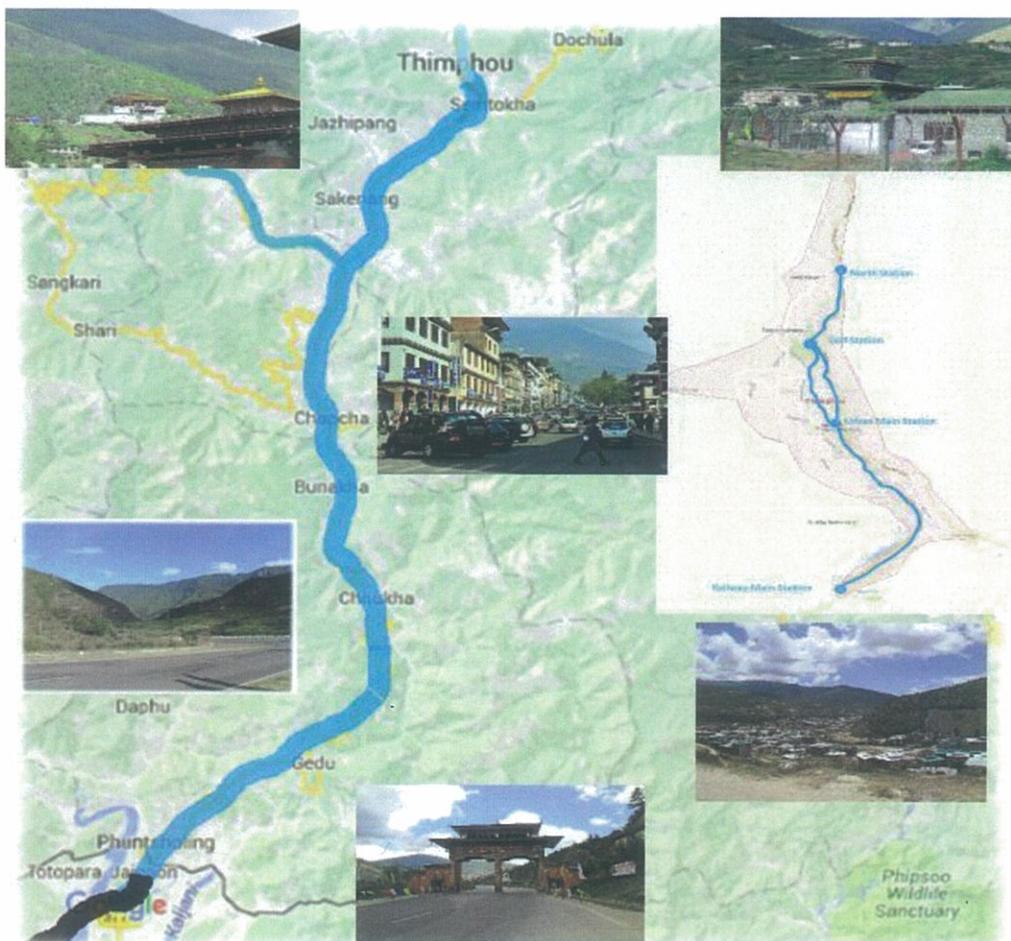




Pre-Feasibility Study to Investigate Potential Mass Transit Options for Bhutan

April 2017



Pre-Feasibility Study to Identify Suitable Mass Transit Options for Bhutan

Final Report April 2017

This report has been prepared by **Dr. Charlie Hargroves**, Director, Strategic Transitions Group, Australia and **Mr. Julien Gaudremeau**, Director, Rail Concepts, France for the Ministry of Information and Communication (MOIC), the Royal Government of Bhutan with technical support from United Nations Center for Regional Development (UNCRD) Nagoya, Japan. The views expressed herein are those of the authors only and do not necessarily reflect the views of the United Nations.

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Foreword

As custodians of Bhutan's amazing and bountiful nature, the people of Bhutan are committed to ensuring that it is protected for generations to come. With our past energy choices now threatening its natural environment, there is an urgent need to update transport energy options to harness world's best practices to deliver clean, safe and affordable energy to ensure mobility for its people and goods long into the future. The choice to base the mobility system on automobiles running on fossil fuel has now led to serious issues related to: air pollution and health impacts, growing greenhouse gas emissions (threatening the Climate Negative Country status); increased road congestion, crashes, and fatalities; and economic impacts (with over 95% of hydro-electric energy revenue used to pay for imports of fossil fuels).

It is in the best interest of Bhutan and its people to invest in a low carbon transition that will see its mobility needs met by a system of highly efficient rail transport options and buses powered by electricity generated by its mighty rivers. In 2015, Hon'ble Prime Minister Lyonchen Tshering Tobgay responded to this situation by stating that, '*My target for Bhutan is a 70 percent reduction in fossil fuel imports by 2020*'. .

Since 2006, the Royal Government of Bhutan has been experimenting with a range of transportation policy options, including the transportation agenda as part of its 'Nationally Appropriate Mitigation Actions' to the UNFCCC Conference of the Parties by:

- Improving mass transit and demand side management of personal modes of transport;
- Exploring alternative modes of transport to road transport such as rail, water and gravity ropeways, cable car;
- Improving efficiency in freight transport;
- Promoting non-motorized transport and non-fossil fuel powered transport such as electric and fuel cell vehicles;
- Improving efficiency and emissions from existing vehicles through standards and capacity building; and
- Promoting the use of appropriate intelligent transport systems.

Such themes are now being considered a core part of Bhutan's economic development agenda with the current Eleventh 5 Year Plan calling for '*Eco-friendly mass public transportation services*'.

The initiatives are indeed encouraging and stand to be advanced through the outcome of this report undertaken through the leadership of the United Nations Centre for Regional Development (UNCRD) as it not only provides a pre-feasibility understanding of the technical requirements of a new transport system for Bhutan but it also shows how this system can be integrated into the existing fabric and provide a range of direct and in-direct benefits.

Pre-Feasibility Study to Identify Suitable Mass Transit Options for Bhutan is a technical study, which was commissioned by United Nations Centre for Regional Development (UNCRD) at the request of the Royal Government of Bhutan. The Ministry of Information and Communications of the Royal Government of Bhutan would like to express its deep appreciation to United Nations Department of Economic and Social Affairs (UN DESA)/UNCRD for all their efforts (including field missions in Paro and Thimphu area) in completing this valuable study.

In order to further expand this study into a complete feasibility study for ground implementation, it would require dedicated funding and technical support. We urge the international community to join hands to support this initiative.

A handwritten signature in blue ink, appearing to read 'D. N. Dhungyel', with a horizontal line drawn through it.

D. N. Dhungyel
Minister for Information and Communications
Royal Government of Bhutan

Notes:

The following chapters have been written by Dr. Karson James Hargroves, Director of the Strategic Transitions Group, with research support from Georgia Grant, Daniel Conley, Kiri Gibbons, and Deana Ho from the Curtin University Sustainability Policy Institute and the University of Adelaide;

1. Transportation, the key to a Carbon Negative Country
2. Potential Mitigation Measures and Recommended Actions
3. Preliminary Assessment of Social Considerations
4. Preliminary Assessment of Environmental Considerations

The following chapters in the report have been written by Mr. Julien Gaudremeau and Mr. Frederic Tardif from Rail Concept, France.

1. Preliminary Assessment of Technical Considerations
2. Preliminary Assessment of Economic Considerations, Understanding a Rail Based Transport System in Bhutan
3. Overview of Assumptions around Economic Considerations
4. Notes on Project Financing, Overview of Feasibility Study Process

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*Dr. Karlson Hargroves, Director, Strategic Transitions Group, and
Mr. Julien Gaudremeau and Mr. Frederic Tardif from Rail Concepts*

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Executive Summary

Based on the pre-feasibility study the following conclusions are made:

- Bhutan is faced with the dilemma that its current transportation system has been designed to be fossil fuel and automobile dependent. This is leading to greater numbers of vehicles on the roads (to grow 5 times by 2040) and a growth in the associated fuel import costs, air pollution health impacts, congestion, road fatalities, and greenhouse gas emissions.
- Fuel imports place a significant economic toll on Bhutan with imports to power the vehicle fleet being nearly equivalent to the entire hydroelectricity revenue. In 2015 Prime Minister Tobgay stated that, *'My target for Bhutan is a 70 percent reduction in fossil fuel imports by 2020'*, and such a goal can only be achieved through greater electrification of transport using hydropower.
- There are strong social, environmental, and economic reasons why the Kingdom of Bhutan should seriously consider upgrading its transportation system to one serviced by a combination of modes of hydro-electric powered vehicles, which can also be used for electricity storage and grid balancing.
- Based on the findings of the pre-feasibility study, including consideration of the anticipated growth in private vehicle use and opportunities associated with a potential freight link to India, it is recommended that a full feasibility study be undertaken to further examine the potential for an electrified rail network that is supported by electric vehicles (cars, taxi's, and buses).
- Despite the current levels of demand being less than what would typically call for investment in a rail based system, such a system would become part of the nation's strategic infrastructure and provide a robust transport system for centuries to come, thus investing in Bhutan's future while reducing pollution, road fatalities, greenhouse gas emissions, and lengthy travel times to India.
- It is recommended that the full feasibility study focus on: a) light rail in Thimphu City; b) light rail between Paro and Chuzom; and c) heavy rail from Thimphu to Phuentsholing via Chuzom. It is also recommended that consideration be given to a set of supporting and reinforcing initiatives that ensure an integrated approach to social, environmental and economic outcomes, such as:
 - Enhancing the existing bus system while the rail system is being constructed.
 - Encouraging electric taxis and buses as feeder services and supplements to public transport (especially as electric vehicles have been found to be 95% cheaper to operate in Thimphu).
 - Discouraging car use to reduce private investment in individual vehicles.
 - Supporting walking, cycling and traditional forms of mobility.
- It is recommended that the pre-feasibility team be engaged to undertake the full feasibility study.

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

Introduction

Bhutan is world renowned for being a vibrant, clean, and beautiful nation whose people respect nature and live happy lives. As custodians of Bhutan's amazing and bountiful nature the people of Bhutan are committed to ensuring that it is protected for generations to come. However, Bhutan's past energy choices are now threatening its environmental, social and economic future. There is a pressing need for the Kingdom of Bhutan to update energy options to harness world's best practice to deliver clean, safe and affordable energy and mobility for its people long into the future. The choice to follow western cities and base the mobility system on automobiles running on fossil fuel has now led to serious issues related to: air pollution and health impacts; growing greenhouse gas emissions; increased road congestion, crashes, and fatalities; and economic impacts (with over 95% of hydro-electric energy revenue used to pay for imports of fossil fuels, and only 5% of the available hydro-electric capacity being harnessed).

It is in the best interest of the Kingdom of Bhutan and its people to invest in a low carbon transition that will see its mobility needs met by a system of highly efficient vehicles powered by electricity generated by its mighty rivers. In 2015 Prime Minister Tshering Tobgay responded to this situation by stating that, *'My target for Bhutan is a 70 percent reduction in fossil fuel imports by 2020'*,¹ with such an agenda set to provide a cleaner, safer and faster mobility for the nation. Since 2006, the Government of Bhutan has developed a range of transportation policies that prepare the way for such an agenda.

These policies have informed the selection of transportation options to focus on as part of the Kingdom of Bhutan's 'Nationally Appropriate Mitigation Actions' nominated as part of the UNFCC Conference of the Parties process. Such themes are being considered as a core part of Bhutan's economic development agenda with the Eleventh Five Year Plan calling for *'Eco-friendly mass public transportation services'*.

Such progress is encouraging and stands to be advanced through the outcomes of this report undertaken through the support of the United Nations Centre for Regional Development (UNCRD) as it not only provides a pre-feasibility understanding of the technical requirements of a new transport system for Bhutan but it also shows how this system can be integrated into the existing fabric and provide a range of direct and in-direct benefits.

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

This report responds directly to both the call in the Bhutanese Eleventh Five Year Plan for ‘*Eco-friendly mass public transportation services*’, and the 2010 call as part of the Bhutan Economic Development Policy for ‘*Clean, safe and reliable mass transportation*’ specifically mentioning ‘... *an electric tram/train network*’, in a manner that strengthens its freight connectivity and significantly reduces growing pollution concerns in Thimphu.

As the report will demonstrate, there is suitable evidence to suggest that a detailed feasibility study be undertaken to examine the concept that the future of Bhutan’s transport system be an appropriate combination of integrated transportation options designed around a core of electrified rail infrastructure that provides both passenger and freight capacity with links into neighbouring nations. Of particular value is the ability to use a heavy rail link between Thimphu and Phuentsholing to allow freight trucks to travel by rail to Thimphu, as is done in India and Europe, reducing the travel time from some 10-12 hours to just 90 minutes.

This aligns to the Thimphu Structural Plan which points out that ‘*movement and transport are a group of systems that are integrated with one another*’. Additionally, with both China and India investing heavily in rail systems, this provides strong incentive for Bhutan to be able to connect to such systems with a domestic rail network that would support economic and social growth of the nation for centuries to come. A shift to such a model will deliver a range of social, environmental and economic benefits, as shown in the table below.

Social	Environmental	Economic
<i>Reduced travel times</i>	<i>Reduced air pollution</i>	<i>Greater access to freight</i>
<i>Employment Creation and Improvement</i>	<i>Reduced Greenhouse Gas Emissions</i>	<i>Increased tourism income</i>
<i>Less congestion</i>	<i>Reduced road construction</i>	<i>Less fossil fuels expenditure</i>
<i>Reduced particulate emissions</i>	<i>Reduced noise</i>	<i>Reduced car related expenses</i>
<i>Increasing transport affordability</i>	<i>Reduced animal collision</i>	<i>Reduce road maintenance</i>
<i>Reduced commute time</i>	<i>Reduced sedimentation in waterways</i>	<i>Increasing land value adjacent to stations</i>
<i>Access to cheaper products/materials</i>	<i>Reduced deforestation from road building</i>	<i>Greater access for rural areas</i>

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

Based on the pre-feasibility study it is recommended to develop the initial stage of Bhutan's Rail Network in three zones, namely:

- 1) A Light Rail System in Thimphu City (running from North to South),
- 2) A Light Rail Link between Paro to Chuzom (to connect with the Thimphu – Phuentsholing Line),
- 3) A Heavy Rail Link between Thimphu and Phuentsholing.

It is recommended that a dual gauge system be used to allow the light rail carriages to travel as passenger trains to Paro and Phuentsholing along with freight trains (however the freight trains would not be able to enter Thimphu City on the light rail tracks). Based only on the pre-feasibility study it is estimated that such a system will cost in the range of USD 1.6 – 3.1 billion to construct with a cost for train carriages of between USD 50 – 75 million. Assuming that the operator will invest for rolling stock but not for infrastructure it is estimated that the rail operator will generate a profit of 5 – 10% each year. A summary of the cost and benefits analysis based on the pre-feasibility study is provided in the following table.

Investment for infrastructure	\$2.4 billion (middle point between min and max of investment)	
For the first year of operation	Benefits for the railway company	\$1 million
	Benefits about safety	\$35 million
	Benefits about pollution	\$35 million
	Benefits about time	\$7 million
	Total benefits	\$76 million
For 50 years, with grow up of 4% / year and actualisation of 4%	Benefits for the railway company	\$50 million
	Benefits about safety	\$1.75 billion
	Benefits about pollution	\$1.75 billion
	Benefits about time	\$350 million
	Total benefits	\$3.8 billion

Hence it is estimated that over a period of operation of 50 years benefits in the order of \$3.8 billion (with actualisation of 4%, and hypothesis of grow up of 4%) can be achieved for an investment of \$2.4 billion. Hence the project is beneficial for Bhutan with a socio-economic ITR of more than 6%.

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The following report outlines key elements of the associated benefits and then provides a recommendation for staging efforts to see the integration of a rail based system in Bhutan, as listed below and shown in the following figure.

1. Detailed rail feasibility study,
2. Encourage zero-emissions taxis (while discouraging private vehicles),
3. Support walking, cycling and traditional forms,
4. Light and heavy rail construction,
5. Discouraging car use,
6. Enhancing the existing bus system (based on rail routing),
7. Cable cars and monorail (as steep terrain distributors in an integrated rail network),
8. Opening of the first stage of the rail system.

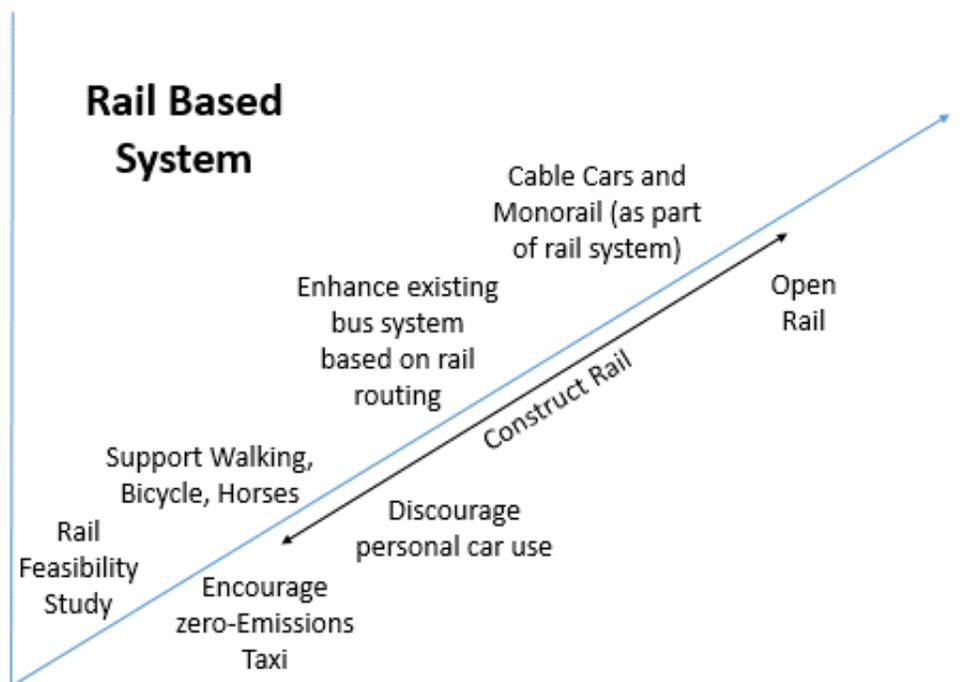


Figure A: Indicative staging of components of rail based transport system in Bhutan (2016-2030)

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

Acknowledgements

This report was developed as part of a UNCRD mission to the Kingdom of Bhutan in close collaboration with the Royal Government of Bhutan. The Executive Summary and Parts 1-5 were written by Dr. Karlson Hargroves with guidance from Professor Peter Newman and research support from Georgia Grant, Daniel Conley, Kiri Gibbons, and Deana Ho from Curtin University and the University of Adelaide. Parts 5-7 and the Appendices were written by Julien Gaudremeau and Frederic Tardif from Rail Concept. The authors would like to acknowledge the valuable contribution of Mr. C. R. C. Mohanty, Environment Programme Coordinator and Dr. Ganesh Raj Joshi, Researcher, United Nations Centre for Regional Development (UNCRD) for the preparation of this report. The report also benefited from the contributions of the number of people (refer below) who provided their valuable comments and suggestions during the consultation meetings.

List of participants in LRT consultation meeting on June 2016		
No.	Name	Organization
1	Lham Dorji	Director General, Road Safety & Transport Authority (RSTA)
2	Kinlay Dorji	Thrompoen, Thimphu Thromde
3	Mewang Gyeltshen	Director, Department of Renewable Energy, Ministry of Economic Affairs (MoEA)
4	Karma Pemba	Chief Transport Officer, Road Safety & Transport Authority (RSTA)
5	Prem P Adhikar	Chief Regional Transport Officer, Road Safety & Transport Authority (RSTA)
6	Meghraj Aadhikari	Urban Specialist, Department of Human Settlement, Ministry of Works and Human Settlement (MoWHS)
7	Dorji Wangchuck	PRO, City Bus Service, Bhutan Post
8	Sangay Dorji	Manager, City Bus Service, Bhutan Post
9	Geley Norbu	Chief Urban Planner, Ministry of Works and Human Settlement (MoWHS)
10	Sonam Dhendup	Offtg. Chief Administrative Officer, Ministry of Information and Communications (MoIC)
11	Karma Thinley	Deputy Chief Program Officer, National Environment Commission (NEC) Secretariat
12	Tashi Tenzin	Executive Engineer, Department of Road (DoR)
13	Tshering Dorji	Sr. Planning Officer, PPD, Ministry of Works and Human Settlement (MoWHS)
14	Pema Tobgay	E&D Ministry of Foreign Affairs (MoFA)
15	Dorji Wangmo	Chief Planning Officer, PPD Ministry of Works and Human Settlement (MoWHS)
16	Bhimlal Suberi	Chief Planning Officer, PPD, Ministry of Information and Communications (MoIC)
17	Pema Lhamo	Assistant Transport Officer, Road Safety & Transport Authority (RATA)
18	Pema Dema	Assistant Transport officer, Road Safety & Transport Authority (RATA)
19	Ugyen Norbu	Dy. Executive Civil Engineer, RSTA, MoIC
20	Khandu Dorji	Planning Officer, PPD, MoIC
21	Tshering Nidup	ICT Officer, RSTA, MoIC
22	Leki Choda	Assistant Planning Officer, RSTA, MoIC
23	Sithar Dorji	Sr. Planning Officer, PPD, Ministry of Information and Communications (MoIC), National Counterpart for pre-feasibility study

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

Part 1: Transport, the Key to a ‘Carbon Negative Country’

Automobile Dependence: A Growing Concern

Many growing cities around the world are faced with the dilemma of their current transport systems being designed to be automobile dependent, which is leading to greater numbers of vehicles on the roads. This is the case in Bhutan, with Figure 1 showing a clear link between length of the road network and the number of vehicles. In part this has been unavoidable due to the geographic nature of Bhutan’s landscape, however, there are clear signs that the level of development in Bhutan now calls for a more effective mass transportation option.

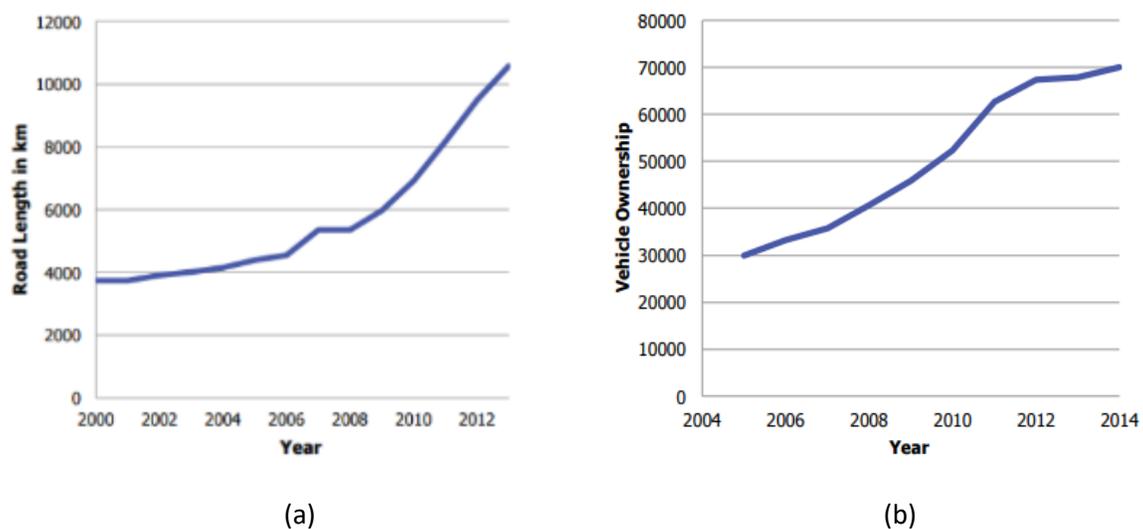


Figure 1: (a) Increase in ‘Road Length’ in Bhutan from 2000 to 2012 compared with (b) the growth in ‘Vehicle Ownership’ from 2005 to 2014 (*Source:* Road Safety and Transport Authority of Bhutan)

Should these trends continue the ownership of vehicles is estimated to soar from just over 75,000 vehicles in 2015 to well over 350,000 in 2040, which will cause significant issues for Bhutan.² Such issues include increasing numbers of road fatalities, greater air pollution, rising greenhouse gas emissions, rising fuel imports, and increased congestion (outlined further in this report). Such future impacts were considered at the 7th Regional Environmentally Sustainable Transport (EST) Forum in Asia, which called for nations to commit to ‘*Vision Three Zeros: Zero Congestion, Zero Pollution, Zero Accidents*’.³

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The Influence of Fossil Fuels on the Balance of Trade

According to research done by the Asian Development Bank, in 2009 exports of hydroelectricity from Bhutan (solely to India) represented some 45 percent of National Revenue. However, according to the Tourism Council of Bhutan the level of fuel imports into Bhutan to power the vehicle fleet is nearly equivalent to the hydroelectricity revenue in 2015, as shown in Figure 2. In 2015, Prime Minister Tshering Tobgay reflected that, 'Electricity is like oil for us and is the most abundant resource'. He then continued to state that, 'My target for Bhutan is a 70 percent reduction in fossil fuel imports by 2020'.⁴



Figure 2: Estimated comparison between the revenue from hydropower and expenditure on fossil fuel imports for Bhutan in 2015. (Source: Data from Bhutan Broadcasting Service)

Hence, not only is there great potential to reduce fuel imports by switching to electrified travel options but there is also potential to increase the level of hydroelectricity production used in Bhutan and exported to India. The ADB estimates Bhutan's hydroelectricity generation capacity at around 30,000 MW with some 1,500 MW of this capacity currently being harnessed - just 5 percent. It is the intention of the Government of Bhutan to reach 10,000 MW of installed capacity by 2020, however, given trends in vehicle use, this new revenue may be used to pay for increasing imports of fossil fuels.⁵

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Curbing Growing Greenhouse Gas Emissions

The growth in vehicles in Bhutan in the coming decade will contribute further to the growing Greenhouse Gas Emissions as shown in Figure 3 by the National Environment Commission of Bhutan, in which the upward trend since late 1997 in transport related CO₂ emissions is clear. Not only does this signal growing levels of air pollution associated with combustion of fossil fuels by vehicles, in time this will also threaten Bhutan's status as the world's first 'Carbon Negative Country'.

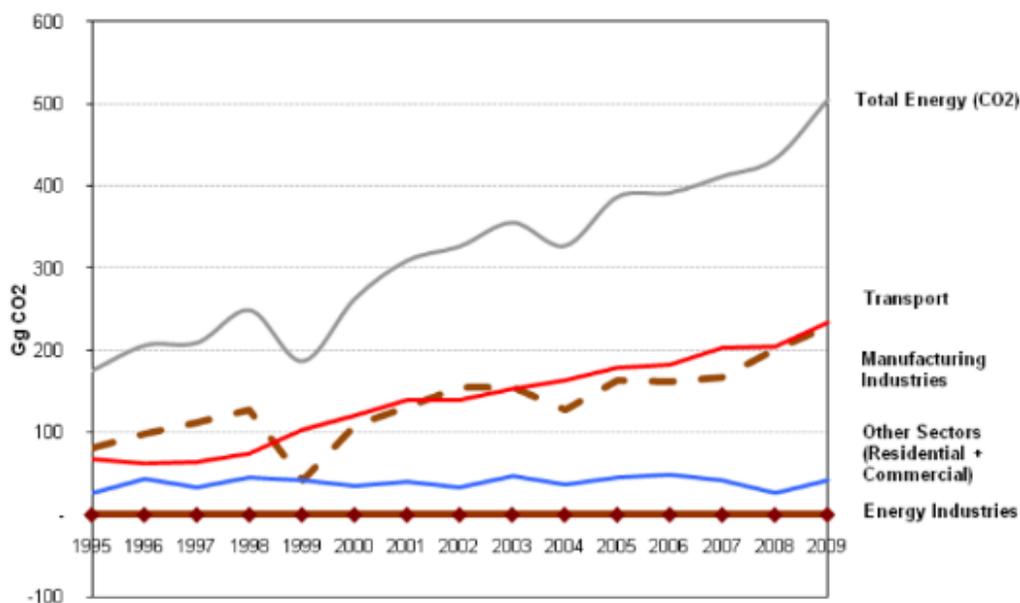


Figure 3: Energy related Greenhouse Gas Emissions in Bhutan between 1995 and 2009 (Source: National Environment Commission, Royal Government of Bhutan, cited in Ea Energy 2012⁶)

In response to such concerns the Government of Bhutan has been developing transportation related policies and strategies since 2006 with the release of the National Transport Policy, as can be seen in Table 1 below. These documents have contributed to the government's understanding of what would constitute a 'Nationally Appropriate Mitigation Actions' (NAMA) as part of the UNFCCC Conference of the Parties process.

These policies and strategies have informed Bhutan's response to the call from the United Nations in the build up to the 'Conference of the Parties 21' (COP21) to provide an indication of the actions that were intended to be undertaken to reduce greenhouse gas emissions. The submission to COP21 by the Government of Bhutan provided a comprehensive list of actions to reduce greenhouse gas emissions and included a number related to transport, as listed below along with specific mention of the potential for an electrified rail network to make a contribution to achieving the outcomes.

