or more, what transportation mode do you prefer to use?
- Car
 - Ordinary train
 - High-speed rail
 - coach
 - Plane
9. Have you ever travelled by a high-speed train?
- Yes
 - No
10. In your last trip (distance 150 km or more), what transportation mode did you use?
- Car
 - Ordinary train
 - High-speed rail
 - coach
 - Plane
11. What was the purpose of your last trip (distance 150 km or more)?
- Work
 - Study
 - Holiday
 - Personal activities
12. What is your main reason for choosing to travel by high-speed trains?
- Travel cost
 - Comfort
 - Reliability
 - Travel time
 - Environmental protection
 - Seat availability
 - Safety reasons
 - Station facilities

13. Choose the strongest barrier that prevents you from using the HSR service (choose only one)
- Economic barrier. For example, the high monetary cost of the ticket
 - Geographical barrier. For example, it is hard to reach the train station; the nearest train HS station is very far away
 - Physical barrier: for example, there are no facilities for disabled people in stations and trains
 - Fear-based barrier. for example, I have fears for my personal safety when using trains and stations
 - Time-based barrier. For example, I am very busy, and I do not have enough time to travel
 - Space management barrier. For example, there are no waiting halls or first-class rooms in stations
 - Exclusion from facilities barrier. For example, I have low accessibility to schools, hospitals shops, and other amenities
14. Typically, a journey of 600 km using HSR will cost you around 200 yuan and 120 minutes. If you were given different options with different prices and durations, which one of the following options would you pick? (choose only one)
- A journey that cost 240 yuan and 100 minutes
 - A journey that cost 280 yuan and 80 minutes
 - A journey that cost 320 yuan and 60 minutes

Appendix E -Travel survey: participant information sheet

“You are being invited to participate in a research project titled Benchmarking International High-Speed Railways from Sustainability Perspective. Labib Azzouz is doing this study from the University of Birmingham in the UK, under the supervision of Professor Anson Jack of the Birmingham Centre for Rail Research and Education.

The purpose of this research study is to explore reasons that encourage/prevent you from travelling by high-speed trains in China and will take you approximately 5 to 10 minutes to complete. Your participation in this study is entirely voluntary, and you can withdraw at any time by exiting the survey. You are free to omit any questions. You will receive no benefits from participating in this study.

It is believed there will be no risks or discomforts associated with this research study. To the best of our ability, your answers in this study will remain confidential, and you do not need to provide any identifying information such as your name, your address, your phone number or your email. Therefore, your responses will remain anonymous. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study. The author will have direct and exclusive access to all results without the help of any third party. The results of this survey will be securely stored and password protected in an electronic format, and they will be deleted after the end of the project in 2020”.

Appendix F -Travel survey: electronic consent

The following information will be provided as a closing statement on the final page of the online survey:

If you have questions at any time about the study or the procedures, you may contact me via email at [REDACTED], or my supervisor at [REDACTED]. Thank you so much for your participation.

ELECTRONIC CONSENT: Please select your choice below. You may print a copy of this consent form for your records. Clicking on the “Agree” button indicates that you agree on the following statements:

- I have read both opening and closing information statements
- I am voluntarily taking part in this project. I understand that I don't have to take part,
- I can withdraw from the survey at any time by closing it;
- I don't expect to receive any benefit or payment for my participation;
- The survey's results will be potentially used by the author in his thesis/publications.

☐ Agree

☐ Disagree

Appendix G -Consultation with experts of the UIC: interview consent form



UNIVERSITY OF
BIRMINGHAM

BCRRE

Interview Consent Form

Research project title: ***Benchmarking International High-Speed Railways from Sustainability Perspective***

Research investigator: Labib Azzouz (PhD student)

Supervisor: Professor Anson Jack

Thank you for agreeing to be interviewed as part of this Project. The interview will take approximately 1 hour, and you have been selected for this interview due to your previous experience and knowledge in the field. Participation in this interview is voluntary and you have the right to withdraw from the interview at any point. You can seek further clarification from the researcher if there is anything which you do not understand prior to participating.