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

The Transport related items presented to COP21 by the Government of Bhutan included:

- *Improving mass transit and demand side management of personal modes of transport* (A rail system could provide a robust backbone for a mass transit system in Bhutan that if would not be at the mercy of landslides and other weather related incidents given appropriate routing and construction options. Furthermore, this would provide a faster, cleaner, and cheaper option in the long run for commuters and travellers to manage their transportation needs).
- *Exploring alternative modes of transport to road transport such as rail, water, and gravity ropeways* (The provision of alternatives to road transport for both passenger vehicles and freight will provide significant social, environmental and economic benefits as listed in Table 2 below and expanded throughout this report. Road transport is solely powered by fossil fuels that not only cost the near equivalent to the revenue generated by hydro power but will continue to contribute to the generation of greenhouse gas emissions. A rail network could be complimented by a number of supporting modes of transport as outlined in this report.)
- *Improving efficiency in freight transport* (Providing a rail link between Thimphu and Phuentsholing could reduce current freight travel times from 10-12 hours by truck to 90 minutes by train, with the option of loading trucks onto the train to avoid loss of livelihood of drivers, allowing two deliveries a day and a comfortable safe ride for drivers.)
- *Promoting non-motorized transport and non-fossil fuel powered transport such as electric and fuel cell vehicles* (Developing rail infrastructure in Bhutan would be a key part of the nation's shift to non-fossil fuel based transportation by not only significantly reducing national spending on fuel, but also providing a domestic market for hydroelectricity to power electric trains that are supported by elected busses and taxis.)
- *Improving efficiency and emissions from existing vehicles through standards and capacity building* (Given the level of investment in a rail based system this will bring great attention to Bhutan and is likely to attract investment in both the train locomotive and carriages and the supporting electric buses and vehicles, which will take many of the fossil fuel based vehicles off the road.)
- *Promoting use of appropriate intelligent transport systems* (Intelligent transport systems, or ITS, can provide some relief to vehicle congestion, however, when the transport system is based around a rail network ITS can become a very powerful tool to ensure that real time data is used to ensure that travellers are well informed and the system delivers high levels of reliability.)

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Table 1: Alignment of Transport NAMA with National and Sectoral Policies, Strategies and Plans

Policy/ Strategy/ Plan	Alignment with Transport NAMA interventions
National Transport Policy (2006)	<ul style="list-style-type: none"> • Introduction of electric buses is in alignment with the Policy’s objective of promoting less polluting vehicles and urban transport, although introduction of electric vehicles as a standalone measure is not mentioned. • One of the objectives for Surface Transport, according to the Policy is “introduction of urban transport where lacking, and an increase in the number of city buses and expansion of route coverage, where already existing”, which is the objective of the NAMA interventions
Economic Development Policy, 2010	<ul style="list-style-type: none"> • The NAMA interventions are in alignment with the objective of “Promotion of clean, safe and reliable mass transportation”. The Policy also states that all Dzongkhags shall have bus networks that run on time and on schedule as well as with high standards of safety and service. • “Green and non-fossil fuel based modes of transportation” is identified as an area of economic opportunity under transport sector and related services. The initiative also contributes to the objective of economic development by improving the county’s balance of trade in the long run, by reducing its reliance on imported fossil fuels.
Bhutan’s Second National Communication to the UNFCCC, 2011	<ul style="list-style-type: none"> • The enlisted mitigation options for transport sector include promotion of mass transportation systems, specifically a bus rapid transit system, to tackle congestion and air pollution in the major urban areas of Bhutan. • The enlisted mitigation options for transport sector also include use of electric vehicles.
Transport 2040: Integrated Strategic Vision, 2011	<ul style="list-style-type: none"> • The progress in the development of electric vehicles for urban use, is highlighted. The possibility of Thimphu becoming a leading city in the promotion of electrically powered vehicles and the eventual eradication of all petrol and diesel vehicles, within a few years, is also mentioned. • The ineffectiveness of the current urban bus services in Thimphu is pointed out, and development of a public transport strategy to better serve current demands and encourage more public transport usage is recommended as a short term measure. Further development into a bus rapid transit system with dedicated bus lanes is recommended as a long term measure.

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<p>National strategy and action plan for low carbon development, 2012</p>	<ul style="list-style-type: none"> • The recommended medium term measures (3-5 years) for mitigation measures in road transport sector include pilot testing of electric vehicles. • The recommended road transport mitigation measures include improvement of the public transport to make it safe, affordable and responsive to demand, and promote the decrease in the number of private vehicles.
<p>Eleventh Five Year Plan , 2013-18</p>	<ul style="list-style-type: none"> • Promotion of electric vehicles to address environmental issues and reduce dependency on fossil fuel, is one of the key programs planned for the Transport Sector, according to the FYP. • Setting up of Bus Rapid Transport systems in Thimphu and Phuentsholing to address traffic congestion and control emissions is one of the key programs planned for the Transport Sector, according to the FYP.
<p>National Environment Strategy for Sustainable Development, 2015</p>	<ul style="list-style-type: none"> • The recommended mitigation measures for the transport sector include, “promotion of electric passenger buses and cars, and development of infrastructure for their operation and maintenance, such as charging stations along highways and in urban centres and facilities for safe disposal of used batteries”. • The recommended mitigation measures for the transport sector also include improvement of urban public transport systems in terms of area coverage and service by introducing Intelligent Transportation Systems with particular attention to route management, transport schedule and timely movement, passenger safety, and information and communication.
<p>National strategy and action plan for low carbon development, 2012</p>	<ul style="list-style-type: none"> • The recommended medium term measures (3-5 years) for mitigation measures in the road transport sector include pilot testing of electric vehicles. • The recommended road transport mitigation measures also include improvement of the public transport to make it safe, affordable and responsive to demand, and promote the decrease of the number of private vehicles.
<p>Bhutan’s Intended Nationally Determined Contribution, 2015</p>	<ul style="list-style-type: none"> • NAMA interventions are in direct alignment with one of the key strategies, which is development of a low carbon transport system. The strategy also includes promoting non-fossil fuel powered vehicles such as electric and fuel cell vehicles. • The strategy also includes improvement of mass transit and demand side management of personal modes of transport, promotion of non-motorized transport, and the use of appropriate intelligent transport systems.

Source: Government of Bhutan

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Part 2: Most Suitable Mode of Mass Transport for Bhutan

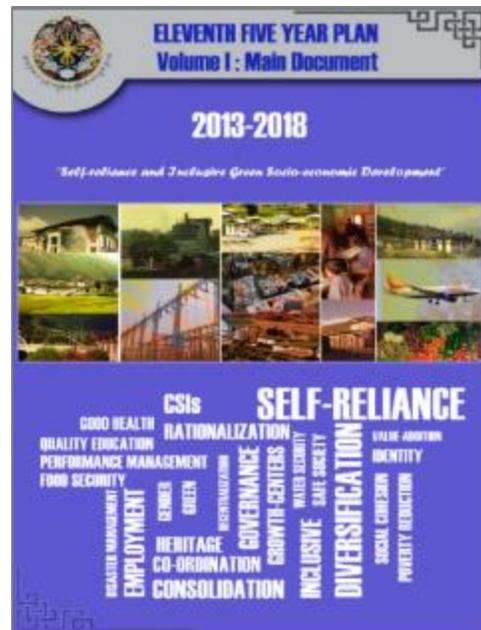
Eco-Friendly Mass Public Transport

The Bhutanese Eleventh 5 Year Plan calls for ‘Eco-friendly mass public transportation services’ which suggests that the future solutions to the growing demands on transportation services and infrastructure in Bhutan would ensure clean and environmentally sustainable outcomes.

Hence a system based on fossil fuels would be less sustainable, especially given the costs associated with importing fossil fuels and the health impacts on Bhutanese citizens from vehicle exhaust fumes. This together with the abundance of hydroelectric power suggests that it would be valuable to undertake a

detailed feasibility study on the potential to create a rail based electrified transport infrastructure that not only reduces import costs of fuels and harnesses local clean energy sources, but provides faster and more comfortable travel for its citizens. This concept is supported in the 2010 Bhutan Economic Development Policy that again calls for ‘Clean, safe and reliable mass transportation’ and specifically mentions the option of ‘... an electric tram/train network’.

When considering the most suitable mode of mass transportation for Bhutan there are a number of factors to consider, including: the suitability of energy sources (fossil fuel vs electricity); impacts on jobs and wellbeing (especially as there are an estimated 30,000 taxi trips per day in Thimphu); possible routes and corridors within cities and between them; the cost of various options (what to invest in first); and how to stage infrastructure investment over time to deliver reliable mobility. Such factors are then compared to a range of modal options, such as non-motorised forms (like walking and cycling), vehicles (such as buses and taxis), light rail systems (such as trams, trolley cars and monorails), heavy rail (such as freight and high speed passenger rail), and even cable cars in areas with limited accessibility and steep slopes.



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The findings of the pre-feasibility study suggest that compelling evidence exists to support a call for a detailed feasibility study into the potential for Bhutan's transport system to be the appropriate combination of electrified vehicle options designed around a core of electrified rail infrastructure that provides both passenger and freight capacity, as presented graphically in Figure 4. Such an approach aligns with the Thimphu Structural Plan of 2000 that seeks 'Balanced Movement', a principle that suggests that *'movement and transport are a group of systems that are integrated with one another'*. Such a concept for a transport system would link Bhutan to India via rail and serve as an ideal freight transport corridor to bring environmental, social and economic benefits in terms of reduced air pollution, reduced construction impacts, reduced road accidents and fatalities, reduced travel times, reduced fuel consumption, and reduce road network maintenance.



Figure 4: A graphic representation of the concept of a future Bhutan transportation system based around an electrified rail backbone and harnessing an appropriate combination of other modes.

However, a key consideration in the selection of a mass transit option for Bhutan is whether it will be in line with neighbouring countries. The preference for rail infrastructure as both passenger movement in cities and for inter-country transit and freight is reflected in both China and India.

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- In 2012 there were rail systems under construction in 82 cities in China and by 2016 the China Railway Corporation announced plans to begin rail projects in 45 new cities. According to the People's Daily Online 'by the end of 2015, the network length in China reached 121,000 kilometres and the length of high-speed rail in operation was over 19,000 kilometres, accounting for 60 percent of the world's total'.⁷
- In 2015 plans for rail systems in 50 Indian cities were confirmed,⁸ including plans for the Nagpur Metro run on solar power. In addition to city based systems the Indian Government is committed to 'the introduction of three new super-fast trains and creation of dedicated north-south, east-west and east coast freight corridors by 2019'.⁹

With both China and India investing heavily in rail systems this provides strong incentive for Bhutan to be able to connect to such systems with a domestic rail network that would support economic and social growth of the nation for centuries to come.

Social, Environmental and Economic Considerations

Based on the findings of the pre-feasibility study it is highly likely that a rail based system would provide significant social, environmental and economic benefits to Bhutan, as outlined briefly in this report and summarised in Table 2 below. Such benefits would need to be investigated in detail as part of a full feasibility study.

Table 2: Examples of social, environmental and economic benefits associated with a rail network

Social	Environmental	Economic
<i>Reduced travel times</i>	<i>Reduced air pollution</i>	<i>Greater access to freight</i>
<i>Employment Creation and Improvement</i>	<i>Reduced Greenhouse Gas Emissions</i>	<i>Increased tourism income</i>
<i>Less congestion</i>	<i>Reduced road construction</i>	<i>Less fossil fuels expenditure</i>
<i>Reduced particulate emissions</i>	<i>Reduced noise</i>	<i>Reduced car related expenses</i>
<i>Increasing transport affordability</i>	<i>Reduced animal collision</i>	<i>Reduce road maintenance</i>
<i>Reduced commute time</i>	<i>Reduced sedimentation in waterways</i>	<i>Increasing land value adjacent to stations</i>
<i>Access to cheaper products/materials</i>	<i>Reduced deforestation from road building</i>	<i>Greater access for rural areas</i>

In particular, as shown in Table 2 and expanded on in Table 3, there are a number of economic considerations related to a rail network, both around benefits and risks, that need to be fully explored, along with social and environmental considerations (as covered in later sections) as part of a full feasibility study.

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Table 3: Economic considerations of shifting to a rail based mass transport system in Bhutan

Potential Economic Benefits	Potential Economic Risks
Greater access to freight (2hrs vs 12hrs)	Securing a suitable Payback Period
Increased tourism income	Attracting Donors/Investors
Less expenditure on fossil fuels	Reaching levels of patronage and low population size
Reduced car related expenses	Disruption of utilities during construction
Reduce road maintenance	Requiring expensive service support
Increased air cargo potential	Lack of maturity in battery storage
Increasing land value adjacent to stations	Problem with land acquisition
Reduced loss of productivity (Congestion)	High capital cost (with strong rates of return from avoided fuel imports alone)
Increase development potential of land	Issues with built up area
Greater return on investment than roads	
Reducing road maintenance costs	
Showcase world class technology	
Provide greater access to rural areas	

The Value of a Rail Link to India

There has long been strong interest in linking Bhutan to India via a rail network, with the Indian Prime Minister Manmohan Singh announcing plans to the Indian Parliament in 2008 to build a ‘Golden Jubilee Rail Link’ between Hasimara in India and Phuentsholing in Bhutan. Despite encountering resistance related to land acquisition in West Bengal the commitment to the rail link was renewed in October 2015 by the Chief Minister of West Bengal Mamata Banerjee and Prime Minister of Bhutan Tshering Tobgay.

The Prime Minister stated that *‘the issue can be resolved and will be resolved’*, and further that *‘there is tremendous potential for Bhutan to work with entrepreneurs of West Bengal and also to form joint ventures in Bhutan’*. The Prime Minister pointed out that doing business in Bhutan had

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many benefits, saying that Bhutan provides '*clean and sustainable environment, good brand name, political stability, easy way of doing business, good rules and regulations that are liberal*'. In response, the Chief Minister of West Bengal pointed out that it would provide a direct link to markets in India for Bhutanese products.¹⁰

Given the projected growth in freight between Bhutan and India the consideration of the use of rail for a freight link leads to a range of social, environmental and economic benefits. For instance, consider the Thimphu-Phuentsholing link that in 2016 had estimated 150-200 trucks road per day. According to a study by the Asian Development Bank and the Government of Bhutan, Ministry of Information & Communications this is anticipated to increase to some 2,000 freight vehicles per day by 2020, and growing to 7,500 by 2040. The report also suggests that the cost of freight in Bhutan is 3 times higher than in India, making it expensive to bring in goods and products and to export Bhutanese goods and products using a road based system.

Shifting freight to rail will provide obvious environmental benefits from reduced fossil fuel consumption and associated pollution along with economic benefits of allowing freight to be delivered faster and cheaper, but often this option overlooks the social implications. However in order to deliver a long term sustainable outcome the social aspect must also be considered, with a shift from trucks to rail freight impacting the livelihoods of truck drivers. There is now strong precedent for combined rail and road freight systems that can both harness the value of a rail freight link and enhance the livelihood of truck drivers (allowing them to sleep in rail sleepers and socialize with other drivers in dining cars).

This precedent first comes from Switzerland that since 2001 has provided a trans-alpine rail link to transport entire freight trucks on rail carriages, as shown in Figure 5. In this system trucks drive onto what are referred to as 'low-loader' rail cars. A typical 'rolling road train' carries up to 27 semi-trailers and can be fully loaded in under 30 minutes, and is used in Canada, France, Italy, Austria and Switzerland.

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Figure 5: An image of the ‘Rolling Road’ in Switzerland (*Source: RAAlpin*)

This method of combining the trucking and rail options is not only being used in developed countries in Europe but also in India. India’s Konkan Railway has a similar system on the 860km line between Mumbai and Goa, known as the ‘Roll-on Roll-Off’ freight train or ‘RORO’, which runs parallel to a national highway, as shown in Figure 6. Comparing average speeds between the RORO and the adjacent Highway, ‘Roll-On Roll-Off’ trucks travel at between 75 and 100 km/h, whereas the road users travel at an average speed of 20km/h.



Figure 6: An image of the ‘Roll-on Roll-off’ train in India.

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What about 'Bus Rapid Transit'?

Given the topography of Bhutan and the potential for a direct freight link to India the rail option was given preference for investigation in this case rather than a road based system.

Contribution to the Sustainable Development Goals

According to the United Nations, the Sustainable Development Goals (SDGs) seek to '*end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda*'.

There are 17 SDG's as can be seen in Figure 7.



Figure 7: The United Nations Sustainable Development Goals (Source: United Nations)

Such an agenda aligns well with the intention of the Government of Bhutan to create sustainable and inclusive transport policies and systems, having stated that, '*The policy objective of Surface Transport is to provide the entire population with a safe, reliable, affordable and sustainable transport system in support of strategies for socio-economic development*'. In particular this statement contains goals aligned to the following specific goals as part of the SDGs:

- SDG 3: Good Health and Well Being: 'By 2020, halve the number of global deaths and injuries from road traffic accidents', and 'By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination'.

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- SDG 7: Affordable and Clean Energy: ‘By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular land-locked developing countries’.
- SDG 9: Industry, Innovation and Infrastructure: ‘Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being.’
- SDG 11: Sustainable Cities and Communities: ‘By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons’ and ‘By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management’.

Further to this, an effective, clean and reliable transport system underpins many of the other SDGs such as: providing job opportunities (both in the new transport sector and reducing commuting times), reducing the cost of living (by providing a cheaper transport option than personal fossil fuel vehicle ownership), increasing resilience to natural disasters (by providing a more robust transport link that can be designed to avoid areas of land slide risk), increasing access to markets for products and produce, enhance trade opportunities with India, and provide rural communities with a fast and reliable way to get into urban areas to access education facilities, markets and employment opportunities.

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Part 3: Mitigation Measures and Recommended Actions

Staging Efforts to Achieve Overall Outcomes

According to the 10th Five Year Plan for Bhutan, ‘For a small, land-locked and underdeveloped economy like Bhutan, the expansion of strategic infrastructure is an absolute requisite for the broader economic and social transformation of the country ... Moreover, accessibility to strategic infrastructure invariably affects the living conditions and welfare of communities all across the country and determines their livelihood opportunities. Strategic infrastructure investments are thus expected to greatly enhance national productivity and competitiveness and stimulate new business while enriching the quality of life for all Bhutanese’.

The transportation network of any country can be classified as ‘strategic infrastructure’ and as such requires a long term view as to its development in a manner that delivers both short and long term value. In order to create an integrated system a strategy needs to be developed to see activities undertaken in the short term (such as encouraging zero emissions taxis, enhancing existing bus systems in readiness for a rail based system, and discouraging personal car use), while construction is underway on medium term options such as light and heavy rail, as suggested in Figure 8.

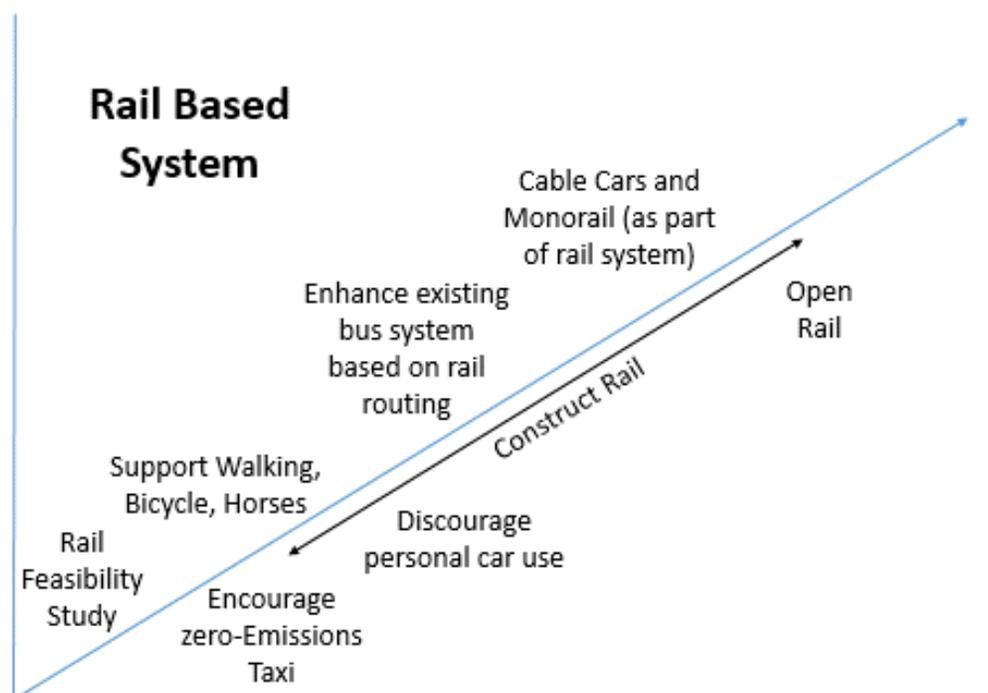


Figure 8: Indicative staging of components of rail based transport system in Bhutan (2016-2030)

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Recommended Stages of Implementation

Detailed Rail Feasibility Study

Building on from the findings in this report, it is recommended that a full feasibility study be undertaken to assess a range of rail configurations, carriage options, and complimentary measures for both the intercity connector rail and the urban passenger rail. An emphasis will be placed on creating a flexible system that allows for cross functionality of carriage types and minimizing the need to change trains or gauges between different types.

The detailed feasibility study will also consider the potential for private interests to create new opportunities by scoping, delivering, and operating rail based public transport services that unlock land development options. The approach was presented by a research team led by Professor Peter Newman from the Curtin University Sustainability Policy Institute in a discussion paper in 2015 and is referred to as the 'Entrepreneur Rail Model'.¹ It is anticipated that this will be of great interest and can attract significant investment, such as from superannuation funds, while significantly reducing the burden on public funds. The appeal of developments around new train stations can be seen by documented cases of an increase in land value. The discussion paper highlights that studies have shown a 42 percent increase over 5 years in Perth, 32 percent in Missouri USA, and 17 percent in England UK. Distinct from a 'land-value capture' model that imposes greater land taxes on land surrounding new stations, this model attracts investment capital that is interested in both providing transportation services and land development. According to the developers, *'This model provides a significant leveraging opportunity that sees private capital invested in greater public transport without large investments from governments'*.¹¹ It is recommended that this approach be based on 100% private capital with government ensuring appropriate land acquisition and assembly (including compulsory acquisition), zoning of land, and integration with existing services and transportation networks. According to the discussion paper it is proposed that the unique value of this approach is that the *"integration of private land development entrepreneurial skill unlocks access to private capital"*. This model is now being further explored as a project with the Sustainable Built Environment National Research Centre (SBEnrc) in Australia, led by Professor Newman.

¹ Newman P., (2015) *The Entrepreneur Rail Model Discussion Paper*, Curtin University Sustainability Policy Institute (CUSP), Curtin University, Perth, Australia.

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Encourage Zero-Emissions Taxis (while discouraging private vehicles)

A key part of a rail based system will be the ability for passengers to quickly access stations. Given the culture of using taxis it is recommended to use this method of transport to provide feeder services to train stations. In such a model, taxis may be allocated a particular area of the city to service, allowing for the development of personal relationships with passengers that may also allow for personalization of the service. The results of early trials of electric taxis in Thimphu showed that in one instance the cost to run the taxi dropped from some US\$403 for fuel and \$48 on engine oil per month to \$16 per month for recharging costs, allowing for a reconfiguration of fares to make a taxi-train-taxi option economically feasible for travellers.¹²

As part of consideration of 'Nationally Appropriate Mitigation Actions' (NEMAs) the Government of Bhutan is considering the development of an electric vehicle Initiative to include the introduction of some 3,000 electric taxis in the city of Thimphu over a 3 year timeframe. The use of electric taxis is primarily intended to reduce dependence on fossil fuels and the associated pollution and is being rapidly adopted in countries around the world, including China and India, for instance:

- The city of Taiyuan China has a population of 2.5 million people and will be the first city in China to have an entirely electric taxi fleet to include some 8,000 vehicles being replaced in just over 1 year. The provincial government has entered into an agreement with the Chinese taxi manufacturer, BYD, with the company investing USD\$3 million to build manufacturing facilities in Taiyuan.¹³
- In 2014, the city of Hangzhou China had a population of 2.5 million people and agreed to purchase 2,000 battery-electric buses and 1,000 electric BYD E6 taxis, with BYD saying they can meet the order in under a year.¹⁴
- In 2015, it was reported that the Chinese Wuhan Third Ring taxi company purchased ten Tesla S85 sedans to be integrated into the Wuhan taxi rotation and have reportedly ordered a total of 100 more.¹⁵
- The city of Bangalore has over 200 lithium battery based taxis that are capable of driving up to 300 kilometres on each charge, as shown in the Figure 9.¹⁶

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Figure 9: Lithium electric taxi fleet in Bangalore (*Source:* The Better India, 2016)

It is important to consider the use of taxis as feeder services to a train based system with local short range routes rather than an alternative to the train, calling for cross town trips contributing to urban congestion. Furthermore, such a fleet of electric vehicles provides new opportunities for decentralised energy storage and grid connect services to be provided by vehicles.

Support Walking, Cycling and Traditional Forms

A number of cities around the world are complimenting a shift to eco-friendly mass transport systems with a focus on supporting walking, cycling and traditional forms of transport, for instance:

- The city of Vauban in Freiburg, Germany is the largest car free development in Europe with 5,000 residents. If residents own a car they must purchase a parking space in a multi-story carpark for €18,000. This has been achieved by removing parking spaces and only allowing delivery vehicles/drop off and pick-ups in the area. Residents who decide to live there with no car receive a monetary incentive, such as cheaper tram use and cheaper housing that doesn't include a parking space. Vauban has increased the car free incentive by adding 5,000 bicycle parking spaces.¹⁷
- Due to the worsening situation of congestion and pollution in Chennai, a city of 6 million citizens in India, 15 key urban departments came together in 2010 to form the 'Chennai Unified Metropolitan Transport Authority'. The authority has created the non-motorized transport policy to promote people walking, cycling or taking public transport as an alternative to private vehicle use. They hope this will increase cycling traffic by 40 percent and take the share of public transport to 60 percent.¹⁸

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- A number of Chinese cities have made the move to electric bicycles, through improvements in non-motorized transport policy, e-bike technology, growing incomes, falling e-bike prices, restrictions on sales of gasoline scooters, and banning cars from city centres.¹⁹ This change has also been helped by the Chinese government, mandating the conversion of motorcycle lanes back into bicycle lanes.²⁰

Light and Heavy Rail Construction

Please refer to later sections for the results of the pre-feasibility assessment. Following the full feasibility study stage, the design and construction of the rail system can be undertaken to include both light and heavy duty rail footings depending on the anticipated weight of the trains being used (either passenger or freight or both).

Discouraging Car Use

The Ministry of Information & Communications through the Road Safety & Transport Authority is working on strategies to discourage the use of personal cars. However, such options need to be implemented as part of an integrated approach where enhanced bus services are made available while the infrastructure for rail services is constructed, which can be an 8-10 year timeframe. In-line with such a strategy the Ministry of Finance has approved the procurement of 18 diesel powered new city buses for Thimphu. The Government is also considering a trial of 2 – 4 electric buses to run on interchangeable batteries, charged by hydropower generation. This is expected to see a significant reduction in the running costs from importing, storing and distributing diesel. (See item on enhancing existing bus system)

Recently Ministry of Information & Communications has restricted the registration of new taxis in Thimphu and Phuentsholing with exceptions for the replacement of existing taxis or the registration of new electric taxis. Furthermore, following the lift of import restrictions on vehicles in 2014, vehicles with an engine capacity over 1500cc are subject to an increase level of taxation rate yet to be determined, with a second threshold at over 3000cc.

The Ministry is also considering a range of other options, such as:

- Increasing registration fees for vehicles in Thimphu as a form of congestion charge,
- Increasing the registration cost for older vehicles,

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- The introduction of road tolls on congested corridors (such as Norzin and Chang Lam) with an initial manual system that would be upgraded to an automated system.

The Ministry is also thinking creatively about how it can itself reduce the pressure on the transport system during peak times. One of the options being considered is the staggering of the office hours across each of the 10 Ministries (which would involve some 3,500 staff and an estimated 1,700 vehicles). In the longer term, the Ministry is considering a range of options that align to the integrated rail based approach outlined in this report such as dedicated bus lanes, providing bus feeder services for main stations, improved cycle lanes and walking paths, the pedestrianisation of Norzin Lam, and encouraging car-sharing.

Enhancing the Existing Bus System (in preparation for the rail system)

A key part of the transition to a rail based system will be the enhancement of the existing bus system to provide a public transport option while the rail system is being constructed, and then to provide feeder services to stations along with taxis. It is recommended that the alignment of the future rail corridors, as suggested in the pre-feasibility findings presented later in this report (to be further investigated as part of a full feasibility study), be used as the basis for the expansion of the bus network, using electric buses. As part of consideration of the 'Nationally Appropriate Mitigation Actions' (NAMAs) the Government of Bhutan is considering the piloting of electric buses that includes the installation of quick chargers (which could also include the option for manually interchangeable batteries to avoid charging times).

An example of the use of electric buses comes from the city of Kochi in India. In 2012, Kochi had a population of 600,000 (comparable to the future anticipated population of Thimphu). The Kerala State Road Transport Corporation (KSRTC) now plans to introduce 650 new buses in the Greater Cochin area, including electric buses and buses fuelled by compressed natural gas (CNG).²¹ According to the KSRTC Strategic Plan, *'The initiative is aimed at ensuring lesser mile-connectivity for the Kochi Metro Rail project and also to rejuvenate the mass transportation facility in the project'*. As part of the plan, a fleet of approximately 100 electric buses would operate feeder services from Kochi Metro stations to commercial hubs and towns in a 10km radius, as shown in Figure 10.²²

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Figure 10: Zero Emissions Bus used in Kochi to feed into Metro Stations (Source: The Hindu)

As part of the ‘Nationally Appropriate Mitigation Actions’ identified by the Government of Bhutan, there is a clear strategy for enhancing the current bus system that provides a robust work plan for enhancing the current bus system. The following provides a summary of the key steps of the strategy proposed by the Government of Bhutan:

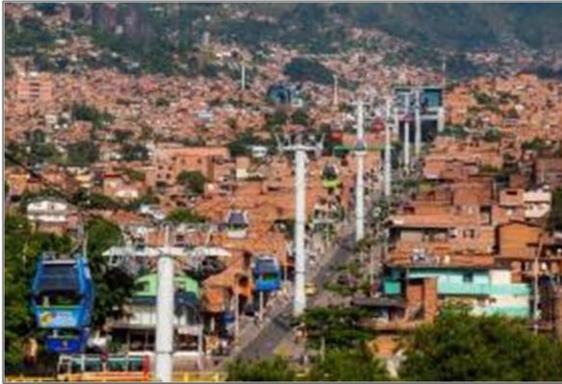
1. Upgrading the Thimphu City Bus Terminal.
2. Integration of ITS Measures (including a real time information system to monitor the speed, location, and the arrival and departure time, with displays in bus stops, along with the provision for electronic ticketing to make purchasing a ticket easier and control revenue leakage).
3. Piloting of Electric Buses (including quick chargers, switch to electric buses, and the institutional strengthening of Bhutan Post as the ‘key implementing agency for operations of electric buses’, and the use of promotional campaigns to encourage ridership).
4. Full Scale Operations (involving an estimated 70 buses).

It is important that enhancements to the bus system are designed in accord with the intended rail network to ensure co-location of bus stops with future rail stations to build traveler patterns of accessing transport services while providing short term protection from the elements at bus stations.

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Cable Cars and Monorail (as steep terrain distributors in an integrated rail network)

In a mountainous terrain, such as La Paz in Bolivia, constructing any form of infrastructure is a challenge, yet alone a rail system. However, much like in Bhutan this does not need to be a deterrent for public transport. Transporting citizens all around La Paz, even transporting to El Alto, is a cable car.²³ Well above any traffic below the cable car system is not effected by the unstable mountainous landscape with an overall length of 10km, costing \$23.4m per kilometre.



(a)



(b)

Figure 11: (a) Urban Cable Car in Medellin, Columbia (b) Monorail in Mumbai, India

Also, as Figure 11 shows, the city of Medellin in Columbia is using cable cars to connect commuters across an area which not previously thought possible due to its urban density and steep terrain.²⁴ Although this started as a sole means of transport in a difficult area to commute, it actually had a flow on effect with tourists travelling to Medellin to ride the famous urban cable car.²⁵

In an effort to reduce congestion and pollution, the city of Mumbai in India has constructed a 9 km monorail system at an estimated cost of \$13m/km²⁶ that can access areas that require sharp turns due to topographical restrictions while travelling at speeds of up to 80km/h.²⁷ The elevated rails allow for complex and curved pathways to be made not restricting routes to following existing roads which can completely avoid areas of high traffic volume. As seen with the Mumbai Monorail, the elevated structure can pass over multiple story buildings and bridges, and can be built near dense and congested infrastructure, encouraging citizens to use the public transport. When considering the cost of a monorail system most systems have an average payback period of 20-25 years and an internal rate of return of around 7 percent, due to the low maintenance and running costs.

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Figure 12: Nepal Cable Car in Chandragiri near Kathmandu.

In May 2016 a privately-owned cable car running some 7kms was opened near Kathmandu to provide access to tourist sites for as many as 10,000 visitors a day in rugged terrain as shown in Figure 12.

Opening of the First Stage of the Rail System

Once the first stage of the rail system is constructed it can be opened and the transition of part of the bus/taxi fleet can be undertaken to provide feeder support to train stations, especially to and from rural areas.

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Possible Development Partners

There will be great interest in supporting the Government of Bhutan to maintain its 'Climate Negative' status which can be harnessed to attract climate finance options.

Sustainable Development Agreement

During the UN Conference on Environment and Development (1992) in Rio de Janeiro, Benin, Costa Rica and Bhutan entered into a bilateral Sustainable Development Agreement (SDA) with the Netherlands, which was formalized in 1994. In 2005, Costa Rica, Benin and Bhutan came under the umbrella of South-South Cooperation, with a US\$13.2 million grant from the Kingdom of Netherlands. Specifically the Netherlands identified the main goals to work towards as being:

- Develop reciprocal projects that will generate knowledge and empower stakeholders.
- Mobilize national governments, the civil society, and the academic and private sectors in partner countries to renew and reinforce commitment to sustainable development.
- Contribute to sustainable development and poverty reduction in partner countries, taking into account environmental, economic and cultural idiosyncrasies.
- Explore the potential of South-South partnership to promote international commitments and mutual cooperation for sustainable development

Accessing Climate Finance for Sustainable Transport

There are various mechanisms for accessing finance for sustainable transport, such as the Clean Development Mechanism which has been applied to three major transport projects, including: the Bus Rapid Transit system in Bogota, Columbia (US\$360 million); regenerative braking system for the Delhi metro, India (US\$51.3 million); and the Cable Car Metro System in Medellin, Colombia (US\$26 million). Significantly more projects are expected in the future, with 23 currently being validated by the UNFCCC.²⁸

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Part 4: Preliminary Assessment of Social Considerations

Social Drivers for Reducing Automobile Dependence

The need to improve the transportation system in Bhutan has a number of drivers as previously mentioned with the key social drivers related to road fatalities and the health implications of air pollution from the combustion of fossil fuels by vehicles.

Greater Road Fatalities

According to the WHO 'more than 1.3 million people die annually on the road in the world and another 20-50 million are injured'. Furthermore, a study by the WHO and the Asian Development Bank found that Bhutan is second only to Nepal in the number of road deaths per 10,000 vehicles in South Asia, as shown in Figure 13. A study by the Asian Development Bank (2011) also suggests that if the increase in vehicle ownership continues as anticipated, annual deaths on Bhutanese roads are set to increase from less than 100 per year in 2010 to over 700 per year by 2040.

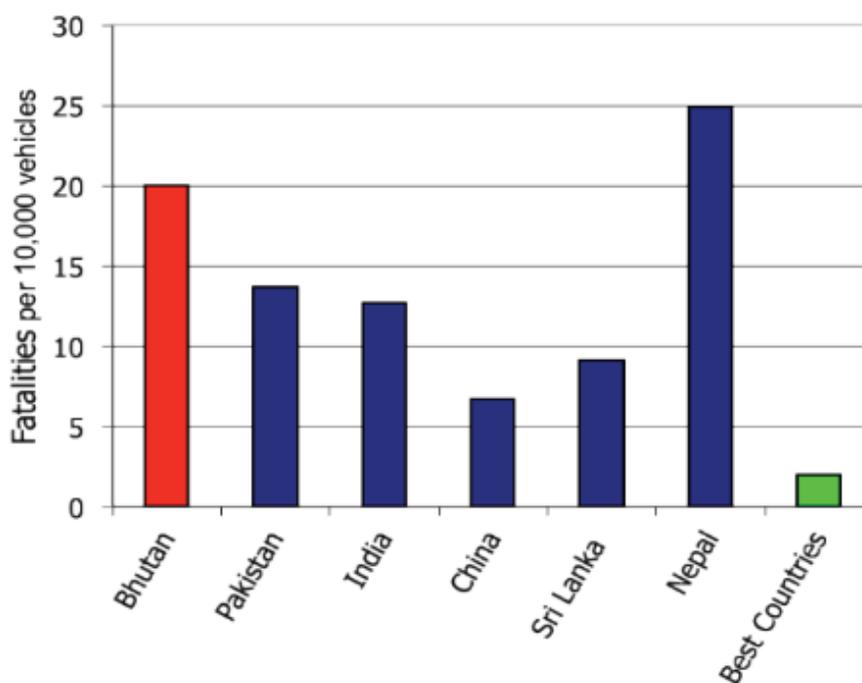


Figure 13: Annual Road Deaths per 10,000 vehicles in South Asia (Source: Road Safety and Transport Authority of Bhutan, cited in ADB 2011)

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Health Impacts from Air Pollution (PM₁₀)

As can be seen in Figure 14, in 2010 the average daily level of PM₁₀ resulting from combustion of fossil fuels in vehicles in Thimphu exceeded the World Health Organizations recommended levels, with incidents of days where this level was significantly exceeded. According to data from the NEC the average annual concentration of PM₁₀ was 40.5µg/m³, just over double the WHO Guideline Level for the annual average of 20µg/m³.

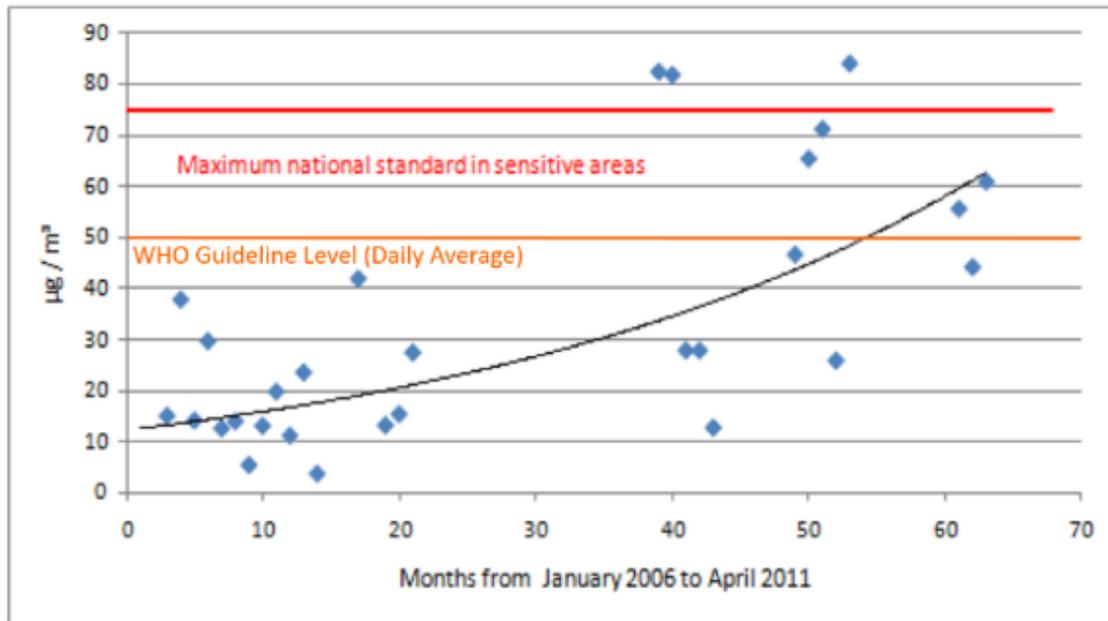


Figure 14: Daily Average Concentration of PM₁₀ in Thimphu (Source: National Environment Commission, Royal Government of Bhutan)

Identification of Social Parameters

As can be seen in Table 4 there are a range of social parameters related to the consequences of the construction of a rail network in Bhutan, both positive and negative, that will need to be further investigated as part of the Full Feasibility Study. A particular consideration is that some 45 percent of the Bhutanese population is under the age of twenty years old, suggesting that a modern transportation system will be needed to meet their expectations for mobility and accessibility to both rural and urban areas.

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Table 4: Potential Positive and Negative Social Consequences of Shifting to a Rail based Transportation Network

Positive Social Consequences (Benefits)	Negative Social Consequences (Risks)
Reduced travel times (commuters and freight)	Require land acquisition for corridors, stations, interchanges and terminals and in some cases built-up areas.
Creation of jobs and ancillary industries (both in rail and integrated bus and taxi feeders).	Potential for reduced employment for bus/taxi
Less congestion during peak times	Construction impacts (dust, noise, vibration.)
Improved health from reduced particulates and other fossil fuel related air pollution.	Impacts to traffic flow during construction
Increasing transport affordability by providing public transport and avoiding need for cars.	Lack of community involvement in planning (which can be overcome in early stages)
Greater transport accessibility for community (especially the vulnerable and disadvantaged)	Physical or economic displacement of inhabitants.
Cheaper imported goods and products and greater markets for Bhutanese exports.	
Reducing summer pollution inversion	
Reduced vehicle use leading reduced accidents and road fatalities.	

Measurement, Analysis and Monitoring Social Parameters

Indicators of projected passenger demand

In 2015 Bhutan had a population of just under 750,000 people with a little over 35 percent living in urban areas. However, it is also anticipated that there will be strong migration from rural areas in the future, with a Asia Development Bank supported study stating that, *'This migration is a consequence of desires and aspirations of the younger, more mobile, and more educated generations for a more varied lifestyle, based on the greater employment, education, and social opportunities available in urban areas'*.²⁹ Hence it is likely that demand for transportation in urban areas of Bhutan will increase in the coming decade.

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Currently much of the transportation needs of the urban population are met with either private cars or taxis. For example, taxis in Thimphu carry an estimated 36,000 passengers per day compared to the bus system which has 35 buses and carries an estimated 4,900 passengers per day. This has led to very low rates of public transport use, with the World Bank estimating that less than one third of urban households in Bhutan used public transport in a given month in the year 2012. Studies undertaken to investigate the feasibility of improving the bus system to provide rapid public transport suggest that by 2018 as many as 14,500 people would be likely to use such a bus system each day and that this would grow to an estimated 80,000 people by 2033.

Building on from the findings of the work undertaken in the various documents in Table 1, the Government of Bhutan has identified specific 'Nationally Appropriate Mitigation Actions' related to the growth in transportation needs in urban areas. One key area is the suggestion of the use of electric buses to service the growing numbers of visitors to Bhutan. According to the Annual Statistical Bulletin of the Government of Bhutan Ministry of the Information & Communications, the annual movement of air passengers to Bhutan has grown steadily since 2002, as shown in Figure 15, growing from 42,990 passengers in 2002 to an estimated 293,551 in 2015.

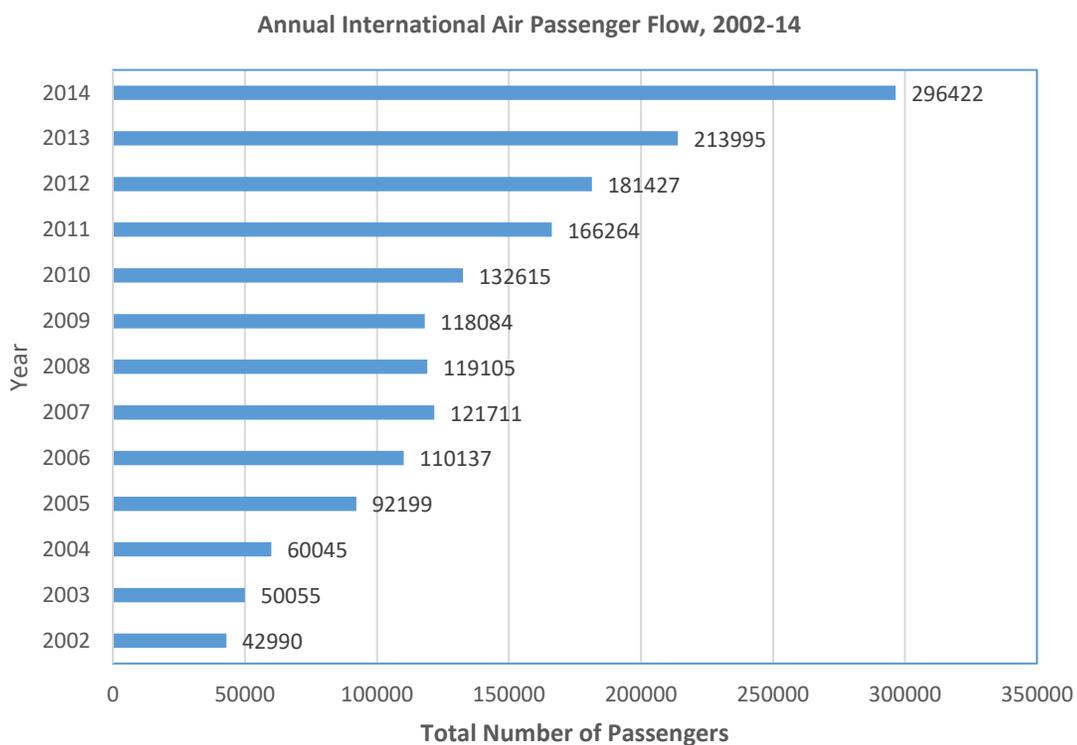


Figure 15: Annual International Air Passenger Flow into Bhutan, 2002-14 (Source: Government of Bhutan)

Pre-Feasibility Study to Identify Suitable Mass Transit Option in Bhutan

Affected Populations, Groups, Settlements, and Transit Dependent Individuals

A rail based transportation network will affect all Bhutanese with the potential for direct day to day benefits for both urban and rural communities. This can be demonstrated using the social parameters identified by the Government of Bhutan as being 'Nationally Appropriate Mitigation Actions' (NAMA), namely:

- *Reduction in traffic congestion measured by the time taken per passenger-trip:* A rail based system supported by a fleet of short route buses and taxis will significantly reduce traffic congestion, reduce travel time, and provide transportation access to a greater number of rural communities with the greater viability of lower density bus routes through subsidies to provide access to the train stations.
- *Cost of transportation measured in either the average cost per passenger-trip or the share of household income spent on transportation:* A rail based system will reduce the cost of transportation providing that it is offered in a way that is suitable, reliable and accessible. The cost of owning and running an electric private vehicle is similar to that of a fossil fuel car (given the average mileage in Bhutan is less than 10,000km per year, however, this is much higher per trip than a train or light rail fare).
- *Health Impacts measured in change in respiratory infections per population:* Given Bhutan's significant clean and renewable energy potential the option to construct an electrified rail network provides many benefits, including reducing the use of fossil fuels in cars and the associated air pollution which has been shown above to currently exceed the World Health Organizations recommended levels in Thimphu.
- *Women's Safety, Convenience and Employment measured in the number of women taking trips at night, number of public transport seats reserved for women, and the number of women drivers and conductors:* A rail network will provide the potential for a higher level of safety for all Bhutanese people with well-lit carriages patrolled by security officers. Furthermore, the jobs associated with driving and collection fares on trains are well suited to women.

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Part 5: Preliminary Assessment of Environmental Considerations

Identification of Environmental Parameters

As can be seen in Table 5 there are a range of environmental parameters related to the consequences of the construction of a rail network in Bhutan, both positive and negative, that will need to be further investigated as part of the Full Feasibility Study.

Table 5: Potential Positive and Negative Environmental Consequences of Shifting to a Rail based Transportation Network

Positive Environmental Consequence (Benefits)	Negative Environmental Consequences – During Construction (Risks)
Reduced air pollution	Clearing of natural areas impacting Flora and Fauna
Reduced Greenhouse Gas Emissions	Construction impacts, such as on waterways around river crossings,
Reduced road construction	Risk of landslides from hill cutting
Reduced noise from vehicle use	Air pollution from earthworks equipment
Reduced animal collision	Generation of construction waste
Reduced sedimentation in waterways	Noise and vibration issues
Reduced deforestation from road building	

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Measurement, Analysis and Monitoring Environmental Parameters

Environmental Parameters and Impacts

Despite the initial disturbance to the environment from the construction phase (which is less impactful than for equivalent road infrastructure) the shift from a road network based transportation system to a rail based system will result in a number of reductions in the impact on the environment, such as:

1. Reduced impact on the air, measured by the average concentration of various pollutants in a given zone, such as Particulate Matter (PM), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), volatile organic compounds (VOCs), and Sulphur Dioxide (SO₂).
2. Reduced contribution to the global greenhouse effect, measured by the volume of Greenhouse Gas Emissions, such as Carbon Dioxide (CO₂), Methane (CH₄), and Nitrous Oxide (N₂O)
3. Reduced impact on the water, measured by the amount of sedimentation in waterways from road construction and landslides from hill cutting and during the operation of the road.

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Part 6: Preliminary Assessment of Technical Considerations

Consideration of Traffic Volumes

The following section provides a summary of the findings of a preliminary assessment into the technical considerations of providing a rail backbone for Bhutan. The assessment began with consideration of traffic demand as shown in Figure 16. It is noted that these are indicative figures based on reported traffic counts and a roadside estimate, and as part of the Feasibility Study the figures would be confirmed through actual traffic counts.

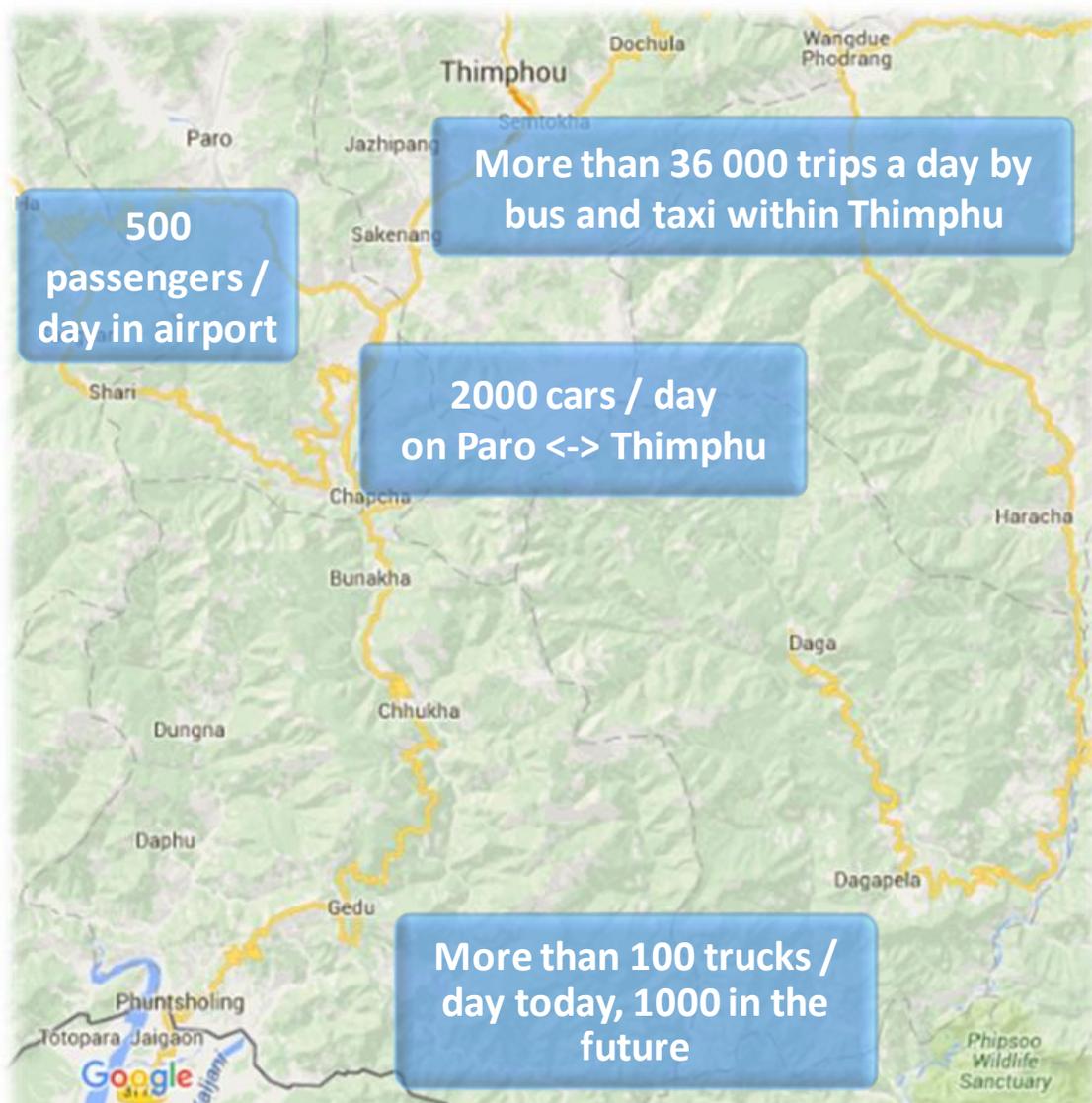


Figure 16 Indicative estimates of traffic volume in East Bhutan

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Based on this initial assessment it is concluded that:

- 1) There is sufficient freight traffic from India both currently and projected to make a rail link viable, and
- 2) There is also sufficient traffic both within Thimphu and between Paro and Thimphu to make a rail network supported by collector services viable.

Consideration of Potential for Connection with Adjacent Countries

Both India and China are investing in expanding their rail network, which presents the opportunity to connect to cities in Bhutan via a rail link. In the case of India, the closest station from Phuentsholing is Hasimara station, located on the 'New Jalpaiguri – Alipurduar – Samuktala Road Line. Although Hasimara is about 17km from the border it is assumed that Indian railways will complete the network up to the border of Bhutan in the future. Between Hasimara and Kolkata the rail distance is approximately 750km, taking some 14 hours (including a change at the New Jalpaiguri Railway Station). In the case of China, a rail extension is planned from Shigatse to Dromo by 2020, with Dromo located just at the border between China, India and Bhutan (some 30km from Damthang) as shown in Figure 17.



Figure 17 - Extensions of Chinese railway in Bhutan

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However, given the topography of Bhutan it is unlikely that the country will be part of a main rail corridor between China and India, and hence should be considered a separate line connecting to Northern India, as shown in Figure 18.

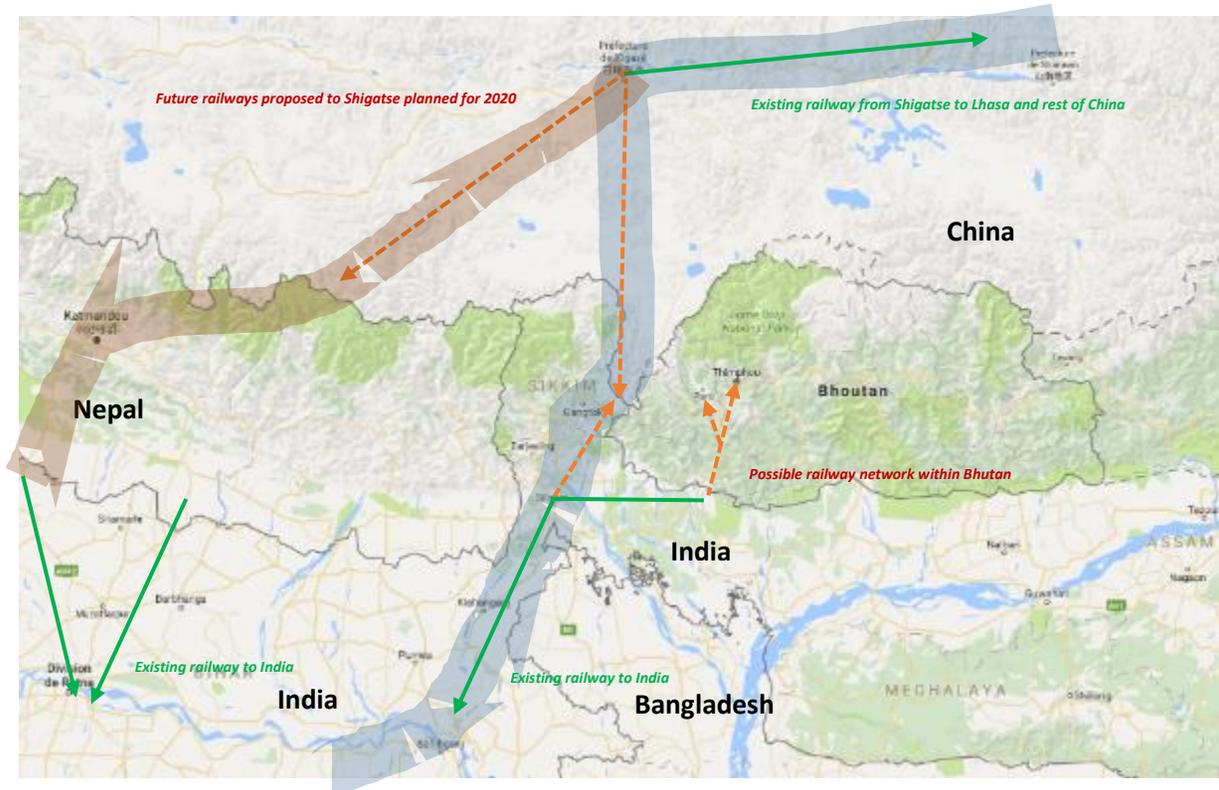


Figure 18: International corridor in the region (red lines are in project, green are in operation)

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Consideration of Key Zones of Initial Rail Network

Based on the pre-feasibility study it is recommended to develop the initial stage of Bhutan's Rail Network in three zones, namely:

- Zone 1: Thimphu City (Light Rail) ,
- Zone 2: Thimphu to Chuzom (Light and Heavy Rail)
- Zone 3: Chusom to Paro (Light Rail), and
- Zone 4: Chuzom to Phuentsholing (Heavy Rail).

The following schematic shows these links and associated rail type.

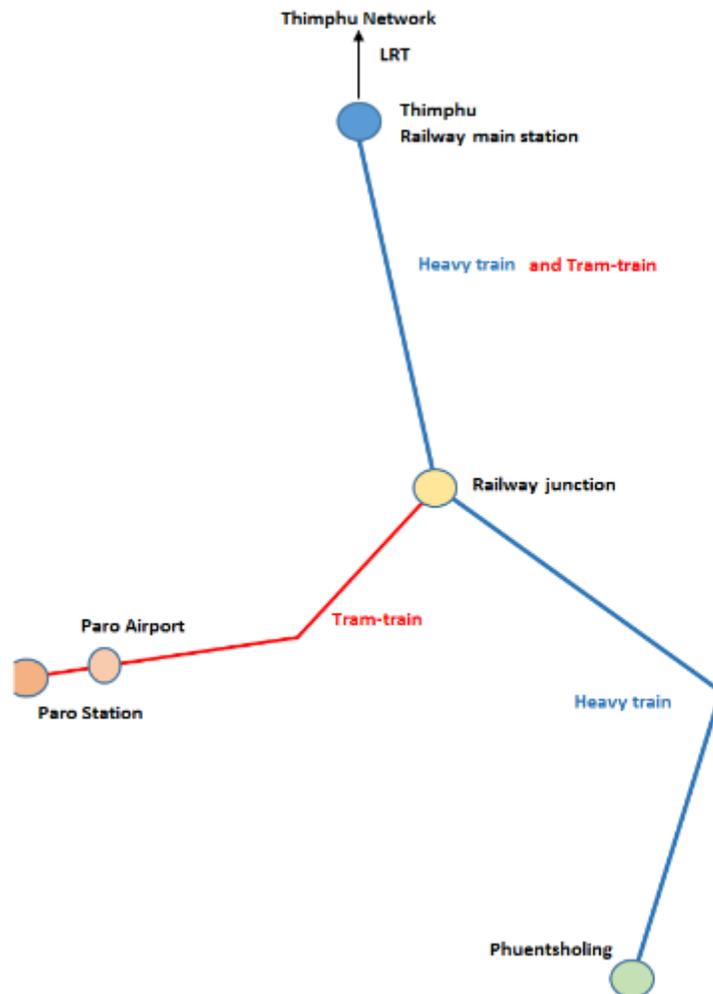


Figure 19: Layout of the railway lines

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Zone 1: Thimphu City

Selection of Rail Type

As described above, it is recommended that a light rail system be developed in Thimphu. However, it is further recommended that this system be designed to connect with the intercity rail proposed in the following two zones. It is also recommended that multimodal connections are designed with other transport modes, such as cable rail, suspended cable car, electric buses, or electric taxis to act as feeder systems to the central light rail system and serve other parts of the city. LRT systems are complementary and totally compatible with other transport modes which could be implemented within the city.