This project aims to discuss the feasibility of building an international HSRs reporting and benchmarking mechanism from the sustainability perspective, and to reach this aim, there are four objectives. First, to discuss and select a pattern of social, environmental and economic factors and challenges that could be considered to achieve a sustainable HSRs system. Secondly, to explore the availability of these sustainability factors in operators' published materials around the world, discussing similarities and differences while reporting sustainable performance among operators and topics they already cover in their reports. Then, key performance indicators framework (KPIs) will be developed as a harmonized system comprising measures that express the new selected sustainability factors besides typical performance indicators. The final stage is to test this framework by benchmarking several HSR systems around the world.

Ethical procedures for academic research undertaken from UK institutions require that interviewees explicitly agree to being interviewed and how the information contained in their interview will be used. This consent form is necessary for us to be sure that you understand what is going to happen, how your data will be treated and the rights you have as a participant. Would you therefore read the accompanying information sheet and then sign this form to confirm that you understand and agree.

What will happen?

- The interview will be recorded, and a written transcript will be produced (after the interview).
- If requested, you will be sent a copy of your transcript to review. If you want to make any changes or add anything extra then you will be able to.
- The transcript of the interview will be analysed by Labib Azzouz as researcher.
- If requested, your name and any identifying information (such as organization name or location) will be changed to protect your identity.
- If requested, any summary interview content, or direct quotations from the interview, that are made available through academic publication or other academic outlets will be anonymised so that you cannot be identified, and care will be taken to ensure that other information in the interview that could identify you is not revealed.
- The recording and transcription will be kept (in accordance with the University of Birmingham's Code of Practice for Research). If you chose to leave the study, your transcript and data will be deleted immediately.
- Any variation of the conditions above will only occur with your further explicit approval

How will data be used?

If requested, you will have the opportunity to review the transcription of your interview and make any changes that you wish. You will also have the opportunity to discuss the researchers' initial analysis of your interview and make comments and corrections. Once this process has been completed then the final transcript may be used as follows.

All or part of the content of your interview may be used;

- In printed and online resources such as a PhD thesis which might be available to the public
- In academic papers, policy papers or news articles
- On a website and in other media that we may produce such as spoken presentations
- On other feedback events
- In an archive of the project as noted above

Agreement

By signing this form I agree that;

1. I am voluntarily taking part in this project. I understand that I don't have to take part, and I can stop the interview at any time;
2. The researcher can make an audio recording of the interview and store the data in accordance with the UoB Code of Practice for Research (outlined above).
3. I can withdraw my involvement in the project within three months after this interview by contacting the researcher.
4. The transcribed interview or extracts from it may be used as described above;
5. I have read the Information sheet;
6. I don't expect to receive any benefit or payment for my participation;
7. I can view a copy of the transcript of my interview and make edits I feel necessary to ensure that my identity has been protected;
8. I have been able to ask any questions I might have, and I understand that I am free to contact the researcher with any questions I may have in the future.

Printed Name _____

Participant's Signature _____ Date _____

Researcher's Signature _____ Date _____

Contact Information

This research has been reviewed and approved by the University of Birmingham Research Ethics Board. If you have any further questions about this study, please contact:

Name of researcher: Labib Azzouz.

Full address: Birmingham Centre for Rail Research and Education, School of Engineering, University of Birmingham, Edgbaston, B15 2TT E-mail: _____

What if I have concerns about this research?

If you are worried about this research, or if you are concerned about how it is being conducted, you can contact Susan Cottam (Research Ethics Officer, University of Birmingham) at _____

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Printed Name _____
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Researcher's Signature _____ Date _____

Contact Information

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Appendix H -Consultation with experts of the UIC: interview questions

1. What are the most important sustainability issues\factors in railways?
2. are there any factors specific for HSRs?
3. What are benefits of sustainability reporting in railway sector?
4. Do UIC teams share the same vision\thinking towards sustainability?
5. is it possible to build a framework that operators can use to report on their sustainable performance and for benchmarking purposes?
6. What are the benefits of a sustainability reporting and benchmarking framework?
And what could encourage operators and agencies to use it?
7. What are hardships and obstacles that might face the framework? Why rail operators might not be interested in using it?
8. On a scale from 1 to 10, can you rate each factor according to its importance?
9. Considering my current framework, do you suggest adding or removing some factors?
10. Do you think my framework is helpful in the current sustainability thinking in the UIC and internationally? With changes how could it help the UIC?
11. What factors in the framework are very important but they are partly being ignored or do not take so much attention?
12. How can we measure effects of HSR on tourism? Any specific indicators?
13. How can we measure the wider economic impacts?
14. How can we measure\ report on resources?