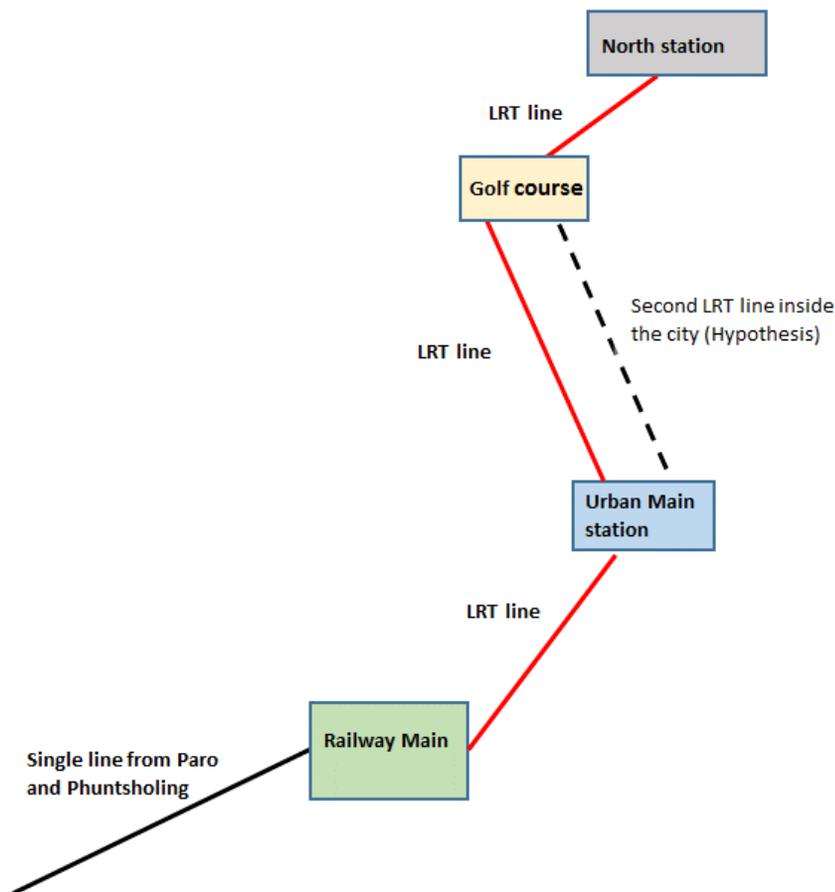


Figure 20: Example for Thimphu city network

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It is proposed that the configuration of the Thimphu City system would run from North to South and be comprised of:

- A railway main station located in the Southern part of the city, with heavy railway tracks for freight trains terminating and with light rail tracks continuing to the city for passengers coming from (or going to) Paro and Phuentsholing;
- A light railway line between the railway main station and the urban main station;
- An urban main station located close to the stadium and the current bus station. This station will be a multimodal station with a bus station, taxi station, and so on;
- A light railway line inside the city center (along the current main avenue or along the river) from the urban main station to the station close to the golf course;
- An urban station close to the golf course, with the possibility of connection with a second line to go to the urban main station (and reverse). This second line could be along the main avenue (if the main line is near the reverse, or could also be);
- An extended line to the northern part of the city to the National Assembly.

This urban network will be completed by different stopping points, with a headway of about 1 min 30s to 2 min. At this stage, the calculation of the distance (from Google earth) inside Thimphu gives the results below:

- From railway main station to urban main station = about 5300 meters including 500m of viaduct to cross the river and the road;
- From urban main station to the golf course station by using the current main avenue = 2000m including a 150m viaduct to pass over Thim Chhu River;
- From golf course station to National Assembly station = 1250m including a 120m viaduct to pass over the Thim Chhu River.

The total distance inside Thimphu city is 8,500 meters including 770m of overpass buildings. Different altitudes and elevations taken within Thimphu allow us to calculate the difference in elevation between the South and the North, and the height difference is 1.1% which allows for a great performance for the rolling stock.

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Except the necessary crossings of Thim Chhu River and the road, there is no technical difficulty to create a new railway light inside Thimphu. However, this will have to be confirmed and validated from the feasibility study. Within Thimphu city centre, regarding the urbanization, the building and the location, we suggest to use the current main avenue. We can also think to put the line near the river, but this will be less central inside the city, and the traffic should be less important. Like the majority of tramways in the world, the rail will use the existing road.

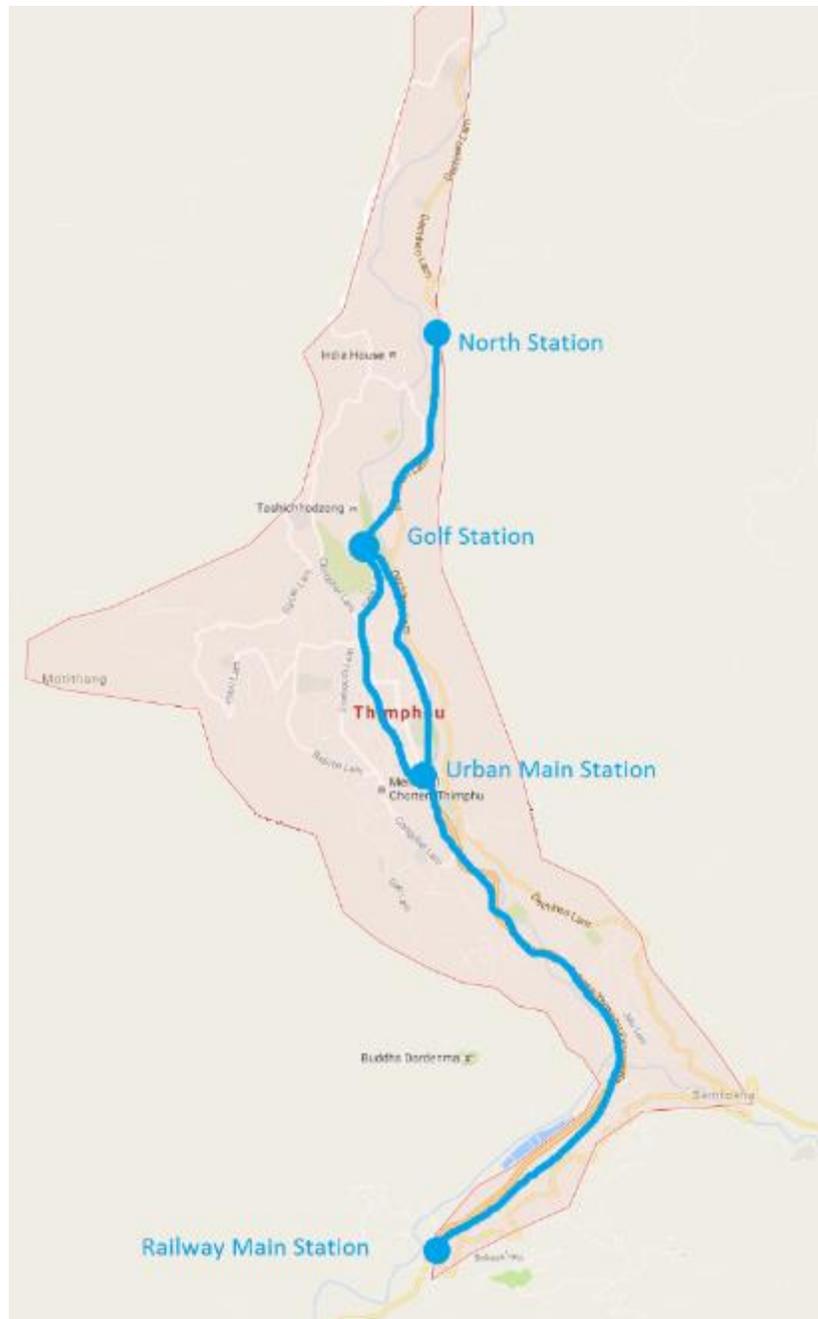


Figure 21: Proposed line inside Thimphu

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Location of Main Stations

Thimphu city will have two main stations. The first one is “Thimphu Railway Main Station” located in the Southern part of the city and connected with the railway line Paro – Phuentsholing (Fig. 24). Passengers coming from (or going to) Phuentsholing, except if there is also Tram-Train rolling stock, will have to change. Passengers coming from (or going to) Paro will continue their trip, in the same train, without changing. Therefore, it will be possible for passengers to travel from National Assembly to Paro airport without changing trains. The railway main station will also have installations which will allow for the loading and unloading of freight coming from (or going to) the Indian border.

The second main station within Thimphu will be “Thimphu Urban Main Station” or “Thimphu Central”. It will be located close to the current bus station to allow ease of transferring from the bus system to the train system. From the ‘Central Station’ to the ‘Golf Course Station’ it is proposed to have two lines: One through the city centre using the current main avenue, and another along the Thim Chhu River. The last station will be close to the National Assembly and will be used to insure the functionality for train terminus with turn back before leaving to the South.

Selection of Line Configuration

At this stage, it is difficult to know whether a single or double line is the best system for Thimphu. It depends on the technical possibilities, the annual number of passengers expected, the rolling stock, the cost and so on. The feasibility study should give us the answer. From the first studies, it looks like a single line could be enough.

However, our first proposal is to operate the urban railway with a single line system with loops within the main stations, but also between the railway main station and the urban main station (Buddha point for example) within the longest part of the network (about 5 km). Regarding the service, a second loop is needed between the urban station and the golf course or between the golf course and the north station.

The electrical power will be supplied by a light catenary, commonly used for tramways. The implemented signalling system could be the same signalling system as for tramways. On the long part between two stations, especially in the Southern part of the network, the speed limit could be 70 km/h. The estimated travel time between the southern railway station and the north station, with 14 stopping points, will be about 25 min divided as shown below:

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- 15 min for servicing the stopping points with 30 seconds (or 1 min) stopping to allow passengers operations (up and down) and 30 seconds more for braking and acceleration.
- 10 min for the travel time between stopping points.

For the zone between the urban main station and the golf course station, with 4 stops, the travel time should be about 7 min.

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Zone 2: Thimphu to Chuzom

On this part of the network, there will be passenger trains and freight trains. The line will be a heavy track. At this stage, regarding the lack of data for the future freight traffic (especially tonnage), we are unable to estimate what will be the specific structure of the track, however, the calculation will be done during the feasibility study. The estimated line will be near the Thim Chhu River from Thimphu to Chuzom with an interchange at the junction to Paro and Phuentsholing. A technical visit and a survey on the field were done along the valley from Thimphu to Paro city and allowed us to see particular points such as the river crossing, and zone where tunnels are needed.

From Thimphu to Chuzom, the estimated possibility for the line was done from the visit on the field and from Google Earth data. For this part of the line the distance estimated is about 17 kilometres with a possible gradient of 0.7%. The river and the mountain need to be on each side of the line with 2 or 3 overpasses and tunnels will be needed to alleviate bottlenecks, as shown below in Figure 22.

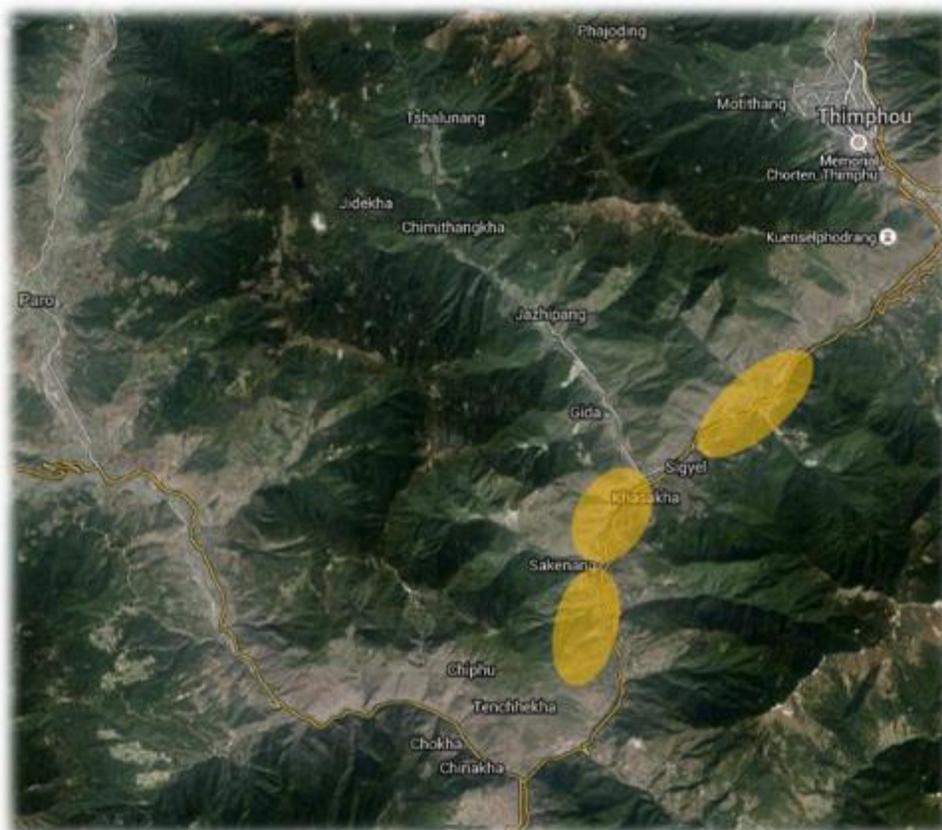


Figure 12: Critical points between Thimphu and Chuzom

With the schematic of the line, pictures taken during the field visit show some possibilities and constraints.

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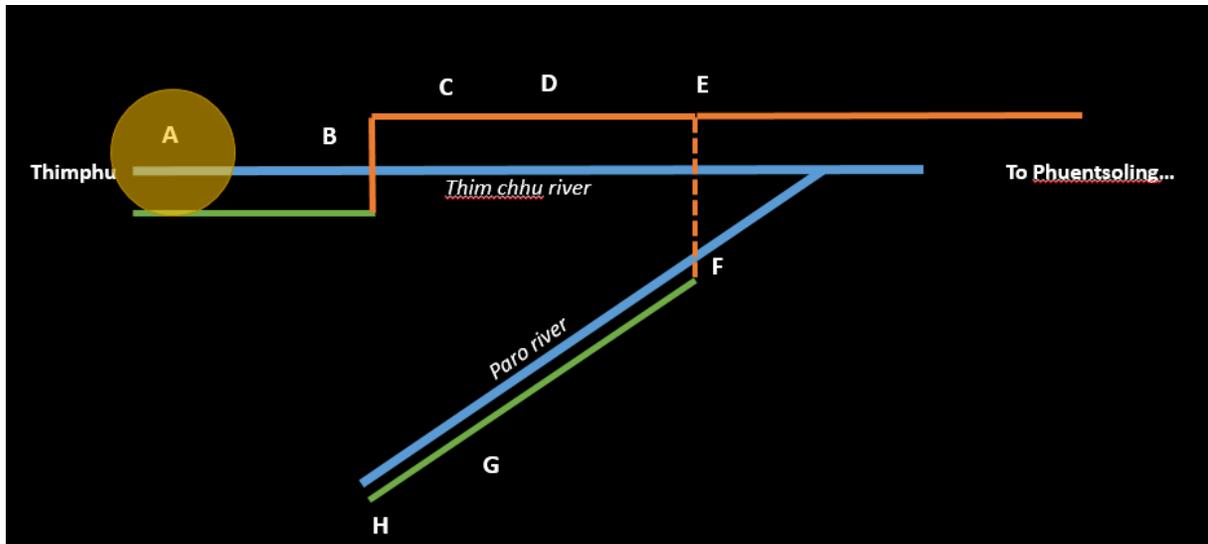
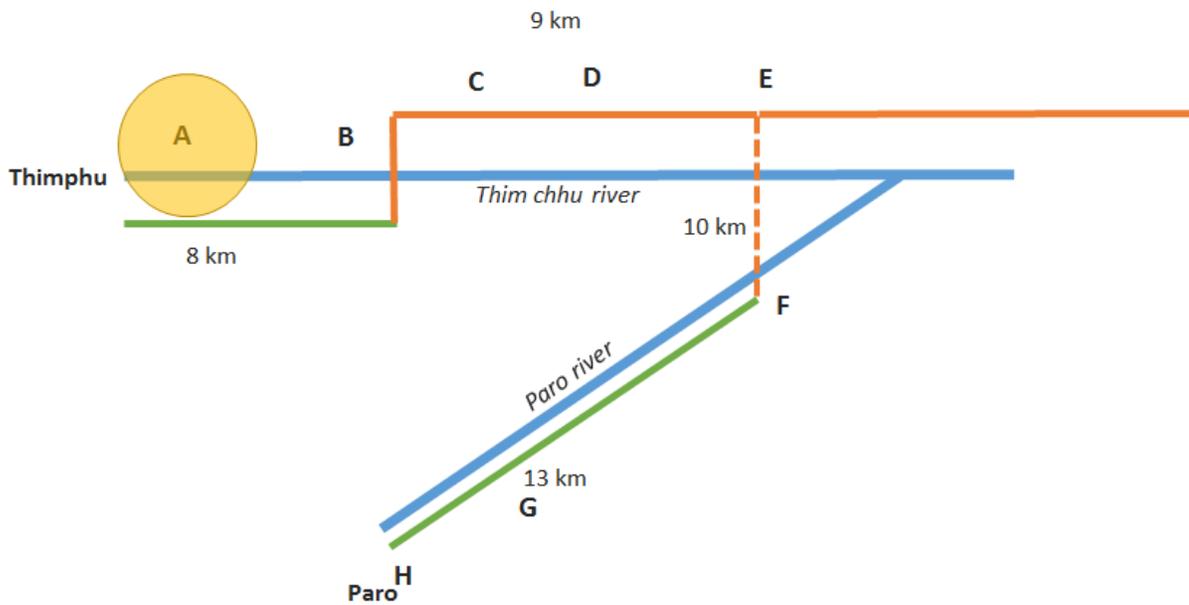


Figure 23: Schematic of Thimphu - Paro line

Zone A



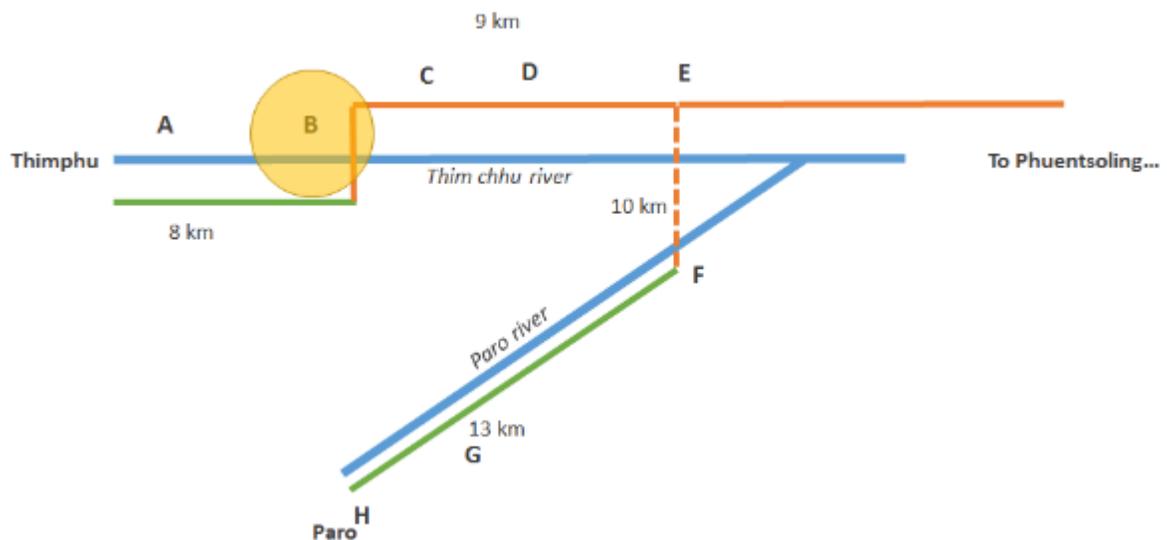
On this area, there is the possibility to have the line on the right side of the river heading towards Chuzom.

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Figure 24: Potential Route for Rail Near Thimphu

Zone B



In this area, the line must pass over the river to move to the other side of the valley, however, there are existing buildings and civil infrastructure that would need to be removed in order to make way for the new rail line.

There are two possibilities:

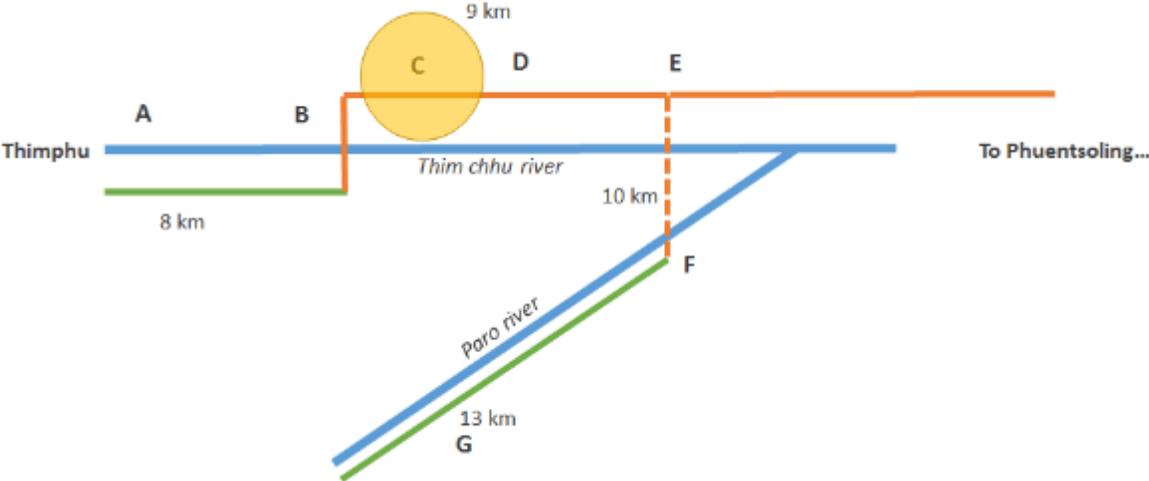
- First (yellow) is to pass over the river quickly to be on the left side of the valley.
- Second is to continue on the right side to pass over the river a bit further down.

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Figure 25: 2.8 km from Thimphu, changing over to the other side of the valley (first solution)

Zone C



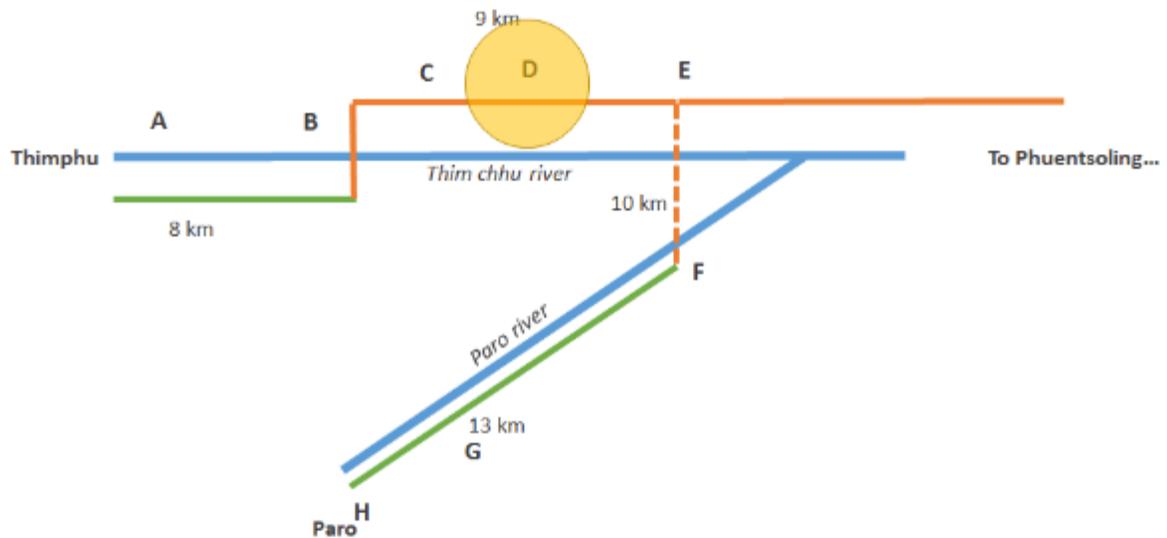
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On this part of the valley, due to the profile of the mountain, the line needs to be on the left side of the river.



Figure 26: Zone C

Zone D



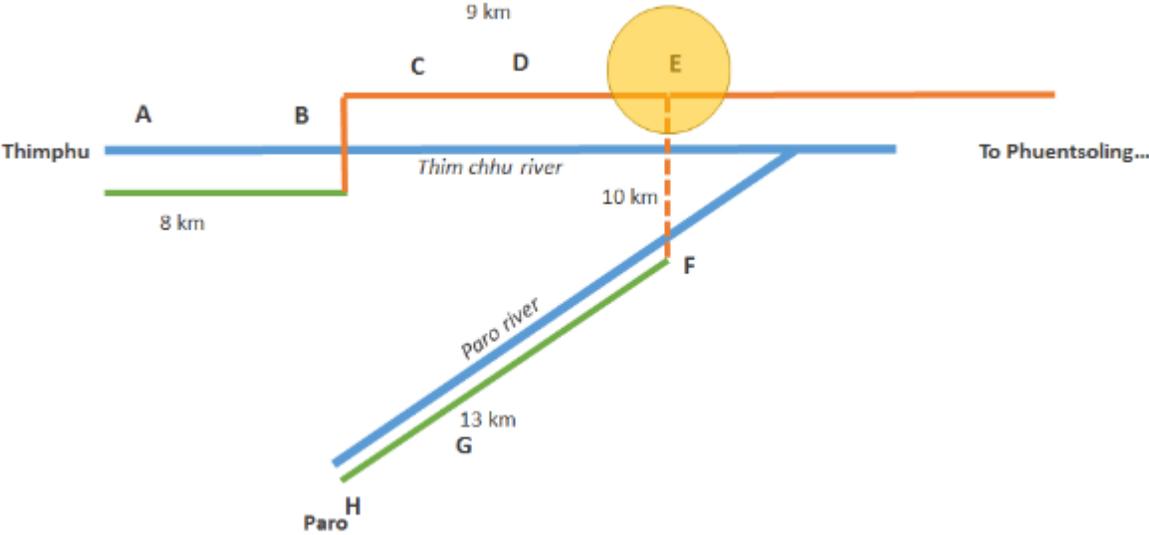
A tunnel is needed to avoid a high number of curves.

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Figure 27: Zone D

Zone E



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The junction point between heavy rail from Phuentsholing and light rail from Paro will be in this area.

A tunnel is needed from Paro.



Figure 28: Zone E

Zone 3: Chuzom to Paro

On this part of the line, there will be only light trains running. The structure of the track will be determined during the feasibility study. The proposal for the line could be as shown below (from Google Earth):

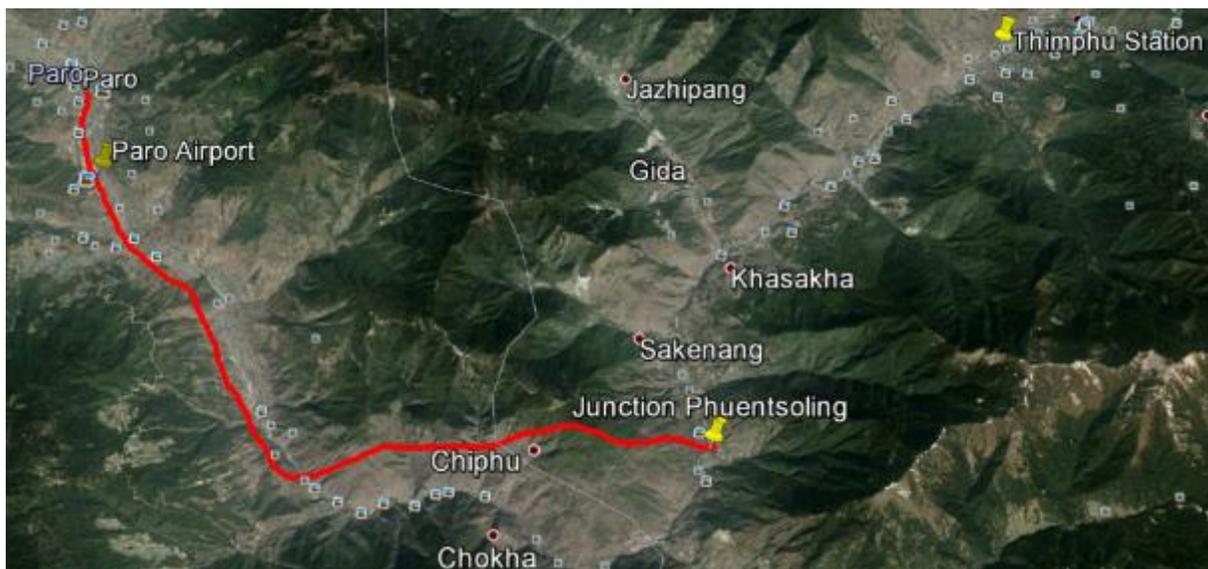


Figure 29:3 Line Paro - Thimphu

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The estimated line will begin in Paro city centre, then after serving the airport, will carry on along Paro River before joining the heavy line in Chuzom area. From Paro to the junction with the line coming from Phuentsholing, the estimated possibility for the line was done from the visit on the field and from Google Earth data. For this part of the line, the distance estimated is about 23 km, including 12 km of viaducts and tunnels, with a light gradient.

The visit on the field showed us that the first part of the line did not present any difficulty except to cross Paro River. There are several constraints and bottlenecks, as shown in the picture below, and a lot of curves in the final part which need a tunnel before connecting the two lines.



Figure 30: Example of Bottleneck on Paro – Thimphu line

From Paro to south of Thimphu, the estimated railway distance is 40 km. With the estimated distance and 90 km/h as a speed limit for passenger trains, the estimated travel time is about 30 min, including a margin due to the uncertainty of the profile. Regarding the time needed to serve Paro Airport, the travel time could be increased. The trains used for this travel continue their trip inside Thimphu. They will be integrated within Thimphu railway operations. From Thimphu to Paro, 2 loops are needed; one will be at the junction station and the second one will be in Paro Airport.

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Zone 4: Chuzom to Phuentsholing

From the junction to Phuentsholing, the line could be within the valley from the North to the South with a tunnel for the last section. The visit on the field was not done, and the estimation was done only from Google Earth. It is difficult to precisely know what are the main constraints and the main difficulties. At this stage, we are unable to determine where the viaducts and the tunnels will be. This part of the study needs to be done during the feasibility study. However, it is possible to show a first proposal for the line as below:

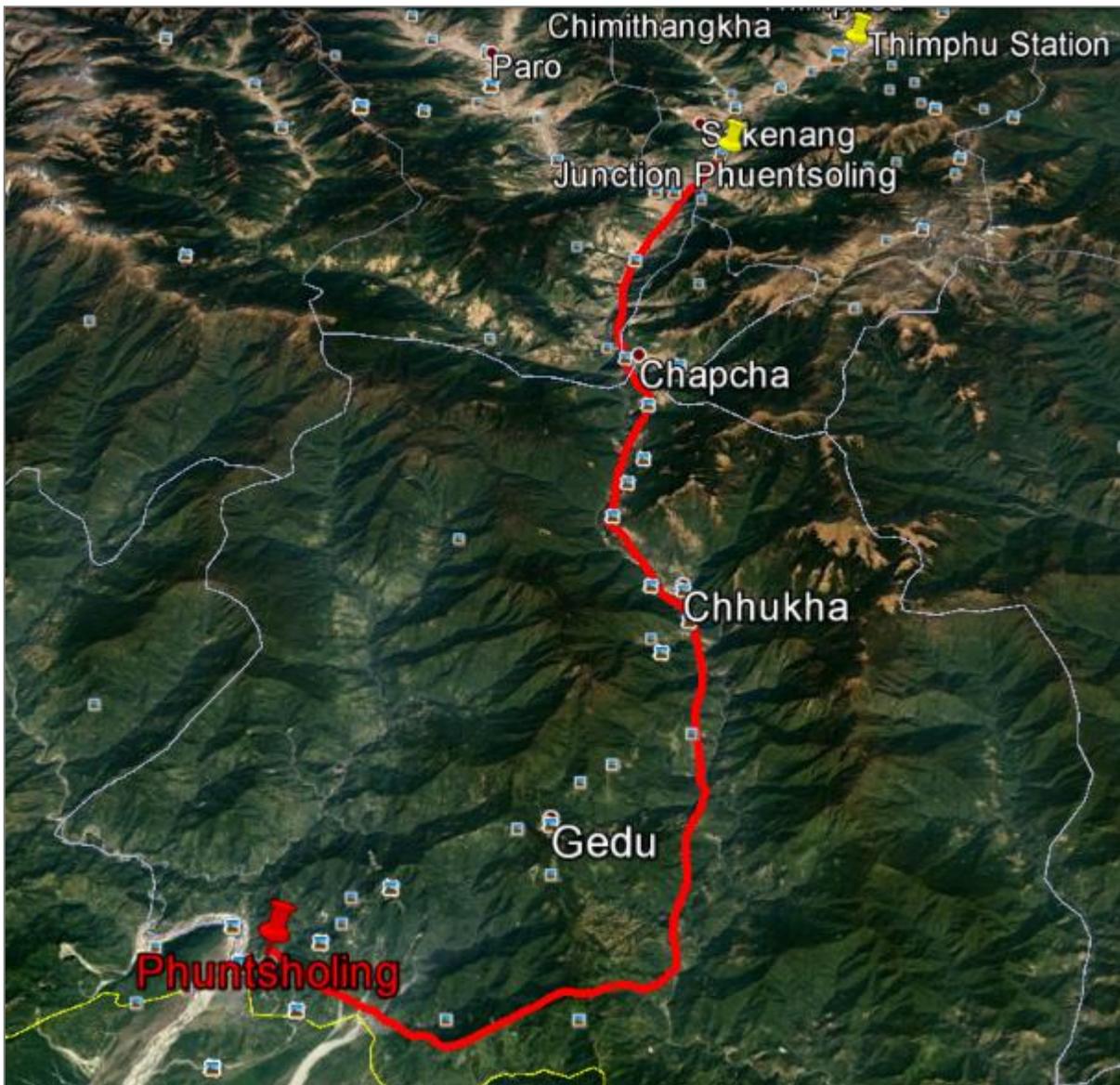


Figure 31:4 Line from junction to Phuentsholing

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From the junction to Phuentsholing, the estimated distance is 80 km; so the total estimated distance from Thimphu to Phuentsholing is less than 100 kilometres. With the estimated distance and 120 km/h as a speed limit for conventional passenger trains, the estimated travel time is 60 min including a margin due to the unknown part of the profile. For freight trains, assuming an average speed of about 60 km/h, the estimated travel time between Thimphu and Phuentsholing is about 2 hours.

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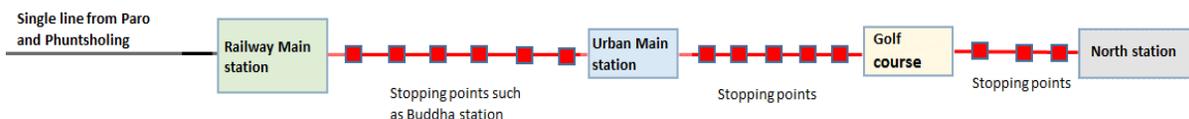
Proposed Passenger Service in Thimphu City

This proposal of service will have to be analysed with the results of a traffic forecast. These first assumptions were done from the first traffic analysis and from discussion with the ministry of transportation. The proposed services are summarized below:

Service	Quantity of trains (for each direction)
LRT within Thimphu	1 train every 10 minutes (on each line if two lines)
Tram-train Paro ↔ Thimphu north	1 train every 30 minutes
Train (passengers) Phuentsholing ↔ Thimphu south (Railway main station)	1 train every 4 hours depending on the traffic forecast (maybe more)

In this part of the report, the subject is the possible services inside Thimphu city. The schematic below does not show the tracks (single or double) but just the services of the trains.

Option 1: One line within Thimphu



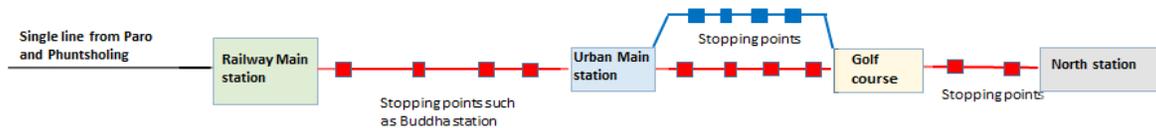
In this solution, operations are easy, even with a single track. Trains will intersect in Urban main stations, in Buddha station and in Golf course station. Another loop is needed between Urban main station and Golf course. There is a train every 10 min within the central zone of the network and trains coming from and going to Paro will be integrated in the service. This hypothesis is the hypothesis taken in account for all economic forecasts.

Option 2: Two lines within Thimphu

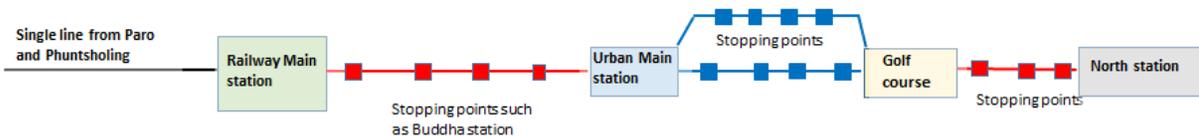
There are two lines inside the main part of the Thimphu Network:

- The red one is the main line from Railway main station to North station;
- The blue one is operated between Golf Course and Urban station with two meet points in those stations.

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For each line, there is one train every ten minutes and some trains are prolonged till Paro and/or North station.



There are two lines inside the main part of Thimphu Network and the blue one between Golf Course and Urban station is a circular line with two meet points in those stations where trains could turn back but could also be integrated within the main service.

Consideration of Types of Rolling Stock (Train Carriages)

Definition of Rolling Stock

We need to distinguish two main systems:

- 1) *A train of cars hauled by a locomotive:* In this system, there is one or more locomotives and multiple cars. With this system, the capacity of train can be easily changed, and it is also possible to change the locomotive (for example for border crossing) without the passengers changing cars (*“direct wagon”*). Operations are more complex at the “end” of the line, to allow the train to go back in the other direction;
 - Freight transportation always uses this type of system, often with more than one locomotive.

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Figure 32: Example of freight trains with multiple locomotives (Switzerland)



Figure 33: Example of passenger trains with locomotive

- 2) *A powered rail car train:* In this system, the capacity of the train is not easily changed (even if it is possible to do “multiple” trains). With this type of train, it is easier to change its direction.

Urban transportation is almost always done with powered rail car trains.

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Figure 34: Example of a powered double deck rail car train. This train can go in both directions without turning around (France)

Recommended Rolling Stock for Initial Zones

Zone 1: Thimpu City - Light Rail Rolling Stock (Tramways)

A lot of examples exist in the world already. Typically, it is a tramway:



Figure 35: Example of a tramway (Dijon, France). This train can go in both directions without having to turn around.

Zone 2: Thimphu to Chuzom – Heavy Rail Passenger and Freight Rolling Stock

See Zone 4.

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Zone 3: Chuzom to Paro – Light Rail Rolling Stock

This rolling stock will look like an urban tramway, with a greater number of seats.

Zone 4: Chuzom to Phuentsholing – Heavy Rail Passenger and Freight Rolling Stock

For this service, the passenger rolling stock could be composed of locomotives and passenger wagons. In this study, we will assume the cost for Indian locomotive WAP7. Its maximal speed is 140 km/h. Powered locomotive 25kV/50Hz. Cost is estimated (2014) at 130 million Indian rupees, around US\$2m/ per locomotive.



Figure 36: Example of In-Use Passenger locomotive (India)

Below is a picture of the interior of a passenger car from one Indian train, cost is around US\$200,000 per carriage.



Figure 37: Example of passenger configuration (India)

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Considering the rolling stock for freight trains a combination of locomotives and freight rolling stock would be used. This locomotive is one of the most used and most powerful freight locomotive of Indian railways. Powered by 25kV/50Hz, its power is around 4,500 kW. Its continuous tractive effort is 32.5 kN and maximum speed of 120 km/h.



Figure 38: WAG9 locomotive (IR)

Once the locomotive is selected there are numerous options for freight wagons as pictured below, including wagons that allow trucks to be loaded as previously presented:



Figure 39: Example of freight wagon (1/3) from IR

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Figure 40: Example of freight wagon (tank wagon) (2/3) from IR



Figure 41: Example of container wagon (tank wagon) (3/3) from IR



Figure 42: An image of the 'Roll-on Roll-off' train in India

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Consideration of Appropriate Track Gauge

The gauge is the distance between the inner face of the two rails as shown in Figure 43. This distance is not the same for each country and network. It is recommended that either the Standard Gauge of 1435 mm is selected or the Broad gauge of 1676 mm, which is used in India, Pakistan, and Bangladesh.

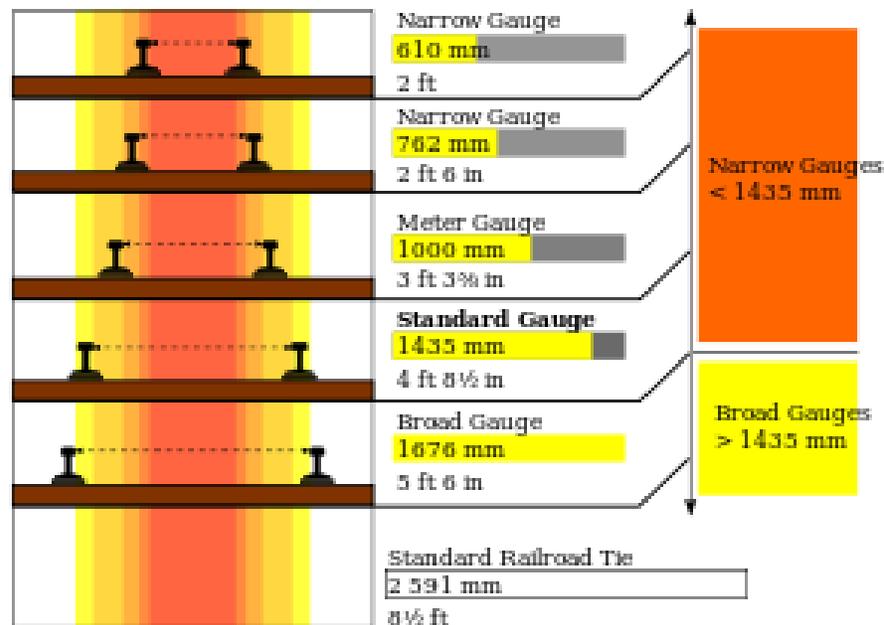


Figure 43: Examples of different categories of railway gauges

For the future railway network of Bhutan, the logical choice is between the Broad gauge used in India, which is 1676 mm, and the standard gauge used typically for light rail, which is 1475 mm. Considering these two gauges there are three potential options for the rail network in Bhutan:

1. **Broad Gauge Option:** All tracks are built using the Broad Gauge of 1676mm to allow seamless connection with the Indian rail network. However, should this be the solution for all rail in Bhutan it may be at a greater expense to have light rail rolling stock manufactured to run on Broad Gauge as this is not the preference.
2. **Standard Gauge Option:** All tracks are built with standard gauge. The main problem is to change the gauge of the rolling stock at the border in order to connect to the Indian rail network. Again this may come at a greater expense to either manufacture rolling stock that can change the gauge (see below), or change rolling stock at the interchange.

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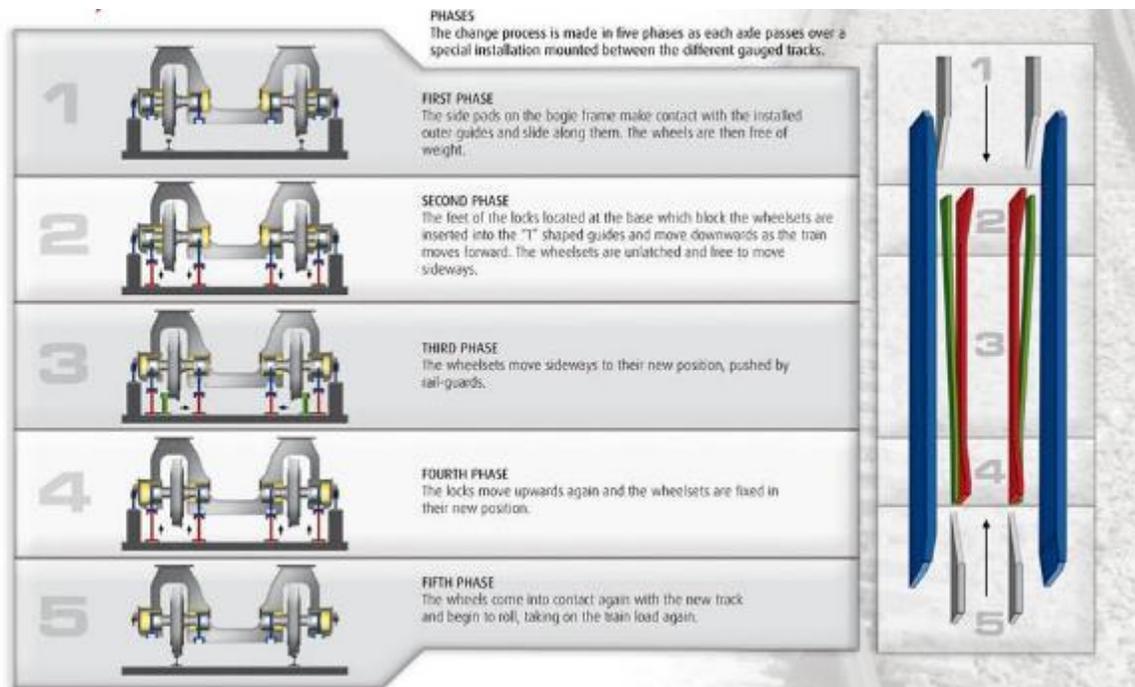


Figure 44: Talgo (change of gauge) process.

The Talgo system is used more for passenger trains than freight trains. With the Talgo system there is no possibility to have second-hand Indian material. Another possibility is to change the bogies of each wagons (passenger and/or freight wagons), as described below.



Figure 45: Bogie change station (Chop, Ukraine, between Russian gauge and standard gauge)

In such a system (used for both passengers and freight trains), each car can be changed in around 5 – 10 minutes.

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3. Hybrid Gauge Option: Given the limitations of the first two options it is proposed to implement a hybrid gauge option across the initial rail network that is capable of running both Broad and Standard Gauge rolling stock. As part of this option the follow track configuration would be adopted:
- a. Zone 1 – Thimphu City: Tracks inside Thimphu would be Standard Gauge for light rail rolling stock.
 - b. Zone 2 - Thimphu to Chuzom: Track from Thimphu to Chuzom would be both Standard and Broad Gauge.
 - c. Zone 3 – Chuzom to Paro: The track from Chuzom to Paro would be Standard Gauge for light rail (no freight or heavy passenger rolling stock)
 - d. Zone 4 - Chuzom to Phuentsholing: Track from Chuzom to Phuentsholing would be Broad Gauge.

Considering the Zone between Thimphu and Chuzom the rail configuration can be constructed to allow both gauges, as shown below.



Figure 46: Two-gauge railway (metric gauge and standard) in Jindřichův Hradec (Czech Republic)

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Considering Rail Gauge Connections

Between Thimphu Railway main station and the junction to Paro and Phuentsholing , there will be two connections for standard gauge and Indian gauge.

One is located at Station junction and the connection could be as below:

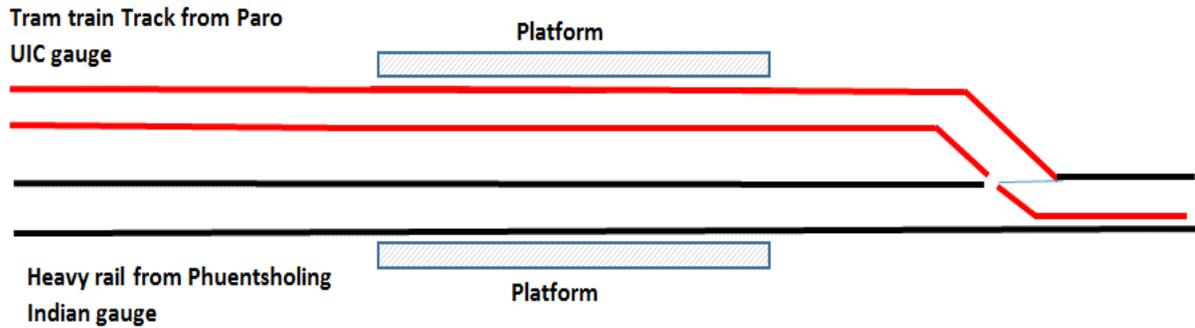


Figure 47: Example of connection between standard gauge and Indian gauge at Station junction (each track is presented with the two rails)

The other one is located at the Southern entrance of Thimphu railway main station:

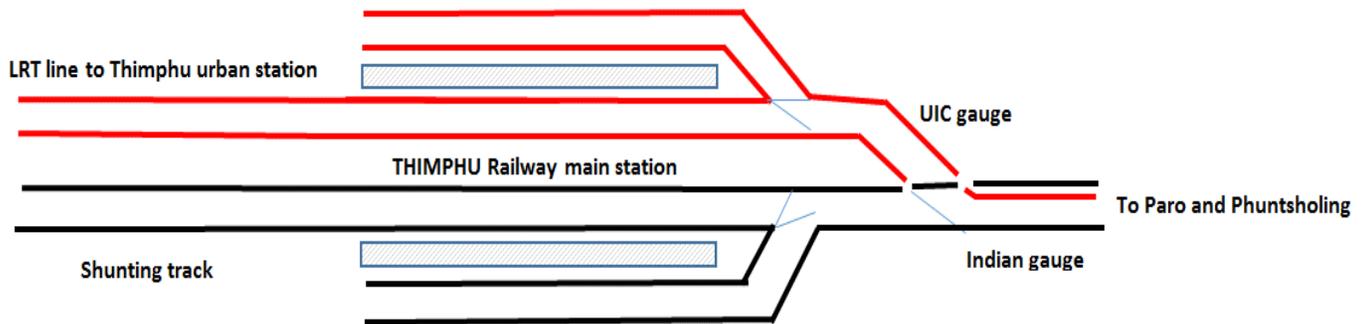


Figure 48: Example of connection between standard gauge and Indian gauge at Thimphu main station (each track is presented with the two rails)

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Consideration of Configuration of Railway Stations

Thimphu Railway Main Station

Within Thimphu railway main stations there will be six zones:

- 1) Two tracks and one platform for tram-trains coming from (and going to) Paro and Phuentsholing via Chuzom
- 2) Tracks for stabling and maintenance for tram-trains
- 3) Area for stabling and maintenance for passenger wagons with a track for shunting
- 4) Area for freight trains (unloading, loading and shunting)
- 5) Zone for a depot for the locomotives (maintenance.

An example of the possible configuration is shown below:

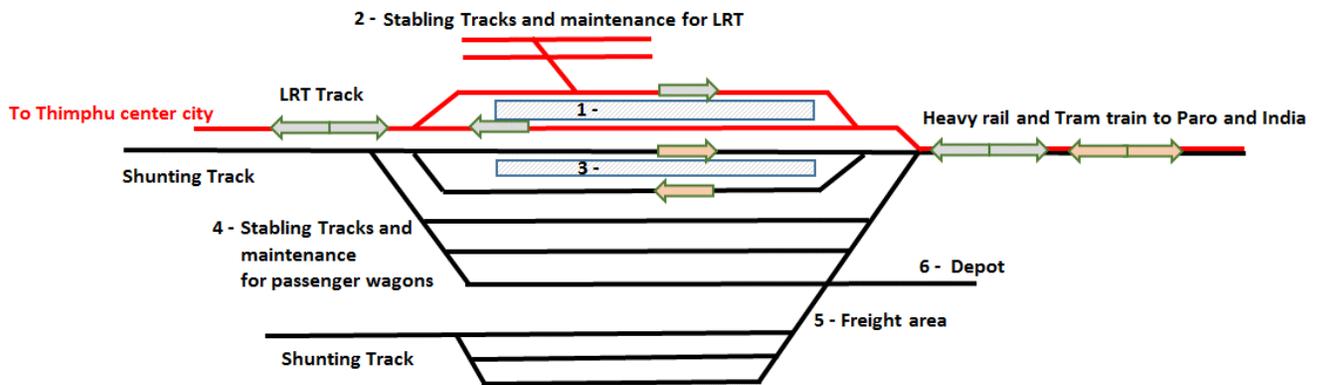


Figure 49: Example of configuration for Thimphu Railway Main Station

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Thimphu Urban Main Station

This station needs to allow trains to meet and pass. If there is a second LRT line within Thimphu network, the second track will be used for this optional line.

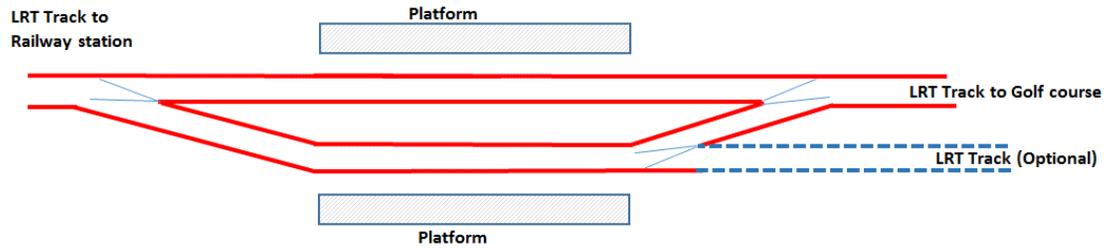
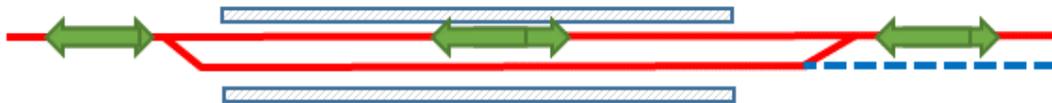
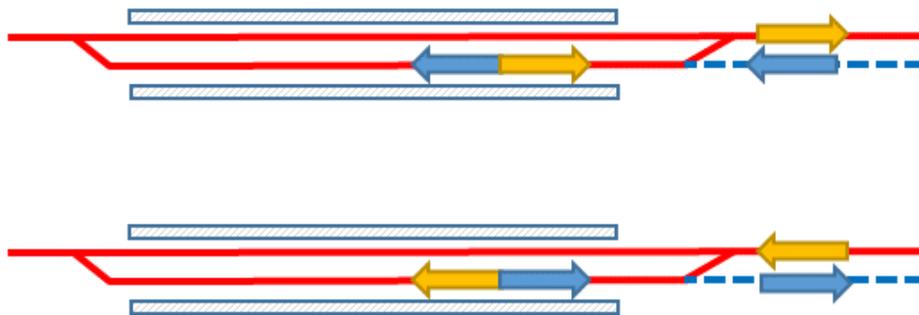


Figure 50: Example of configuration for Thimphu Urban Station (on this schematic, the track is presented with the two rails)

The different movements for LRT main service could be on the same track:



In the case of a circular line, trains coming from (or going to) the Golf course will turn back, as shown below:



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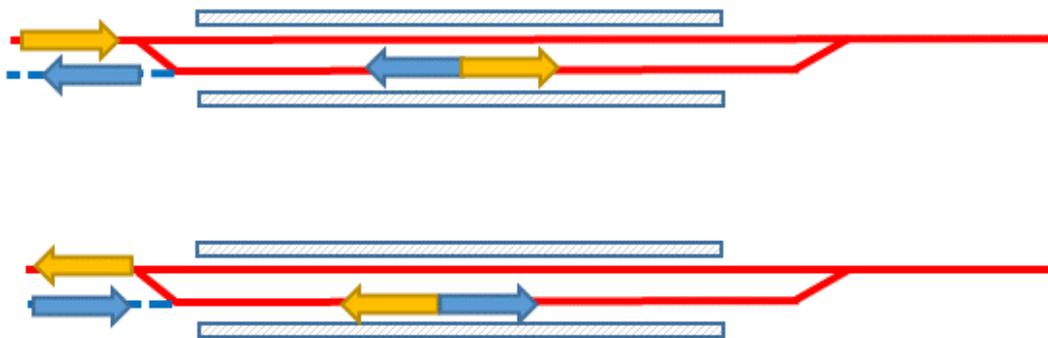
Thimphu Golf Course Station

This station needs to allow trains to meet and pass. If there is a second LRT line within the Thimphu network, the second track will be used for this optional line.



Figure 51: Example of configuration for Thimphu Golf Course Station

In the case of a circular line, trains coming from (or going to) Urban station will turn back as shown below:



North Station

For this station, it needs to have two tracks to allow trains to meet and pass.

The shunting track could be used to liberate the line along the platforms (especially in case of disruption).

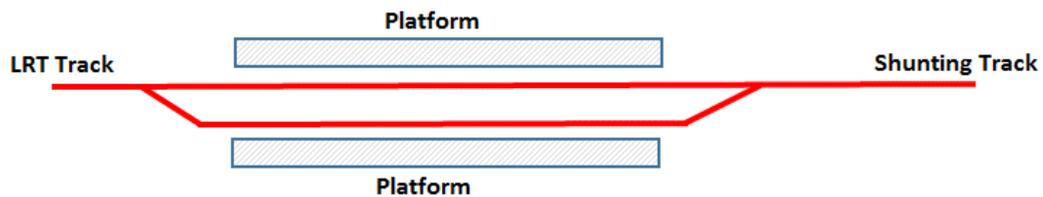


Figure 52: Example of configuration for the North Station

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Standard Stop within the City of Thimphu

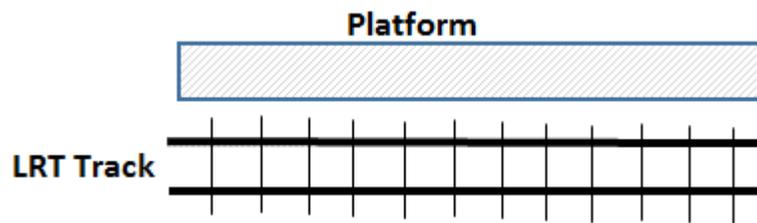


Figure 53: Type of station for standard stopping point

This type of station would allow inter-connection with a range of other transport options such as a Cable Car, Buses, Taxi...

Station for the Chuzom Junction

This station needs to have two tracks to allow tram-trains and heavy trains to meet and pass.

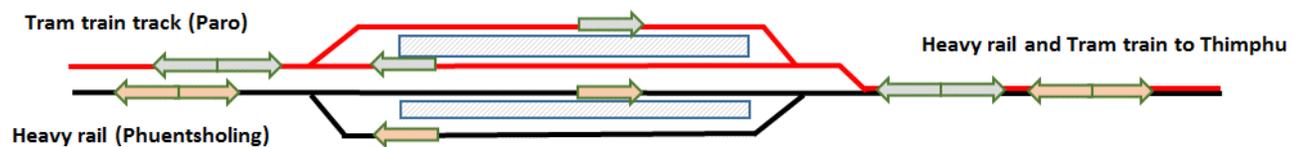


Figure 54: Example of configuration for a station at the junction to Paro and Phuentsholing

Paro City Station

This station needs to allow trains to meet and pass.

The shunting track could be used to liberate the line along the platforms (especially in case of disruption) or to be used for maintenance.

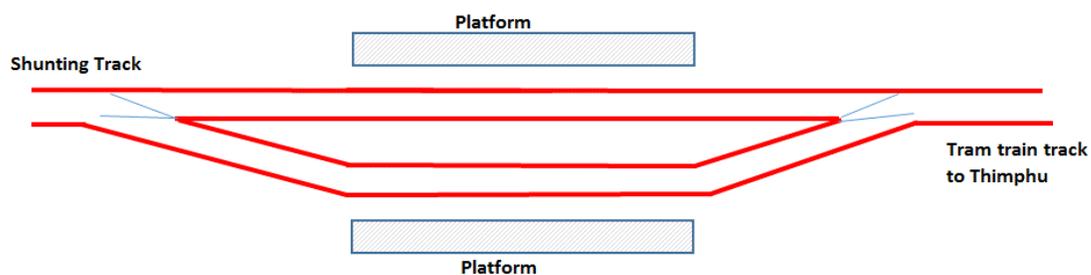


Figure 55: Example of configuration for Paro station

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In-line Stations

This type of station could be created for Paro Airport and for any other standard station (if any).

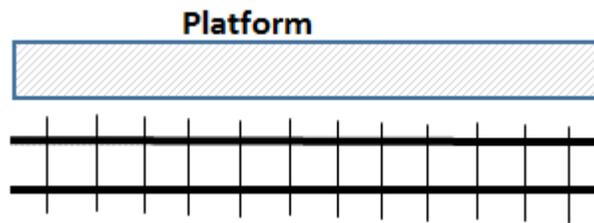


Figure 56: Example of configuration for standard station on line

If other stations are needed on the line for meets between Thimphu and Phuentsholing, the configuration could be as below:

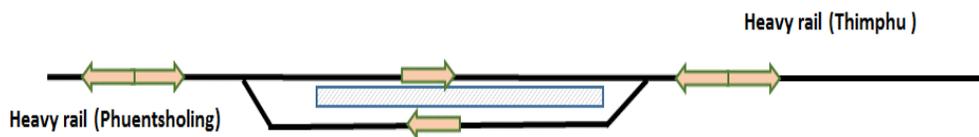


Figure 57: Example of configuration for meets on the line

Phuentsholing Station

This station needs to allow passenger trains to meet and pass. As a station located at the end of a line, facilities are required to perform light maintenance of the locomotives. The station needs to have tracks for freight.

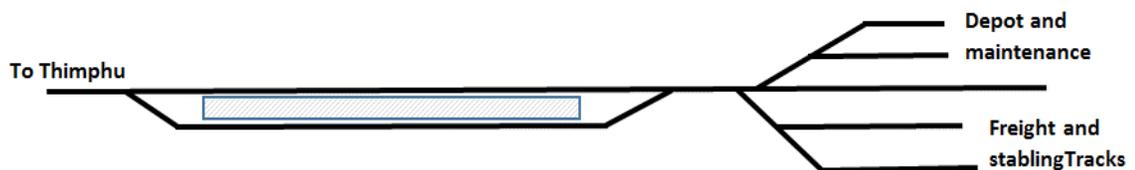


Figure 58: Example of configuration for Phuentsholing Station

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Consideration of Approach to Organisation of Rail Network

This part is about the final organisation of the railway system in Bhutan. We will discuss the organisation around public financing and some specifications will be added in the case of a Public-Private Partnership.

A railway in Bhutan should be structured with one public company, which will have the responsibility of:

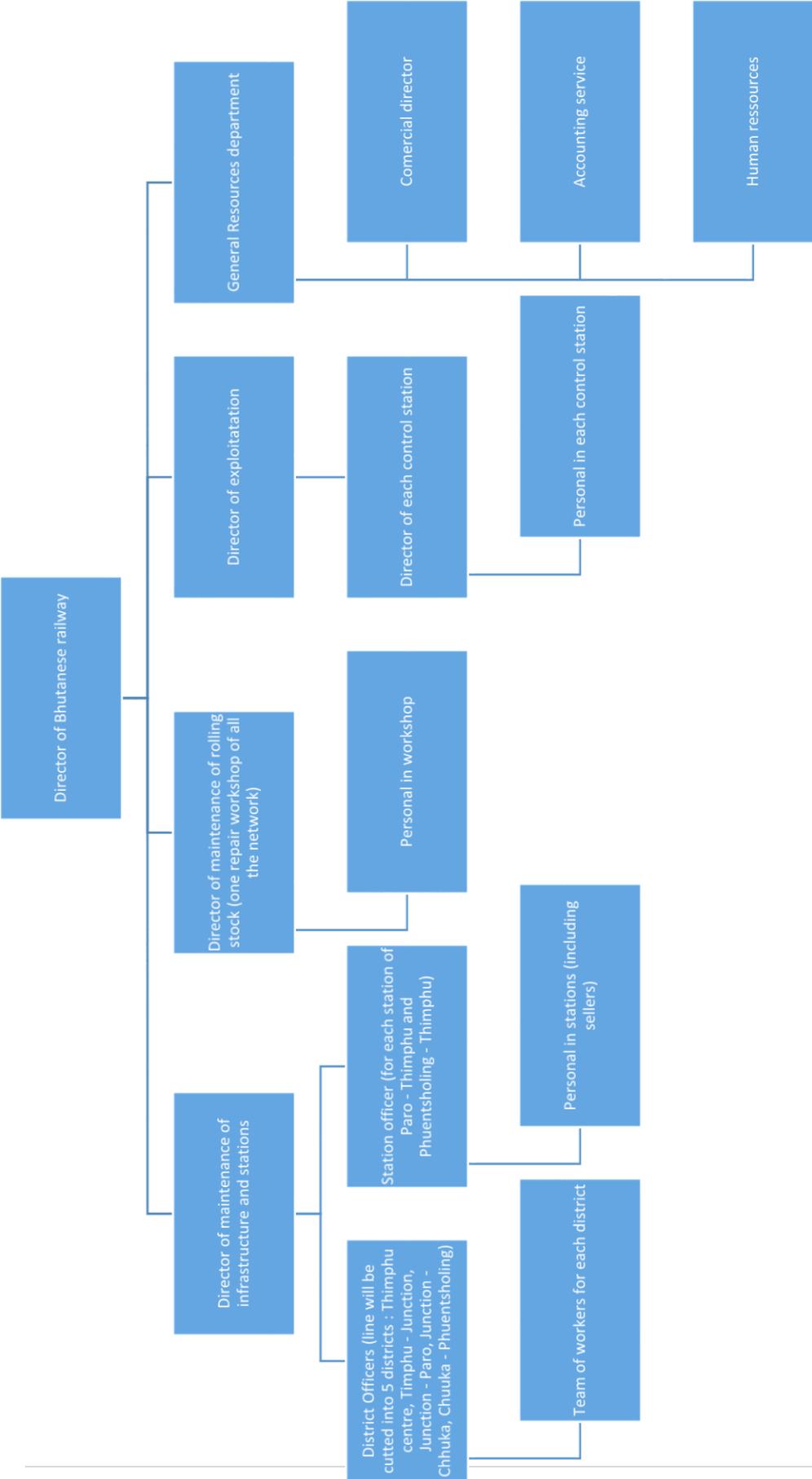
- Maintenance of the infrastructure;
- Exploitation of the trains;
- Stations management, selling of the tickets, and so on.

The head of the company should be represented by a director which will be responsible for the railway system which will be under the authority of the ministry of transportation. We assume the roles of:

- Director of maintenance of infrastructure and stations
- Director of maintenance of the rolling stock
- Director of exploitation
- General resources department

We assume the organizational chart below:

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Powered by 25kV/50Hz, its power is around 4,500 kW. Its continuous tractive effort is 32,500 N and maximum speed of 120 km/h.

In terms of geographical distribution, we assume:

- Personnel in the central office of Thimphu, which will centralize:
 - o Director of maintenance of infrastructure and stations
 - o Director of maintenance of the rolling stock
 - o Director of exploitation
 - o General resources department
- 4 control stations: Thimphu (in Thimphu main railway), Paro, Phuentsholing, Junction with director of each control station, and team of control station
- Personnel in the stations, including 4 main stations (Paro, Junction, Thimphu, Chhuka, Phuentsholing) and maintenance personnel.

The need for personnel is expressed below:

Drivers	50
Other personal on board	40
Personal on control centre (Thimphu)	5
Personal on main stations (Thimphu, Junction, Phuentsholing, Paro)	30
Personal for other stations (except previous one)	20
Personal in the workshop (rolling stock maintenance)	20
Personal in central office	20
Personal in districts (infrastructure maintenance)	50
TOTAL	Around 200 – 250 ppl

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Part 7: Preliminary Assessment of Economic Considerations

Overview of Findings

As part of the preliminary assessment of the economic considerations of providing a rail backbone for Bhutan, a review of other rail project infrastructure costs was carried out and presented in Table 6 below. Throughout this part it is assumed that the cost of tunnelling is 10 times more expensive than surface rail given normal topography and it is assumed that the average cost of track in easy topography is \$2m – \$4m per kilometre.²

Table 6: Summary of Construction Costs for Rail Projects for Comparison to Bhutan

LINE	Description	PRICE
Benin – Niger railway	Construction of new line (metric gauge / single track) between Parakou and Niamey for freight and passengers (and rehabilitation of line between Cotonou and Parakou). Very easy topography	200 million Euro for section from Cotonou – Parakou (upgrade) for 425 km 1 billion Euro for section from Parakou to Niamey for 670 km Price of new line: US\$1.5m/km
Qing – Zang line (China) for section between Golmud and Lhasa	Single track with standard gauge. Very difficult topography. Highest railway of the world with 7% of line in tunnels or bridges.	36,000 million Yuan for 1142 km (around US\$6 billion) Price of new line: \$5m/km
India (general source from ministry)	Description of one kilometre of normal railway compared to high speed railway (which is said 10 – 14 times higher)	Price of 10 Crore / km => \$1.4m/km
Cambodia – proposed line Poipet - Sisophon	Line in flat part (50km) for meter gauge	\$1.7m/km

² All the economic figures will be expressed in constant Ngultrum (BTN) of 2016. This means that the inflation is not taken into account. Values will sometimes be expressed in USD of 2016 (written \$). The exchange value is 65 BTN for 1 USD.

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Cambodia – proposed line bat Doeng - Kratie	Line in mainly flat part (258km) for meter gauge	\$2.7m/km
Lao – proposed line Boten - Vientiane	Very mountainous (417km) for standard gauge	\$17m/km
Vietnam – Dong Ha -Lao Bao	Some mountainous (82km)	\$7m/km

Using the findings in Table 7 as a comparison, a preliminary economic assessment was undertaken of the proposed option for the first stage of Bhutan’s rail network, incorporating findings from a site visit in collaboration with the UNCRD and the Royal Government of Bhutan, as shown in Table 7 and 8.

Table 7: Findings of Economic Assessment of Proposed Option for First stage of Bhutan’s Rail Network - Line outside of Thimphu

Section	Distance (km)	Cost (million USD)
Thimphu Rail Station – Chuzom	17 km of single track (including an estimated 9km of engineered structures)	200 - 400
Chuzom – Paro	23km of single track (12km of tunnel)	250 – 500
Chuzom – Phuentsholing	80km of single tracks (50km of tunnel)	1,100 – 2,100
	TOTAL	1,550 – 3,000

Table 8: Findings of Economic Assessment of Proposed Option for First stage of Bhutan’s Rail Network - Line inside

Section	Distance (km)	Cost (million USD)
Rail station – Urban station	5.3 (including 500m of viaduct)	20 – 40
Urban station – Golf Station (Branch 1)	2.0 (including 150m of viaduct)	7 – 14
Urban station – Golf Station (Branch 2)	2.0	7 – 14
Golf station – North station	1.25 (including 150m of viaduct)	5 - 10
Stations		10 – 20
TOTAL		50 - 100

The cost of tracks and buildings inside Thimphu is more complex to estimate. If we take intermediate cost, we assess around \$50m - \$100m for the project within Thimphu.

Total estimated cost for infrastructure is around USD\$1.6 – 3.1 billion.

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Assumptions Related to Fares and Travel Times

When considering passengers the follow fares are proposed:

Service	BUS FARE (One direction)	taxi FARE (One direction)	Proposed train fare (One direction)
Within Thimphu			20 BTN / any distance Monthly price of 600 BTN
Paro – Thimphu (any station)	55	200	140 (3 BTN / km)
Phuentsholing - Thimphu	240	680	400 (4 BTN / km)

Travel times are summarized below:

Service	BUS TIME	TAXI TIME	TRAIN TIME
LRT (North to South)	1h00	0h30	0h30
Tram-train Paro South – Thimphu	2 hours	1h00	0h30
Tram-train Paro North Thimphu	3 hours	1h30	1h00
Train (passengers) Phuentsholing - Thimphu	8 hours	5 hours	1h00

When considering freight the following fares are proposed. Travel time from the border to Thimphu is 8 – 10 hours by truck, which carries up to 20 tons. We don't have an estimation of the freight transport price for companies or individuals, but we can assume that the minimum price is the cost of salary, the cost of diesel, the cost of capital of trucks. If we suppose that one truck carries 20 tons each day from Phuentsholing to Thimphu or Thimphu to Phuentsholing, this truck carries 250 x 20 = 5000 tons each year. The cost is:

- Cost of driver: \$3 billion /year (yearly salary of \$2,000)
- Cost of diesel: \$10,000/year (assumption of \$0.9/litre and \$30litre/100 km)
- Cost of truck (capital, maintenance, etc.): \$4,000/year

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We assume a total cost of around \$20,000/year for 5000 tons. Cost for one ton from Phuentsholing to Thimphu will be around \$4/ton. For the railway, we shorten the distance and travel time. Fare by rail could be the same as fare by truck. Because the distance is 100km, we put a price of \$0.03/ton.km (25% lower than bus), so 2 BTN / ton.km

Assumptions around Traffic Volumes

During Commissioning

No traffic forecast is done in the pre-feasibility study. Computations below are done with assumptions of the number of passengers / train, and are compared to actual traffic:

Table 9: Traffic forecast at the beginning of the project

<i>All figures are for both directions</i>	Thimphu North - Paro	Thimphu South - Phuentsholing (passengers)	Thimphu - Phuentsholing (freight)	LRT Thimphu	Total
<i>Length of line (km)</i>	48	97	97	8,5	
<i>Travel time (hour)</i>	1	1	2	0,5	
Service	2 trains/hour/direction during peak hour	1 train/4 hours /direction	6 - 10 trains / day	6 trains / hour / direction	
Trains / day	40	6	6	190	242
Days / year	310	365	260	310	
Millions trains.km / year	0,6	0,2	0,2	0,5	1,5
Thousands of trains.h / year	12,4	2,2	3,1	29,5	47,2
Commercial speed (km/h)	48	97	49	17	211
Passengers (or tons) / train	75	200	500	100	875
Passengers (or tons) / day	3 000	1 200	3 000	19 000	26 200
<i>Actual passengers (or tons) / day</i>	6000 (2000 cars)	Unknown	2000 tons (100 trucks)	36000 by {taxi+bus}	
Millions of passengers (or ton) / year	0,9	0,4	0,8	5,9	8
Millions passengers.km (or ton.km) / year	45	42	76	25	188
Price - km (BTN)	3	4	2	5	
Revenues / year (millions of BTN)	133,9	169,9	151,3	125,2	580,3
Revenues / year (millions of USD)	2,2	2,8	2,5	2,1	9,7

For the Thimphu – Paro line, we forecast around 3000 passengers / day. It is around 50% of actual traffic (estimated to 2000 cars, so around 6000 passengers). The decrease of travel time and the attractive price will easily create such traffic.

For the Thimphu – Phuentsholing line, we don't have actual figures of travel demand. But, we saw the high quantity of buses each day, and also some cars on the road. Moreover, we think that development of a direct line to India will increase the quantity of traffic. For the freight on Thimphu – Phuentsholing, we have around 2000 tons / day by road. We suppose that all the traffic will go to rail, especially because of cheaper price, and dramatic decrease of travel time. For the LRT inside Thimphu, it is interesting to compare this figure of 20,000 passengers / day with population of Thimphu (around 100 000, meaning that just 10% of people will use two times the tramway each

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day). If we compare with the traffic forecast of tramways in Europe, this figure is conservative, and real traffic will be higher.

To summarize, we forecast, for the first year of the project, around 7 million passengers (including 5.9 millions of passengers on LRT) using the future rail system in Bhutan, and around 1 million tons of freight. It will be around 110 million of passengers/km each year, and around 75 million of ton/km each year on the future network. Revenues from traffic will be around 10M\$ / year, with more than 50% coming from Phuentsholing – Thimphu line.

During the Life of the Project

The traffic will increase over the years. Growth of traffic is correlated with growth of GDP. If we look at the growth of GDP of Bhutan since 1980 (see diagram below), a growth rate of 4% can be forecasted for the next 50 years.

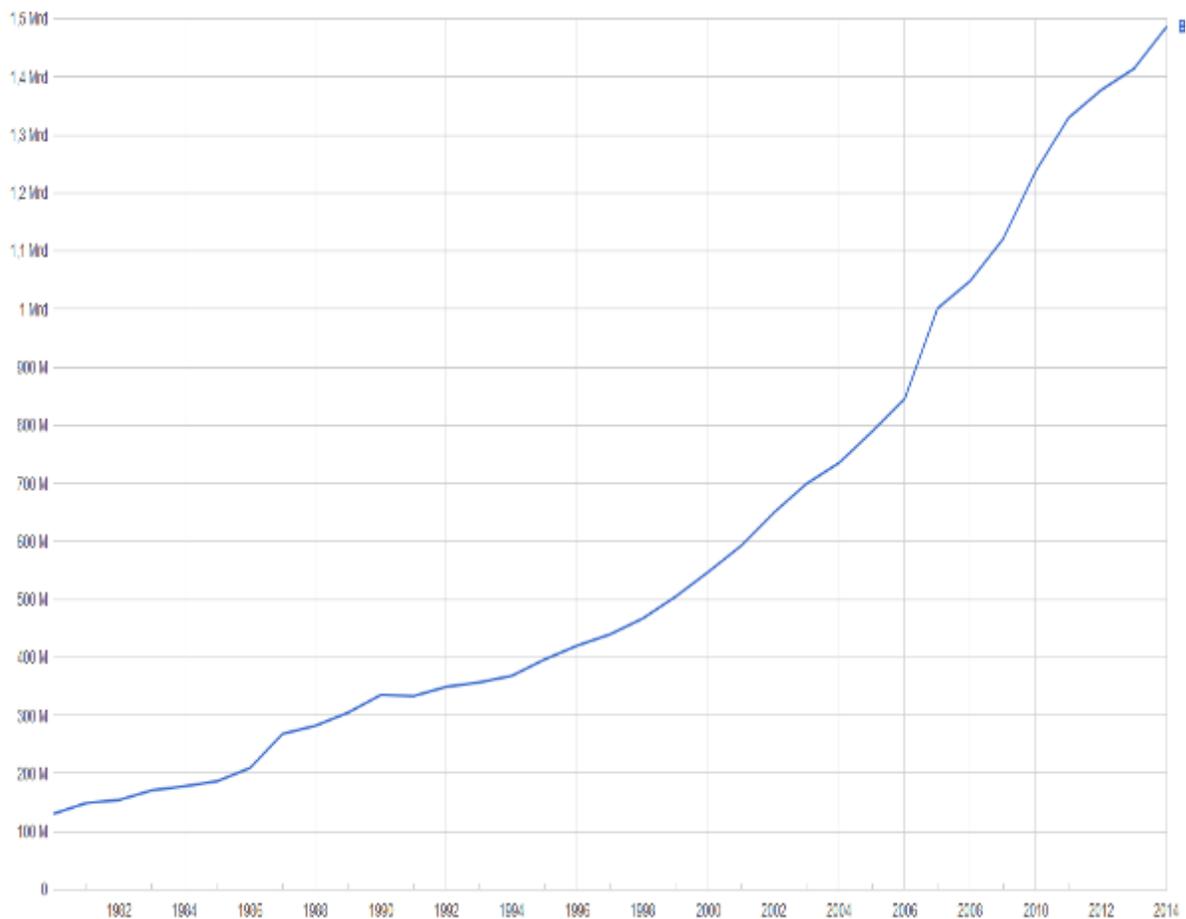


Figure 59: GDP of Bhutan (in US\$ of 2000). M = million, Mrd = billion

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If economic growth of 4% is forecast, the traffic will be multiplied by 7 in 50 years. If growth of 2% is forecast, the traffic will be multiplied by 2.7 in 50 years.

Table 10: Growth of traffic, 50 years after beginning of project

	hypothesis of 4% of growth	hypothesis of 2% of growth
Traffic at the beginning of the project (travellers.km + tons.km)	200	
Revenues from traffic at the beginning of the project (M\$ 2016)	10	
Traffic 50 years after the beginning of the project (travellers.km + tons.km)	1300	500
Revenues from traffic 50 years after the beginning of the project (M\$ 2016)	70	25

Growth of traffic is also summarized in the graph below:

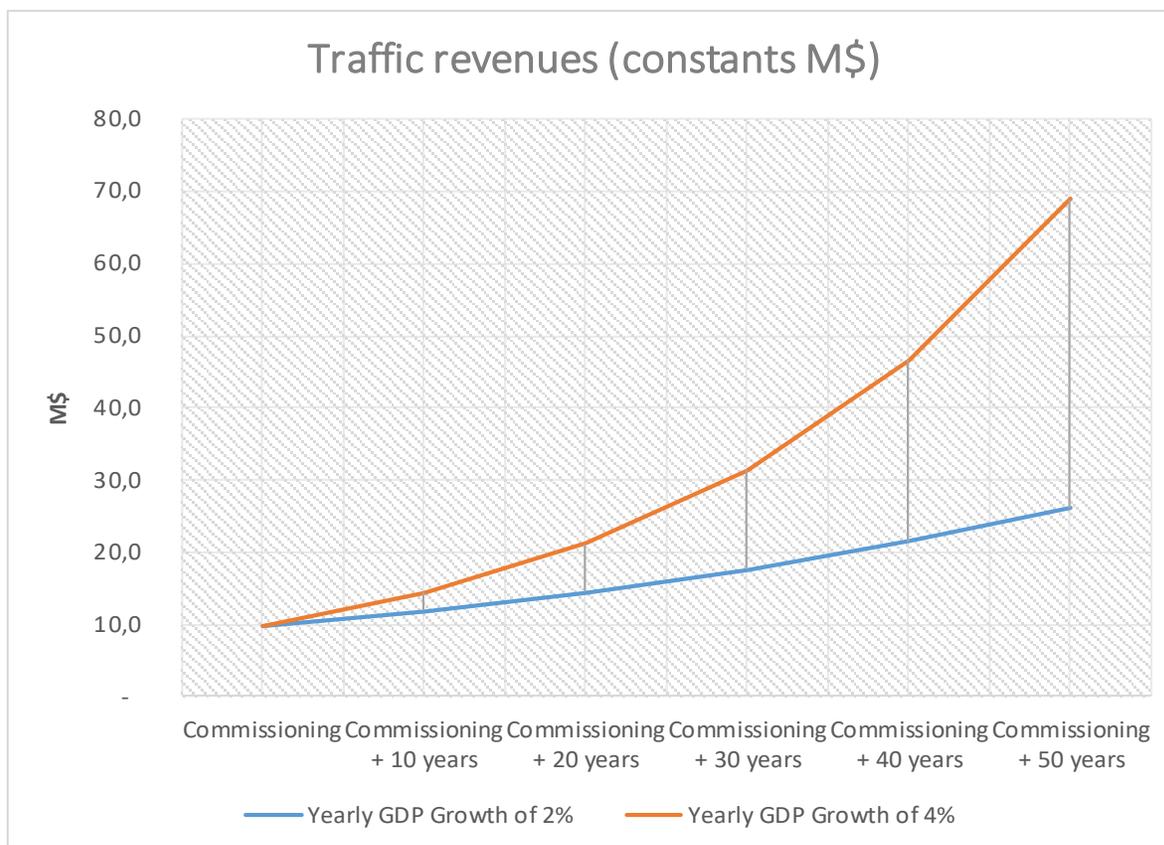


Figure 60: Projected growth of revenues

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Assumptions around Quantity of Trains

The technical pre-feasibility study provides a number of trains necessary to perform the services. This calculation is just a first approach. The rolling stock needed will be determine in the feasibility study.

- Zone 1 - Thimphu City: The calculation of the number of rolling stock needed for Thimphu city is done with the hypothesis of service listed below. With headway (spacing between two trains) of 10 min, 10 trains are needed including the reserve for maintenance.
- Zones 2 and 4 – Thimphu to Phuentsholing: The calculation of the number of rolling stock needed for Thimphu to Phuentsholing (and reverse) is done with a hypothesis of a passenger train every 4 hours and 60 min of travel time and 30 min for turning back in each station at the end of the line, 2 trains are needed including a reserve for maintenance. Regarding freight trains, we consider 2 locomotives and 100 wagons.
- Zone 2 and 3 – Chuzom to Paro: The calculation of the number of rolling stock needed for Thimphu to Paro (and reverse) is done with a passenger train every hour and 30 min of travel time on line and 30 min more for the travel through Thimphu city and 30 min more for turning back in each station at the end of the line, 4 trains are needed including a reserve for maintenance.

Assumptions around Rolling Stock Investment

Compared to infrastructure cost, rolling stock cost is more difficult to estimate. Some figures are given below, but cost of rolling stock is difficult to compare because price mainly depends on the quantity ordered.

Country	ROLLING STOCK (and price)
France	Train of 50 – 100 seats (X73500, smallest passenger trains): 5M\$ Freight locomotive: \$3m Wagon for freight: \$100,000 - \$200,000
India	Freight locomotive: \$2m Wagon for freight: \$50,000 – \$100,000
Germany,	Siemens LRT (S200) : \$3-4m/unit

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Regarding the costs listed in the paragraphs before, the investment cost for rolling stock is assessed at 3M\$ for each unit of LRT and 5 M\$ for each unit of passenger trains and freight trains.

Service	QUANTITY OF TRAINS	UNIT PRICE (M\$)	TOTAL (M\$)
LRT	10	3	30
Tram – train Paro Thimphu	4	3	12
Train (passengers) Phuentsholing - Thimphu	2	5	10
Train (freight) Phuentsholing - Thimphu	2	4	8
TOTAL	18		50 - 75

Estimation for rolling stock investment is around \$50 – 75 million USD.

Assumptions around Operating Cost

Operating cost for rail companies are:

- Staff costs:
 - o Drivers
 - o Other staff in the trains
 - o Staff in the stations
- Energy cost (electricity)
- Rolling stock costs:
 - o Capital cost
 - o Maintenance cost

Operating cost for infrastructure managers are:

- Staff costs:
 - o Staff for operation of train
 - o Staff for railway maintenance
- Rail components

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The following costs relate to the operation of the rail network.

Staff Cost

We assume a monthly net salary of \$250 (15 000 Ngultrum) for all members of staff. We suppose that the cost will be 1.5 times the monthly net salary.

Type	quantity of ppl
Drivers	50
Other staff in the trains	30
Staff in the stations	30

Energy Cost

After basic computations, we assume energy use of 5 kWh per train/km for passengers and freight trains. We suppose a cost of energy of \$0.05/kWh

Rolling Stock Cost

We assume that the expected lifetime of the rolling stock is 40 years. We assume that the rail company will borrow capital with interest of 5%. This means that for a rolling stock of \$50m, the yearly cost will be around \$3m

Rolling Stock Maintenance

We assume a rolling stock maintenance cost of \$1/ train/km

The following costs relate to the management of the rail network infrastructure:

We assume a cost of \$2/train/km

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Financial Balance of Rail System

During Commissioning

Table 11: P&L without capital cost of rolling stock

<i>All figures are for both directions</i>	Thimphu North - Paro	Thimphu South - Phuentsoing (passengers)	Thimphu - Phuentsoing (freight)	LRT Thimphu	Total
<i>Length of line (km)</i>	48	97	97	8,5	
<i>Travel time (hour)</i>	1	1	2	0,5	
Service	2 trains/hour/direction during peak hour	1 train/4 hours /direction	6 - 10 trains / day	6 trains / hour / direction	
Trains / day	40	6	6	190	242
Days / year	310	365	260	310	
Millions trains.km / year	0,6	0,2	0,2	0,5	1,5
Thousands of trains.h / year	12,4	2,2	3,1	29,5	47,2
Commercial speed (km/h)	48	97	49	17	211
Passengers (or tons) / train	75	200	500	100	
Passengers (or tons) / day	3 000	1 200	3 000	19 000	26 200
<i>Actual passengers (or tons) / day</i>	<i>6000 (2000 cars)</i>	<i>Unknown</i>	<i>2000 tons (100 trucks)</i>	<i>36000 by (taxi+bus)</i>	
Millions of passengers (or ton) / year	0,9	0,4	0,8	5,9	8
Millions passengers.km (or ton.km) / year	45	42	76	25	188
Price - km (BTN)	3	4	2	5	
Revenues / year (millions of BTN)	133,9	169,9	151,3	125,2	580,3
Revenues / year (millions of USD)	2,2	2,8	2,5	2,1	9,7
Drivers	10	4	8	30	52
Other personal in the trains	20	8	10	0	38
Cost for 1 member of staff (USD / year)	3000	3000	3000	3000	
Cost of personal / year (millions of USD)	0,1	0,0	0,1	0,1	0,3
Quantity of energy / year (millions of kW.h)	3,0	1,1	1,5	2,5	8,1
Prix kWh (\$)	0,1	0,1	0,1	0,1	
Cost of energy / year (millions of USD)	0,1	0,1	0,1	0,1	0,4
Maintenance cost / year (millions of USD)	0,6	0,2	0,2	0,5	1,5
Staff in the stations + ticketign system (millions of USD)	0,2	0,2		0,0	0,5
Overhead costs (millions of USD)	0,2	0,1	0,1	0,1	0,5
Total cost / year (millions of USD)	1,3	0,6	0,3	0,9	3,1
Operational Margin without track cost & Capital costs	1,0	2,2	2,2	1,2	6,6
Operational Margin without track cost & Capital costs	43%	78%	87%	58%	68%
Total "track" cost / year (millions of USD)	1,2	0,4	0,3	1,0	2,9
Operational Margin without Capital costs / year	-0,2	1,8	1,9	0,2	3,6

The P&L presented before is without any investment. It is considered that the rail operator has to give back the money used for rolling stock investment. Note that If it is supposed \$50m of rolling stock cost, yearly cost is around \$3m. With benefit of around \$3.6m each year, profit including capital cost of rolling stock is around \$0.6m for around \$10m of turnover (6-7% of margin).

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Table 12: P&L with capital cost of rolling stock

<i>All figures are for both directions</i>	Thimphu North - Paro	Thimphu South - Phuentsoling (passengers)	Thimphu - Phuentsoling (freight)	LRT Thimphu	Total
<i>Length of line (km)</i>	48	97	97	8,5	
<i>Travel time (hour)</i>	1	1	2	0,5	
Service	2 trains/hour/direction during peak hour	1 train/4 hours /direction	6 - 10 trains / day	6 trains / hour / direction	
Trains / day	40	6	6	190	242
Days / year	310	365	260	310	
Millions trains.km / year	0,6	0,2	0,2	0,5	1,5
Thousands of trains.h / year	12,4	2,2	3,1	29,5	47,2
Commercial speed (km/h)	48	97	49	17	211
Passengers (or tons) / train	75	200	500	100	
Passengers (or tons) / day	3 000	1 200	3 000	19 000	26 200
<i>Actual passengers (or tons) / day</i>	<i>6000 (2000 cars)</i>	<i>Unknown</i>	<i>2000 tons (100 trucks)</i>	<i>36000 by (taxi+bus)</i>	
Millions of passengers (or ton) / year	0,9	0,4	0,8	5,9	8
Millions passengers.km (or ton.km) / year	45	42	76	25	188
Price - km (BTN)	3	4	2	5	
Revenues / year (millions of BTN)	133,9	169,9	151,3	125,2	580,3
Revenues / year (millions of USD)	2,2	2,8	2,5	2,1	9,7
Drivers	10	4	8	30	52
Other personal in the trains	20	8	10	0	38
Cost for 1 member of staff (USD / year)	3000	3000	3000	3000	
Cost of personal / year (millions of USD)	0,1	0,0	0,1	0,1	0,3
Quantity of energy / year (millions of kW.h)	3,0	1,1	1,5	2,5	8,1
Prix kWh (\$)	0,1	0,1	0,1	0,1	
Cost of energy / year (millions of USD)	0,1	0,1	0,1	0,1	0,4
Maintenance cost / year (millions of USD)	0,6	0,2	0,2	0,5	1,5
Staff in the stations + ticketign system (millions of USD)	0,2	0,2		0,0	0,5
Overhead costs (millions of USD)	0,2	0,1	0,1	0,1	0,5
Total cost / year (millions of USD)	1,3	0,6	0,3	0,9	3,1
Operational Margin without track cost & Capital costs	1,0	2,2	2,2	1,2	6,6
Operational Margin without track cost & Capital costs	43%	78%	87%	58%	68%
Total "track" cost / year (millions of USD)	1,2	0,4	0,3	1,0	2,9
Operational Margin without Capital costs / year	-0,2	1,8	1,9	0,2	3,6
Rolling stock capital Cost / year	0,7	0,3	0,3	1,7	3,0
Operational Margin / year	-0,9	1,5	1,6	-1,4	0,7
(%)	-40%	51%	62%	-69%	7%

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During the Life of the Project

Regarding the growth of cost, one assessment has been done about the efficiency of the operator, surmising that it will increase and trains will be more loaded. Fifty years after commissioning, it is supposed that the load will be two times higher.

Table 13: P&L at commissioning and 50 years after

		Yearly GDP Growth of 2%	Yearly GDP Growth of 4%
Commissioning	Millions trains.km / year	1,5	
	Millions passengers.km (or ton.km) / year	187,8	
	Revenues / year (millions of USD)	9,7	
	Total operation cost / year (millions of USD)	3,1	
	Track costs / year	2,9	
	Capital cost for rolling stock / year	3,0	
	Operational Margin / year (%)	7%	
Commissioning + 50 years	Millions trains.km / year	2,7	5,9
	Millions passengers.km (or ton.km) / year	505,5	1 334,8
	Revenues / year (millions of USD)	26,0	68,7
	Total operation cost / year (millions of USD)	5,7	12,6
	Track costs / year	5,4	11,8
	Capital cost for rolling stock / year	5,5	12,0
	Operational Margin / year (%)	36,2%	46,9%

The growth of benefit is illustrated below:

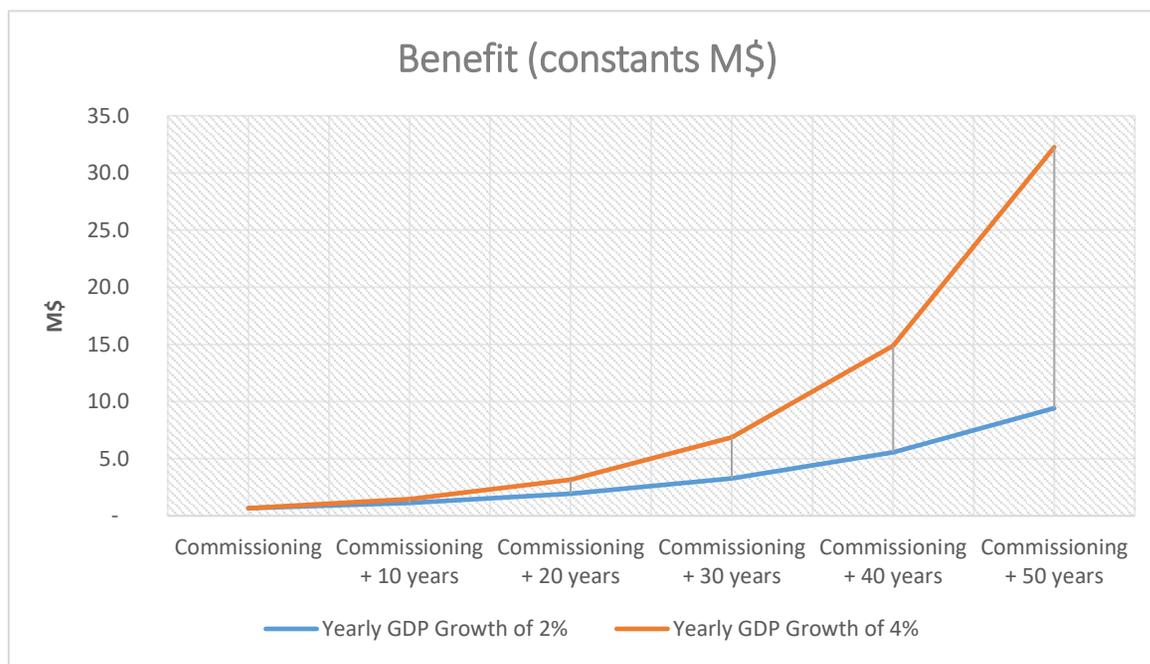


Figure 61: Projected growth of the benefit

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Assumptions around Socio-Economic Considerations

A complete socio-economic study will be done in the feasibility study. In this pre-feasibility study, we give some elements about socio-economic benefits of the project. We discuss what is a socio-economic study in the paragraphs below.

Without specific norm, we will suppose:

- *Socio-economic value of life*: The socio-economic value of life is correlated to GDP. Regarding GDP and European value of life, we obtain a value of life of \$500 000 (and \$200 000 for injured people)
- *Time Savings*: Regarding GDP and European values of time, we obtain the value of time of \$2 / hour.

Public transport market share is 25% in Thimphu and along the corridors. We summarize the most important socio-economics benefits for the first year of operation in the following:

1. *Safety*: In 2015, statistics give figures of 99 people dead and 373 injured (source Road Safety and Transport Authority / Ministry of Information and Communication). If we suppose market share of 25% with public transport, we obtain a reduction of 25 dead and around 90 injured. Thus, regarding safety, we estimate savings of \$35M / year. Detail of the computation is done below:

	Safety		
	Number of People	Price of Human life	USD millions
No. Deceased	25	0.5	12.5
No. Injured	90	0.25	22.5
Total			35

2. *Pollution*: We estimate the number of people who have died due to air pollution each a year. If we consider European statistics, we see that number of people dead by road fatalities are the same as people who have died by pollution from the road. So, we can consider that it could be the same for Bhutan.

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We obtain a reduction of 25 dead and around 90 injured, so around \$35M / year.

3. *Time savings*: We suppose that passengers of Thimphu will gain 10 min, passengers on Paro – Thimphu will gain 30 minutes and passengers on Phuentsholing – Thimphu will gain 4 hours. Time savings will be around 3 million hours. We obtain around \$7m/year. Explanation of the computation is below:

	Time savings			
	Time saving per trip	Millions of Travelers	Millions of hours	Millions of \$
LRT	0.2	5.9	1.0	2.0
Line to Paro	0.5	0.9	0.5	0.9
Main line	4.0	0.4	1.8	3.5
Total		7.3	3.2	6.4

The minimum socio-economic benefits are around \$80 million/year for the first year of operation.

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Considering a 50 year timeframe the socio-economics benefits will continue to expand. Growth of the socio-economics benefits is illustrated below:

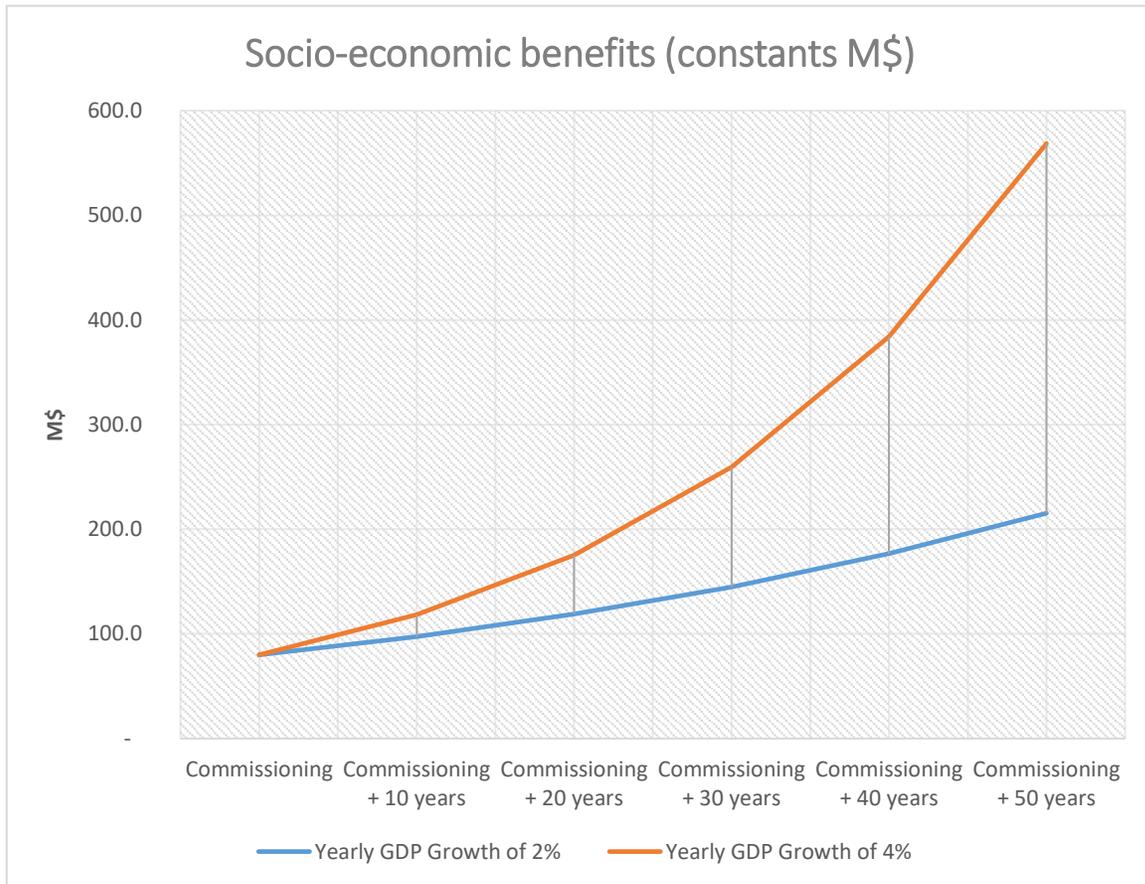


Figure 62: Complete socio-economic results

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Appendix A: Understanding a Rail Based Transport System in Bhutan

Overview

The current transportation system in Bhutan is not sustainable:

- With almost 99 people dead and 373 injured in 2015 (*source: Road Safety and Transport Authority*), the road is very dangerous. With road traffic intensifying, car fatalities will increase;
- Given the large number of trucks and cars on the two main roads (Phuentsholing – Thimphu and Paro – Thimphu), pollution is increasing and deteriorates the quality of life in Bhutan. Pollution is also fatal, and a publication from the International Energy Agency reports that in China and India, pollution (created by cars and industry) causes more than 100 deaths each year per 100 000 people.
- Because of the mountainous landscape, travel times are long and journeys are unsafe. From the border town of Phuentsholing to the capital City of Thimphu, travel time is almost 6 hours for 171 kilometres of roads.

Bhutan has the capacity to dramatically improve the quality and safety of its transportation system with the construction of a railway. Indeed, rail systems offer:

- Safety: Railways are 30 times safer than roads;
- Low pollution: Trains consume 10 times less energy than road vehicles. Especially electric trains which do not use fossil energy.
- Faster travel time: For example, travel time from Phuentsholing to Thimphu can be reduced from 6/8 hours to around 1 hour and half.

A rail system will also:

- Increase the employment opportunity and quality of local labour. Bus drivers will for example be able to become train drivers, which is a job with more qualification than a bus driver. Travel distances and times for truck drivers would be shortened, as a part of the freight transport can be done by rail. New jobs will be created in rail system: train drivers, train conductors, personnel

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in the stations, personnel in the workshops, personnel in the office of the rail company. Just for personnel on the trains, we estimate creation of around 100 jobs.

- Decrease in the cost of transportation for goods, because a freight train will be able to carry higher quantity of goods than trucks, and for a lower price. Manufactured goods from India will be less costly to import and prices will decrease. Therefore, the purchasing power of the Bhutanese people will increase.

The solution that we propose is a complete system where each part compliments the others:

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Figure 63: Proposed railway system in Bhutan (first phase)

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The railway network for Bhutan would be broadly composed of three components:

1. A railway from the border town of Phuentsholing (with possible connection to the Indian Rail Network) to Thimphu. This is the main line of around 100 kilometres
2. A railway from Thimphu serving Paro Airport and Paro town via the junction at Chuzom and connecting with the main line. This junction line from Chuzom and to Paro will be around 20 kilometres. The complete distance from Thimphu south to Paro will be around 40 kilometres.
3. A light rail serving Thimphu. This is the urban line of around 10 kilometres

The backbone of this system is the railway from the bordering town of Phuentsholing to Thimphu. It will allow freight and passenger trains. It will also allow other lines to connect to it and will earn the highest revenues for the network.

Such systems allow three main services:

1. Freight trains and passenger trains from the bordering town of Phuentsholing to Thimphu South station.
2. Trains from Paro (serving Paro Airport) to Thimphu North, through the city of Thimphu.
3. Light Rail Transit (LRT) system inside the city of Thimphu. Two lines are planned, with trains every ten minutes. This line will serve the entire city of Thimphu from the South to the North. Fares will be lower than taxis, and the same as urban buses. Travel times will also be shorter.

This railway network should be seen like the first step to a complete network inside Bhutan. This network will be able to extend further to the other parts of the country, especially to North (Punakha) and East of the country (Trashigang, Samdrup Jongkhar) in the future. That is why it is necessary to think of this transportation system like a network and not like separate corridors.

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Within Thimphu, the proposed alignment is described below:



Figure 64: Proposed alignment in Thimphu

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The first idea about the configuration of the Thimphu urban network is from south to north:

- **A railway main station located in the Southern part of the city**, with heavy railway tracks for freight trains terminating and with tracks continuing to the city centre for passengers coming from (or going to) Paro and Phuentsholing;
- A light railway line between the railway main station and the urban main station;
- An urban main station located close to the stadium and the current bus station. This station will be a multimodal station with a bus station, taxi station, and so on;
- A light railway line inside the city centre (along the current main avenue or along the river) from the urban main station to the station close to the golf course;
- An urban station close to the golf course, with the possibility of connection with a second line to go to the urban main station (and reverse). This second line could be along the main avenue or along the river, depending on the choice for the first one.
- An extended line to the northern part of the city to the National Assembly.

This urban network will be completed by **different stopping points, with a headway of about 1 min 30s to 2 min**. At this stage, the calculation of the distance (from Google earth) inside Thimphu gives the results below:

- From the railway main station to urban main station = about 5300 metres, including 500 m of viaduct to cross the river and the road;
- From the urban main station to the golf course station by using the current main avenue = 2000 m including a 150 m viaduct to pass over Thim Chhu river;
- From the golf course station to National Assembly station = 1250 m including a 120 m viaduct to pass over Thim Chhu.

The total distance inside Thimphu city is 8500 metres, including 770 m of overpass buildings.

Different altitudes and elevations taken within Thimphu allow us to calculate the difference in elevation between the South and the North, and the height difference is 1.1% which allows a great performance for the rolling stock.

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Except the necessary crossings of the Thim Chhu river and the road, there is no technical difficulty to create a new railway light inside Thimphu. However, this will have to be confirmed and validated from the feasibility study. Within Thimphu city centre, regarding the urbanization, the building and the location, we suggest the use of the current main avenue. We also suggest to put the line near the river, but this will be less central inside the city, and the traffic should be less important. Like the majority of tramways in the world, the rail will use the existing road.

Investment is around \$1600 – \$3200 M for infrastructure, around \$50M for rolling stock. From a technical point of view, the line should be a single line, with an Indian gauge for the main line (but with a third rail from junction to Paro), and an international gauge to junction to Paro and within Thimphu. Traffic forecast for the first year of the project is around 7 million of travels (including 5.9 million of travels on LRT within Thimphu) in future rail system in Bhutan, and around 1 million tons of freight. It will be around 110 million passengers.km each year, and around 75 million ton.km each year on the future network. These traffic will increase over the years.

About economy of project, and **if we suppose that operator will invest for rolling stock but not for infrastructure** (around 1600 – 3200 M\$), the rail operator will generate a profit of 5 – 10% each year. We summarize the yearly P & L below (for complete detail of the calculation, see part 8)

Revenues from traffic (freight & passengers)	9.7 M\$
Operating cost (personal, energy, maintenance of rolling stock, overhead cost)	3.1 M\$
Track cost (maintenance of infrastructure)	2.9 M\$
Capital cost for rolling stock	3.0 M\$
Total costs	9.1 M\$
Benefit	0.6 M\$

Socio-economic benefits are very high because of the value of safety, as well as from the reduction of pollution and congestion. We summarize the cost and benefits analysis below:

Investment for infrastructure		2400M\$ (middle point between min and max of investment)
For the first year of operation	Benefits for the railway company	1 M\$

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	Benefits about safety	35 M\$
	Benefit about pollution	35 M\$
	Benefits about time	7 M\$
	Total benefits	76 M\$
For 50 years, with grow up of 4% / year and actualisation of 4%	Benefits for the railway company	50M\$
	Benefits about safety	1750M\$
	Benefit about pollution	1750M\$
	Benefits about time	350M\$
	Total benefits	3800M\$

Over 50 years, benefits are around \$3.8 billion (with actualisation of 4%, and hypothesis of grow up of 4%), for an investment of \$2.4 billion. Project is beneficial for Bhutan with a socio-economic ITR of more than 6%.

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Bhutan should continue the study with a complete feasibility study. This study should provide:

- Drawings and diagrams for the trace
- Note for operating program with impacts and effects
- Spreadsheet with costs for each installation
- Schedule of works and operations
- Multi criteria analysis method for each scenario to select the best one
- Note for synthesis with detailed cases

At the end of the feasibility study, it will be possible to know:

- What will be the trace (with each specific part);
- Where will be stations;
- What will be the proposed transport plan;
- What will be the cost.

Such study could be done in around one year for around 250 k\$. Rail Concept will be able to provide this feasibility study. This study could begin in 2017.

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General Considerations about Railway Systems

What is (and what is not) a railway system?

Rail transport is a means of conveyance of passengers and goods on wheeled vehicles running on rails, also known as tracks. In railway operations, everything begins with the wheel-rail interface.

1. Metal wheels on metal rails have a significant advantage of overcoming resistance compared to rubber tire wheels on any road surface: the necessary force to move a train at same speed and of same weight is ten times lower than for a truck. In other words, it uses considerably less energy to offer the same service
2. Guided transportation allows higher speed and higher safety than roads.

This report will discuss all possibilities of a traditional railway system: metal wheel/metal rail. The report will not speak about untraditional railway systems like monorail or magnetic train which represent a tiny part of transportation and which don't have the advantages of the traditional railway system.

About magnetic trains, they quite don't exist in the world (only 4 lines in the world, for high speed train from one point to one other without intermediate stop).

Monorail is more frequent technology (even if the part is really tiny compared to classic rail system), which is possible for urban train. The main problem about monorail is that monorail system will be a different system from the classic one which will be used for long-distance services => it will not allow services like the proposed tram-train from Paro to the centre of Thimphu. The classic system will be able to integrate all the services in one technology.

Other point which is important to notice is that the classicism of rail system give possibility to Bhutan to use second-hand rolling stock, to have better access to the universal knowledge about rail system.

The different possibilities for rail are:

- Heavy rail for passengers and freight; Heavy urban rail system;
- Light rail:
 - o Light rolling stock
 - o Light infrastructure
 - o Tramway
 - o Tram-train

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These systems total more than 99% of all the guided systems. They offer enough variety to answer to any situation.

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Interesting Figures

Environmental emissions

Rail system is one the most efficient transportation for freight. US Statistics (2010) give the following figure for freight.

Table 14: Use of energy for different transportation modes (about freight)

Mode	Use of energy (kJ per tonne kilometre)
Rail	200
Trucks	2000
Air	7000

Rail system is one the most efficient modes of transportation for passengers. European Statistics (2010) give the following figure for passengers.

Table 15: Use of energy for different transportation modes (about passengers)

Mode	Use of energy (kWh per 100 PASSENGER kilometre)
Rail	5 - 10
Car	60
Air	50

We see that rail uses around ten times less energy than trucks for freight transportation. We have the same ratio about passenger's transportation. Moreover, rail allows the use of electricity (without batteries which carries a lot of pollution) which can be produced without carbon (hydro-electricity for example).

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Safety

Rail systems are very safe compared to road transportation. EU (2012) Statistics are the followings, expressed in fatalities per billion passenger-kilometres, which is the most used unity to express the safety.

Table 16: Risk fatalities per mode of transport in European Union (source: EU transport in figures, 2012, DG MOVE - European commission)

Mode	Fatalities per billion passenger-kilometres
Air	0.101
Rail	0.156
Bus	0.433
Car	4.450
Powered two-wheelers	52.593

Trains are around 3 times safer than buses, around 30 times safer than cars.

Cost for passengers and freight

For mountainous or land-locked countries (like Bhutan is), a main part of the cost of the goods come from the cost of transportation. Small trucks (around 15 – 20 tons / truck) which are used in Bhutan cost more to transport one ton than what will do a railway (700 – 1000 tons / train).

It is the same for passengers: the use of personal way of transport (like car, or taxi) or even the use of collective transportation of small capacity cost more to the traveller than train (around 400 travellers / train).

Therefore, the price of these goods will decrease, and the purchasing power of the people will increase.

Technical Points

What is a track?

Track is the structure consisting of the rail fasteners, railroad ties and ballast (slab track) and underlying subgrade. It enable trains to move by providing dependable surface for their wheels to roll.

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Regardless of the railway system (heavy rail or light rail system), it is necessary to have a track with similar structure.

Classic track is made up of four main elements.

- The rails,
- The sleepers and their fasteners,
- The ballast.

But the first part of the track is a planar structure which can be a concrete structure such as viaduct and/or tunnel or can be a compacted undercoat and levelled ground.

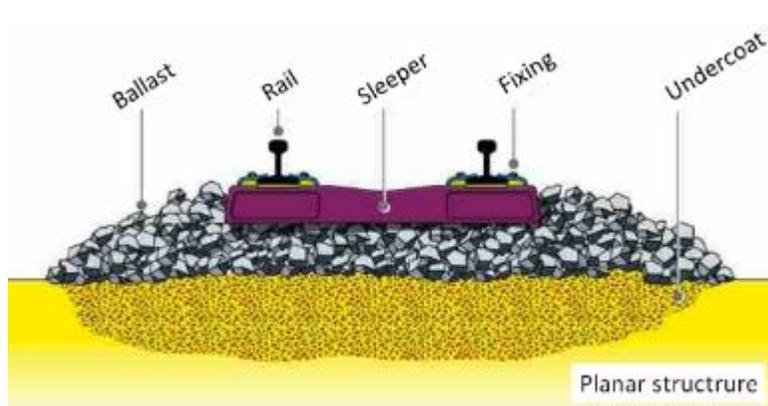


Figure 65: Structure of a track



Figure 66: View of a track

On the ground, the four parts of the track are installed:

The ballast is formed of stones on which the track rests. Its different roles are an indispensable element of the track.

The elements of the ballast form a firm but permeable base to absorb the static and dynamic forces transmitted by train movements and provide an anchorage for the track and allow to reduce noise, to absorb vibrations and to drain the rainwater.

The sleepers are laid in the ballast which fixes the track in position.

There are other types of support, especially for viaducts and tunnels, such as concrete slab track.

The sleepers are a fundamental part of the railway. They are placed at right angles to and under the rails and maintain the track alignment and profile.

There are several types of sleeper: Monobloc, twin block, concrete and wood.

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Generally, there are 1666 sleepers per kilometre; so the distance between the axis of each sleeper is approximately 60 centimetres.

The sleepers also transfer the weight to the ballast. Concrete sleepers provide better anchorage to the ballast than traditional wooden sleepers.

The fastening of the rails on the sleepers is usually comprised of a steel plate placed under the rail on which the rail is fastened by bolts or clips. Rubber isolating pads are often placed between the rail and plate or between the plate and the sleeper, to absorb shocks and reduce noise.

The rails serve to support and guide moving trains. There are two main types of rail installation

- The lengths of rail are assembled with mechanical joints such as fishplates.
- Continuously Welded Rails (CWR) which are used for modern track.

The advantages of welded rails are improvements to wear on the rolling stock, increase in comfort and reduction in noise. However, this technology has mechanical constraints due to temperature changes.

The rail can serve as transmission lines for systems to detect trains and for the transmission of signalling information. For that, the rails must be isolated from each other.

To allow trains moving from one line to another or to provide protection against incompatible or unsafe routing, there are points and crossing.

There are several types of points and crossings with switches, turnout. But the fundamental philosophy for points and crossings is: The switch, which is in contact with the stock rail, is referred to as the closed switch and the other switch as the open switch.

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Figure 67: Switch *and* direction allowed

Heavy train vs Light train

To understand what a **'heavy train'** is we have to note that this type of train is able to run on a normal track for long distance with a dedicated signalling system. As heavy trains it is possible to have passenger trains and freight trains.

For **'light trains'**, we have to specify that there are different kinds:

- Tram (or tramway in French language)
- Tram-train

A **'tramway'** is a public transport, mostly electrical, running on urban railway at ground level. Generally, tramways run on dedicated tracks except on road junctions.

Trams constitute an urban road transport. Traffic safety is dependent on the driver's control of the vehicle, as buses. However, there is one significant difference: guiding.

The speed is limited and there is a light signalling system.

A **'Tram-train'** is a modern type of train, which is able to run on normal track, between cities, as a heavy train, but it is able to run on tramway track, inside the city.

Connections between urban tram network and heavy railway lines offer customers rail travel service between outer suburban areas and city centres with no change of vehicle, at reduced investment and operating costs.

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Tram-train rolling stock is designed for operation on two types of sites:

- On urban sites with dedicated ways or on ordinary road with road vehicles;
- On normal railway lines, with variations depending on the type of infrastructure.

For heavy trains and light trains running on the same part of the track, there is no difference; track, electrical power and signalling system under control of a single command and control centre are the same.

Light trains can run on the same track as heavy trains but the reverse situation is not possible.

There are two advantages with light rail:

- Trains running on line but also within Thimphu network. Passengers will stay on the same train from Paro to centre of Thimphu.
- Less expensive.

What about the powering of the rolling stock?

There are two ways of powering rolling stock. Vehicles may be self-contained carrying their own supply of fuel, or the line may be electrified.

Autonomous self-contained traction

When this type of traction is used, the fossil fuel is supplied at the railway depot.

The main advantage of this type is that the infrastructure is reduced to the necessary supply points to provide diesel fuel.

The inconveniences are that the available power is more limited and for sustainable development trains produce greater noise and exhaust fumes. Rolling stock maintenance costs for self-contained traction are also higher than for electrical power.

Electric traction

There are many systems with different types of voltage, power supplies and electrical frequencies.

For electric traction, power supply is taken from the national supply grid directly to the railway substations. Then, energy is supplied to the trains either by an overhead catenary or by a third rail system.

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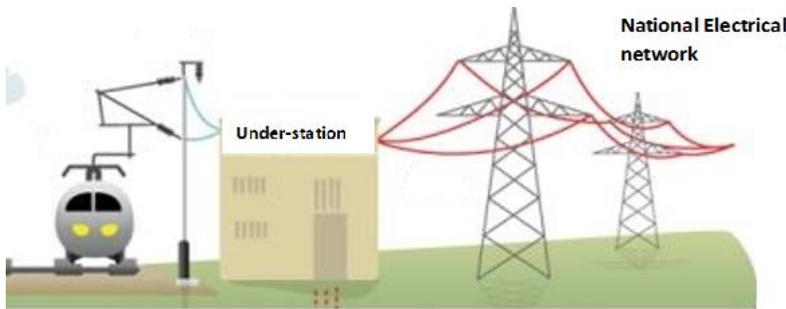


Figure 68: Electrical power supply from National network to catenary **Figure 69:** Pantograph

Amongst the advantages of electrical traction are that it allows a higher rated power supply to be provided to the rolling stock and local pollution and maintenance costs are reduced. Electric traction is not dependent on supplies of fossil fuel.

Today, the majority of new railway lines are electrified. Continuing price rises in oil fuel and consideration of other factors such as sustainable development makes electrification project more attractive. The following advantages are obtained with electrification:

- Operating speeds are higher;
- Optimization of the use of the rolling stock;
- Reduction in the risk of fire on-board the trains;
- Reduction of fumes within the tunnels;
- Reduction of noise and vibrations.
- Reduction of emission

Regarding the situation in Bhutan to reach a sustainable development and be the world's first carbon negative country and due to the capacity to supply electrical hydropower (compared to the fuel imports), this study is done with the hypothesis of electrical traction.

Railway operation

The structure of a railway system is distinguished by its nodes, crossing points and junctions and by stations where passengers can board or disembark trains and for handling freight traffic. Between those nodes are lines which may be single lines or with multiple tracks such as double lines. It is obvious that a single line is less expensive than a double line, but we will have to compare the two systems which are daily efficiently used all around the world.

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From the first analysis, railway in Bhutan will be single line. Such system will provide enough capacity for the trains. Even if railway in India is double track, it will be no problem at the border.

Single line

On single lines there is a major risk of trains travelling in opposite directions on the same section. The functions of keeping trains separated and preventing possible head-on collisions are controlled by a signaller. It is also possible to have reversible lines where the functions are performed automatically by the signalling system. To allow trains to pass each other safely and to allow quicker trains to overtake slower trains, loops are installed at regular intervals.

In France, there are two types of configuration:

- Left hand operating loop. Trains always circulate, in stations, on the left hand track. Speed is limited by the switch and the curve leaving the station.

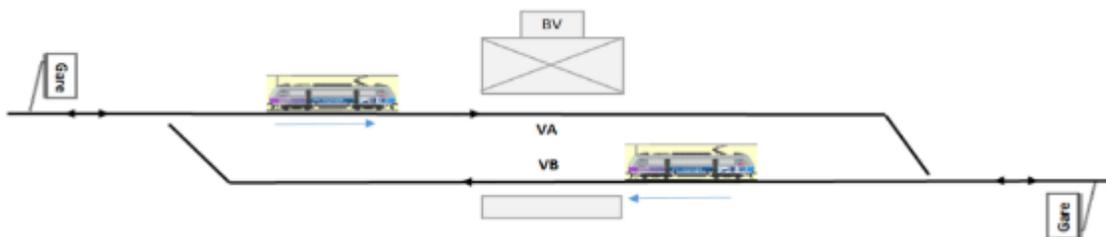


Figure 70: Left hand operating loop

- Direct operation through the loop. Trains can operate at the maximum speed on the direct through line.

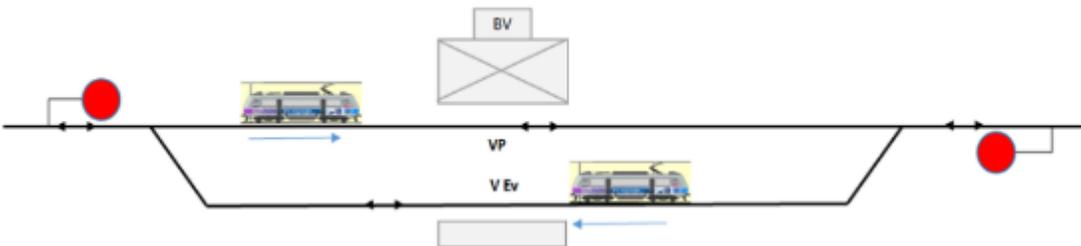


Figure 71: Direct operation through the loop

On a single line, the capacity for the number of train is limited.

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Double line

On double lines, trains circulate on the same line in the same direction at all times. The objective is to separate trains. With this kind of line, if necessary (especially in case of an incident), it is possible to circulate in both directions on one line only.

Connections are provided to allow trains to transfer from one track to another.

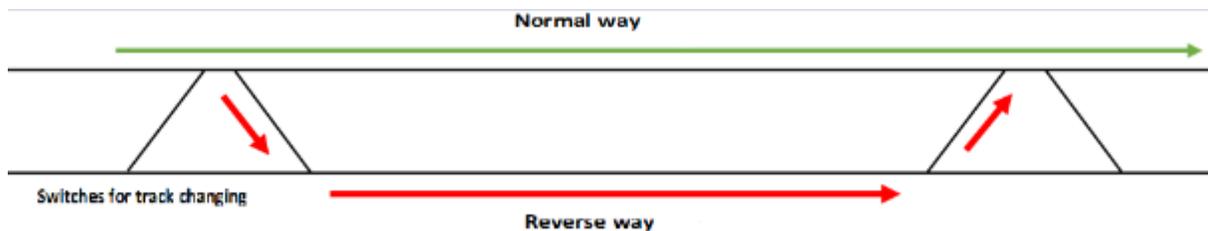


Figure 72: Possibilities for train running on a double line

Signalling system

Regardless of the final system selected, the Bhutan railway must be an efficient system with modern signalling technology, with two objectives: Safety and efficiency.

It should be noted that railway operations present five major issues:

1. Protection of a train from another in the same direction
2. Protection against a train from a converging route
3. Protection against a train travelling in the opposite direction on the same track
4. Derailment
5. Road level crossing

Some examples are shown below:



Figure 73: Risk of catching in the same direction

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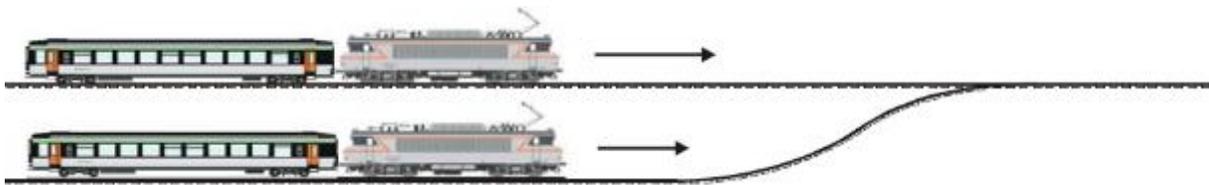


Figure 74: Risk for converging routes



Figure 75: Head to head risk

On line, between Thimphu, Paro and Phuentsholing, the signalling system for a single line could be the same as the one used in the French Alps between France and Switzerland. The system uses radio and automatic control of the number of axles and light signalling. Trains must stop at each station where it is possible to have two tracks with access from each side on the left track to allow crossing and to avoid head to head (see Figure 75).

The command and the control of the line is done from a control centre which could be located within the main station. For trains passing through the station or before leaving a station, the driver of the train asks the command control centre which verifies, from panel control, if the line is free. Then he allows, by giving a code, the train to leave. The driver inserts the code within his computer and, if it is ok, the train can leave the station. This system does not need an operator at each station and can operate from the command control centre.

Within Thimphu, the signalling system could be an urban system as used for tramway with lights and signals to protect the switches but also the road crossing. For the final system, there will be an obvious coherence between the system for the line and the system within Thimphu urban network to allow to have a single command and control centre.

If we suppose trains from 5 am to 10 pm, it is necessary to have one operator from 5 am to 9 pm for 2 shifts inside the control centre and within each station such as Paro, Phuentsholing and the junction. Because of absence, illness, and so on, it will be necessary to have 3 operators in control center, and in each station of Paro, Phuentsholing and junction.

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If we suppose trains all the day (24 hours), which can be necessary for freight train, it will be necessary to have 5 operators in control center, and in each station of Paro, Phuentsholing and junction.

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Appendix B: Overview of Assumptions around Economic Considerations

Investment

There are two main investments:

- The infrastructure
- The rolling stock

In this study, we suppose that rolling stock will be paid by the railway company (which can be public or private). Part 4.4.5 give explanations about financing of infrastructure.

Railway economics

Railway economics involve three main actors:

- The state (and all the public entities)
- The railway companies:
 - o Railway operators
 - o Rail Infrastructure Managers
- The travellers (for passenger trains) and the customers (for freight transportation)

From a socio-economical point of view, we add also the travellers from other modes of transportation, the companies of other modes of transportation, the “third parties” which include the non-travellers which will benefit from externalities (increase of safety, decrease of noise, decrease of pollution...)

Railway economics are based on the balance of the operators and the infrastructure manager (which can be the same company as the railway operator). In the following part, we will summarize the exchanges between the actors and explain the balance of the actors:

1. Everything begins from the passengers and the customers of freight transportation. They will provide the revenues of the rail operators. The quantity of passengers depends of two main factors:

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- a. The population and the wealth of the population. The more population there is and the wealthier the population, the more traffic there will be
 - b. The quality of transportation. The better the transportation system will be (time, price, comfort), more traffic there will be. The market share of transport will also depend of the relative quality of each mode of transportation
- ⇒ Traffic is a question of market
2. The first balance which is computed is the revenues and costs of the railway operator (RO). The railway operator is the owner of the rolling stock (but not of the infrastructure). His revenues come from traffic, his costs come from the quantity of trains he has to operate. The cost is split between operation costs (salary of drivers, price of energy, maintenance of trains, capital cost for train, ...) and track access that the rail operator has to pay to the infrastructure manager.
- ⇒ Operation costs are question of industrial efficiency
3. The second balance is the revenues and the costs of the railway infrastructure manager (RIM). RIM builds the railway (infrastructure) and is responsible of the maintenance. Both are costs. His revenues come from track access, paid by the railway operator.
 4. Because of socio-economics (next page) advantages of railway, the State will compensate for the eventual losses the RO and RIM suffer

For the RO, it can be two compensations:

- About the price of ticket. For example, some social fares can be done. A family could pay only 50% of the full fare and the State would compensate the remaining;
- About the cost. For example, the state will compensate some loss of regional trains which are not profitable in order to develop one territory, or to offer possibility to travel to the population. Such trains are done to develop rural territory, or to develop one part of the country which can be poorer than one other, or more land-locked than one other one.

For RIM, there is also two compensations:

- About the construction of the railway infrastructure, the State could pay a part of the project;
- About maintenance cost, the State could pay some maintenance costs.

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Why compensate? Because trains have advantages which cannot be expressed in monetary terms.

They are socio-economic effects which are summarized in the figure below:

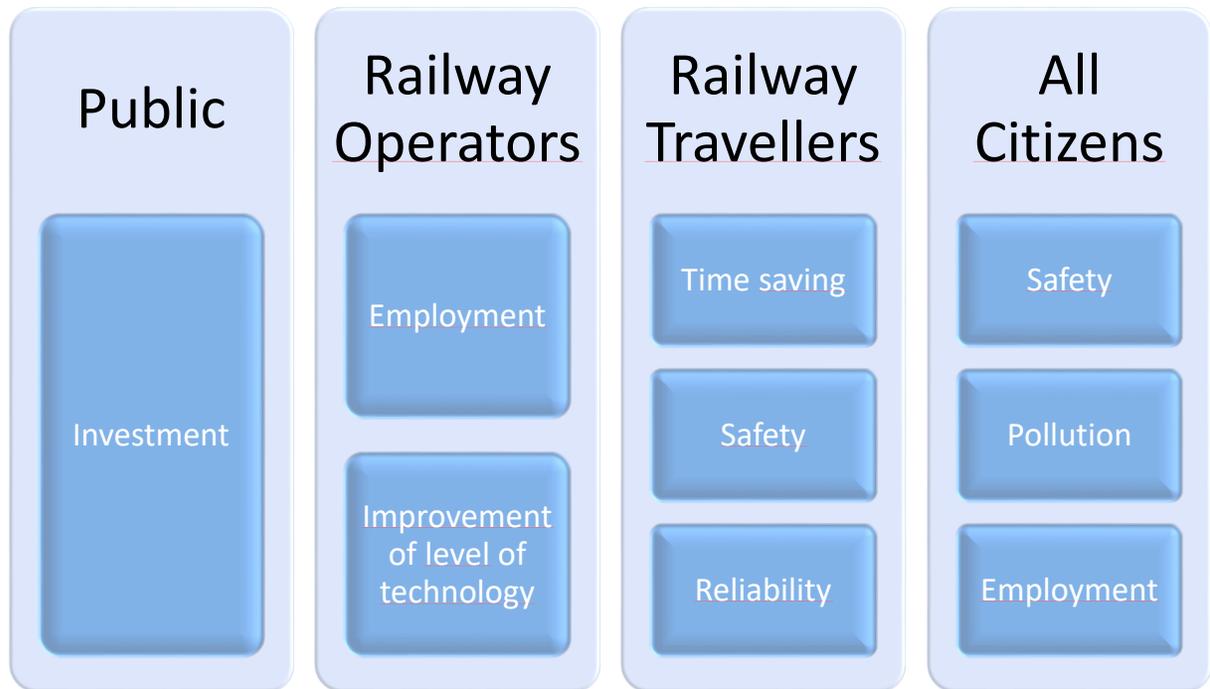


Figure 76: Socio-economic benefits

The socio-economics effects are for different actors:

1. For railway travellers:

- a. Trains are faster than cars: time savings are an important source of profit;
- b. Trains are more reliable than cars: this reliability is, like time savings, an important source of socio-economical profits
- c. Trains are safer than cars: this safety must also be taken into account in socio-economy
- d. Trains fare are significantly less compare to car and bus; it saves travel cost and freight cost

2. For citizens:

- Trains are more environment-friendly
- Trains remove cars and trucks from road => the road becomes safer

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- Trains will provide employment during the construction phase, and will offer new and more qualified jobs (bus drivers will become train drivers)
- Trains will provide better work conditions in transportation (truck drivers will – for example - drive less further from home)

All these effects are called socio-economics because they are quantified in terms of money for analysis purposes. For example, (French official figures for socio-economics benefits):

- The price of each saved life is 1 million of euros;
- The price of each hour saved for one passenger is 20 euros;
- The price of each saved ton of CO₂ is around 30 euros

Basics of transportation economics modelling

Traffic forecast

Traffic forecast is the basis of economics transportation study. Traffic forecasts are now generally done by “traffic models”, which are mathematical formulations to forecast future traffic. Traffic forecasts follow the steps below:

1. Data collection: existing statistics, or inquiries to know actual traffic for passengers and freight for all modes of transportation
2. The actual methodology (from the 1960's to nowadays) follow the sequential “four-step model”.
 - The region to study is divided by zones and population, industries, employment, tourism are determined for each zone
 - The four steps are:
 - o Trip generation which determines the frequency of origins or destinations of trips in each zone by trip purpose, as a function of land use and household demographics, and other socio-economic factors
 - o Trip distribution matches origins with destinations
 - o Mode choice computes the proportion of trips between each origin and destination that use a particular transportation mode

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- Route assignment allocates trips between an origin and destination to a route by a particular mode

Revenues and costs of the system

The balance of each actor is computed following the principles expressed above. This part is in the centre of the whole study, along with the technical study which provides infrastructure cost, and operation studies providing operation costs.

Socio-economics benefits

The main principle is the computation of the **net present value (NPV)** which is the balance between actual cost and investment and the future benefits. Time value of money dictates that time affects the value of cash flows. In other words, to receive \$100 today is not the same as receiving \$100 tomorrow (you always prefer the “safe” present). Computation of NPV is done by using the discount rate. For example, a discount rate of 4% means that \$100 today will become around \$96 in one year, and around \$92 in two years. The future earnings will be converted into present values to summarize all the effects over the time.

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Summary of Railway Economics Study Approach

The following charts explain the way to conduct a railway economics study:

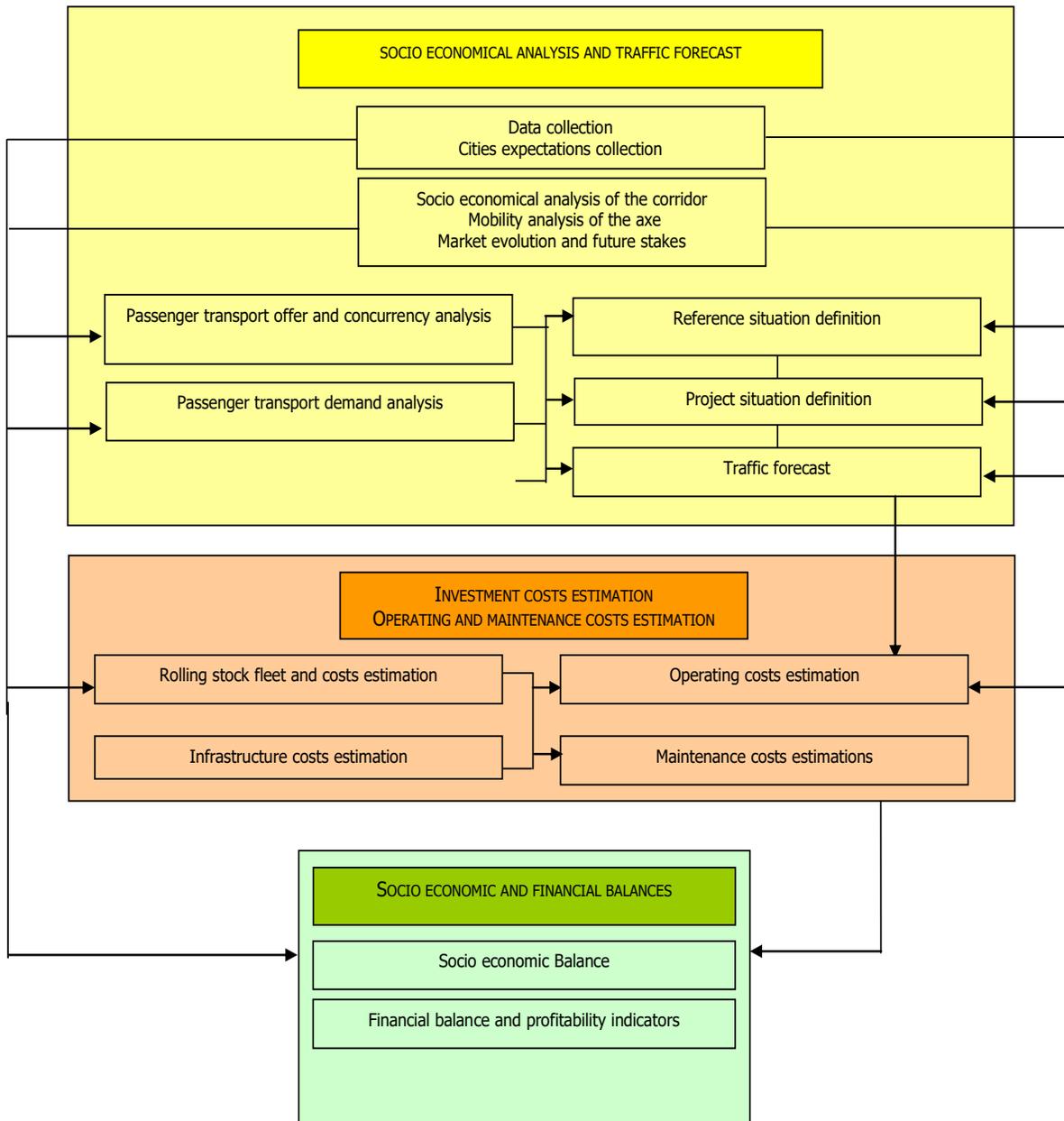


Figure 77: Railway economic study

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Project financing of infrastructure

How to finance a project? Two main ways:

1. Public financing
2. PPP (Public-Private Partnership). A PPP involves a contract between a public sector authority and a private party, in which the private party provides a public service or project and assumes substantial financial, technical and operational risk in the project.
3. Aid and Soft Loans

Part 10 gives the recommendations for financing project.

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Appendix C: Notes on Project Financing

In the previous parts, it is demonstrated that the future railway operator will be able to generate a benefit over the years, even if railway operator invests for rolling stock.

The main question concerns the investment for infrastructure (around \$1.6 – 3.2 billion).

To improve the profitability of the project, it could be **interesting to use the infrastructure created by railway to put a power line from Bhutan to India**, which will be able for Bhutan to export electricity. Bhutan has a large hydropower potential assessed at around 30,000 MW. With 1480 MW capacity being created till date, just about 6% of this has been exploited. Bhutan has a ready market in India, which is in lack of electricity.

There are three main solutions for financing the project:

1. Public financing: It means that Government of Bhutan will finance the complete project.

Regarding the amount of investment, this solution looks not sustainable;

2. PPP: This solution involves a contract between a public sector authority and a private party, in which the private party provides a public service or project and assumes substantial financial, technical and operational risk in the project. The main question about PPP is the question of profitability of the project. This project looks to not have enough internal profitability to be able to interest a private partner.

3. A soft loan: A soft loan is a loan with below-market rate of interest, or loans made by multinational development banks (such as the Asian Development fund), affiliates of the World Bank and government agencies to developing countries that would be unable to borrow at the market rate. This way of financing looks interesting for Bhutan.

For example, Ethiopia received a soft loan from the Chinese government, in September 2012. The Chinese government announced a grant and soft loan package totaling US\$23 million to support Ethiopian development activities. The loan is part of China's plan to support Ethiopia and to promote the development of trade between Ethiopia and China. In another example, the Chinese government extended a \$2 billion soft loan to Angola in March 2004. The loan was made in exchange for its commitment to provide a continuous supply of crude oil to China. Another example is the interest free soft loan of Rs. 20 billion given by the Asian Development Bank (ADB) to the

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government of West Bengal (India) on the condition that it be used for health, education and developing infrastructure.

This project of soft loan should be studied in the feasibility study, with link with hydroelectric power and electricity exportation.

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Appendix D: Overview of Feasibility Study Process

Technical studies

What is the study?

Technical studies will include the following steps:

Evaluation of technical feasibility

This part of the study needs visits on the field, and needs also aerial views (from helicopter and topographic map) to have a better knowledge about the valley and other closed valley.

The places to visit are from Phuentsholing to Thimphu, and the connexion to Paro.

Drawing of the trace

This part will allow to see on a topographic map what will be the future line *from Thimphu to Phuentsholing, from Paro to Chuzom junction, and within Thimphu city.*

Schedule of the proposed works and operations.

Allows to have an estimated planning from feasibility study to the commissioning

- *Phasing of the various stages of works and operations.*
- *Evaluation of costs of the proposed installations*
- *Evaluation of signaling system for railway operations*
- *Precise calculation for travel time for each branch and each type of train*

From the proposal line, modelling will be done to know the travel time. Modelling will be with Ingetime which is Rail Concept own software. The gradient, the curve and technical characteristics of the rolling stock will be taken into account.

Proposal for transport plan for freight and passengers train

Done from the travel time and the service wished from the Government of Bhutan

To determine the number of trains needed

Allows to calculate the rolling stock

- To propose freight installation close to Thimphu main station and Phuentsholing
- To propose location and cost for building the stations within Thimphu, Paro and Phuentsholing
- To propose method to protect the railway from the mountain

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For instance, steel safety net to avoid rock falling down.

Determination of future needs for storage and maintenance of trains

Rolling stock needs to have light and heavy maintenance (stabling tracks, workshops...)

Multi criteria analysis

Method to compare several scenarios (cost, travel time, technical constraints...)

Deliverables

Deliverables are:

- Drawings and diagrams for the trace
- Note for operating program with impacts and effects
- Spreadsheet with costs for each installation
- Schedule of works and operations
- Multi criteria analysis method for each scenario to select the best one
- Note for synthesis with detailed cases

During the study, each proposal will be shared with UNCRD technical team and the concerned Ministry in Bhutan coordinating this study. The evaluation of technical feasibility will allow to precisely know the location of the trace (line) and the civil works needed, the length of each part of the track including normal track, tunnel, bridge or overpass, protection from mountain...).

With this analysis it will be possible to calculate a precise cost of the operations.

At the end of the feasibility study, it will be possible to know:

- What will be the trace (with each specific part).
- Where will be stations.
- What will be the proposed transport plan.
- What will be the cost.

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Economic studies

What is the study?

Concerning the economic studies, the main ideas are to:

1. Improve the knowledge about traffic forecast. Future traffic will have impact on:
 - a. Technical assumptions (number of tracks, number of stations, rolling stock type).
 - b. Economic balance and financing project.
2. Propose financing project

It will follow the steps below:

Traffic forecast

Traffic forecast will be conducted with the following steps:

1. Data collection. All data concerning actual transportation will be collected, especially concerning number of cars/trucks on the road, main origin – destination, evolution of population.
2. Polls to improve data collection.
3. Development of traffic model. The traffic model will allow to forecast rail traffic for freights and passengers. It will be possible to test different scenarios.

Economic balance study

This part of the study will analyse the cost and revenues for railway operator and infrastructure manager (who can be two different entities).

Socio-economic balance study

This part of the study will analyse all cost and benefits of the project.

Financing study

This study will include analyses of the possibilities of financing the project using money from the market. It will provide an optimal plan of projects. The possibilities for the project to be financed by the railways or the government will be assessed at that stage.

Once the phasing has been designed, the Consultant will start in drawing a plan for financing. The first stage will consist in calculating the resulting cash flow derived from the implementation of the

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project at a stated date. From that stage, requirements for funding will be identified and presented on a yearly basis, showing a split by main items.

The final stage will encompass the identification of funding sources, both private and public, national and international. The documents produced will enable the respective government concerned to use the findings for further negotiations with international financing institutions in order to carry out feasibility evaluation.

Deliverables

Deliverables are:

- Report on the traffic forecast.
- Traffic model (Excel model).
- Report on the economic study.
- Report on the socio-economic study.
- Report on financing project.

During the study, each proposal will be shared with UNCRD technical team and Ministries of Bhutan representatives.

At the end of the feasibility study, it will possible to know:

- What will be the traffic for passengers and freight?
- What will be the P&L for rail operator and infrastructure manager?
- What will be the cost and benefits analysis?
- What will be ways to finance the project?

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Planning and budget

Planning

The planning will be this one:

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Technical studies									
<i>Technical visits</i>									
<i>Drawing of trace</i>									
<i>CAPEX assesments</i>									
<i>Transportation plan</i>									
<i>Rolling stock</i>									
Economical studies									
<i>Traffic forecast</i>									
<i>Economic studies</i>									
<i>Socioeconomic studies</i>									
<i>Financing projects</i>									

Budget

Budget should be around 10 times the budget of the pre-feasibility study, circa \$200,000 – 250,000, not including the investigation of environmental and social elements. This budget is to also include \$100,000 for the complimentary study of environmental and social considerations along with the design and implementation support for the staging of efforts as outlined previously.

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Key Conclusions and Recommendations

Based on the pre-feasibility study the following conclusions are made:

- Bhutan is faced with the dilemma that its current transportation system has been designed to be fossil fuel and automobile dependent and this is leading to greater numbers of vehicles on the roads (to grow 5 times by 2040) and a growth in the associated fuel import costs, air pollution, congestion, road fatalities, and greenhouse gas emissions.
- Fuel imports place a significant economic toll on Bhutan with imports to power the vehicle fleet being nearly equivalent to the entire hydroelectricity revenue. In 2015 Prime Minister Tobgay stated that, 'My target for Bhutan is a 70 percent reduction in fossil fuel imports by 2020'.
- Such a reduction can only be achieved through an upgrade in the transportation system, part of the nation's strategic infrastructure, that has Bhutan transition from an automobile dependent nation to one serviced by a backbone of hydro-electric powered trains, buses and vehicles.
- The first investment in the rail system should include: 1) light rail in Thimphu City; 2) light rail between Paro and Chuzom; and 3) heavy rail between Thimphu and Phuentsholing via Chuzom. A dual gauge system be used to allow the light carriages to travel to Thimphu and Phuentsholing.

Based on the pre-feasibility study the following recommendations are made:

1. Undertake a *Detailed Rail Feasibility Study and Design* to consider both the technical considerations along with approaches to financing and operating the system that stand to reduce the burden on public funds or need for donors (such as 'Entrepreneur Rail Model').
2. *Encourage zero-emissions taxis as feeder services* - that are 95% cheaper to operate – to provide access to train stations (located at or near previous bus stations), with taxis allocated a particular area of the city. Electric taxis can also be used for grid management and energy storage.
3. *Support walking, cycling and traditional forms*, through the provision of appropriate on-road line-marking and infrastructure such as secure storage of bikes and showering facilities.
4. Begin *Light and Heavy Rail Construction*, following the detailed feasibility and design stages.
5. *Discourage Car Use* to reduce private investment in individual vehicles through registration restrictions, road and congestion tolls, and staggering office hours to reduce bus crowding.
6. *Enhancing the existing bus system* while the rail system is being constructed then to provide feeder services to stations aligned to rail routes along with taxis. Electric busses should be used with interchangeable battery technology.
7. Open *the First Stage of the Rail System* and link in to feeder services using electric busses and taxis, using cable cars or mono-rails in difficult terrain.

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