The impact of rail transit systems on urban regeneration and development in a Chinese large city-
A case study of Chongqing

Lixun Liu

Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

The Bartlett School of Planning,
University College London
2017
I, Lixun Liu, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.
Acknowledgements

This thesis would not have been possible without the guidance and support of my supervisors, Robin Hickman, Adam Dennett, and Professor Sir Peter Hall.

My heartfelt thanks go to my primary supervisor, Dr Robin Hickman, who helped guide me towards this specific research subject, led me through this exciting and challenging journey, and offered his deep insight in the field, to help me bring all of the elements together into this final thesis. You have always quickly replied to my questions and given me excellent guidance throughout the research process; you have generously given your time (and endured the occasionally awkward turn-of-phrase in my writing!), and supported me with never-failing patience; you have constantly enlightened me, not only with your academic views, but also your wisdom on life. Many thanks; you have been an excellent primary supervisor.

I am also particularly grateful to my wonderful second supervisor, Dr Adam Dennett, for his sage advice and great ideas. You have taken great effort in helping me solve problems and structure the work. Without your constructive criticism and encouragement, this research could never have reached this final stage.

I give my eternal gratitude and greatest respect to Professor Sir Peter Hall, who was my supervisor before he sadly passed. It was he that opened the door for me to the broad and exciting new field of urban and regional planning. I thank him for his far-sighted academic view, and his willingness to spend time helping and encouraging me with my academic endeavours. He has been, and will always be, a source of true inspiration and courage in my lifetime pursuit of knowledge and truth.

Finally, I would like to say a big thank-you to my parents, who have given me never-failing support and understanding in my endeavours over these last few years.
Thanks must also go to all my friends who have helped throughout. A special thank-you is reserved for Yujiang, for his constant support and encouragement.
Abstract

Many urban rail transit systems are being built or upgraded, especially in rapidly-developing Chinese cities, with the aim of redeveloping and regenerating particular neighbourhoods. There are direct impacts (such as improved travel accessibility) and also indirect impacts (land use changes, as well as economic, environmental and social changes) typically associated with transport investment. However, transport investment is only one of the factors affecting the success of a particular development initiative. Previous research studies into other factors have varied in their methodology, and it has been difficult to isolate the most important factors, clearly establish causality, and draw general conclusions that can be used in practice.

There is an emerging body of evidence suggesting that regeneration effects, triggered by urban transit systems, exert different types of impact, not only on geographic locations, but also on different income groups. Hence there are different ‘winners’ and ‘losers’ from investments, and a social equity dimension exists. The social impacts of transport investment are quite poorly understood in the literature.

Evidence is derived from Chongqing (重庆, simplified Chinese), a large, newly-emerging and rapidly-developing city in the Southwest region of the People’s Republic of China (hereafter referred to as, simply, ‘China’). This research aims to understand how investment in urban rail transit might affect urban development in China; how the impact of rail transit differs spatially and across income groups; how to assess the dimensions of (in)equity that arise; and how societies might develop an appropriate strategy for future investment that coordinates and balances the diverse motives and needs of stakeholders in the process.

This research utilises both quantitative and qualitative methodological approaches:
using analysis of census and citywide travel survey data, and also a bespoke local residential survey. A range of statistical techniques is used to examine the socio-spatial distribution of the impacts of rail transit, including logistic regression, geographic weighted regression (GWR), multilevel modelling, MANOVA and discriminant analysis. Based on the interviews of different stakeholders in the transit development process, reflections are made on the policies and planning interventions which might be introduced to achieve greater equity in impacts.

As a result, this thesis has successfully addressed the research questions and contributed to: developing a methodological framework for understanding the direct and indirect impacts of rail transit investment on development; providing a comparative study examining the spatial distribution of the indirect impacts of rail transit investment; evaluating the distribution of benefits and burdens across social groups in Chongqing; and proposing a process to help understand governments’, developers’ and other stakeholders’ views on the impacts of rail transit investment and development.
# Table of Contents

**Chapter 1. Introduction** ................................................................. 23

1.1 Inspiration for this research ......................................................... 23
1.2 Public transit in China: context and gaps in the literature .......... 28
1.3 Research aims and questions ...................................................... 31
1.4 Thesis structure ........................................................................ 32

**Chapter 2. Literature Review** ....................................................... 35

2.1 Introduction: growth in China .................................................... 35
2.1.1 Growth-oriented planning and urban rail investment in Chinese cities .......... 35
2.1.2 Social changes in Chinese society: Labour force and employment ............. 38
2.2 Identifying and measuring the impacts of rail transit .................. 40
2.2.1 Rail transit’s direct impact on travel ......................................... 43
2.2.2 Rail transit’s indirect impacts .................................................. 47
   2.2.2.1 Economic performance ...................................................... 47
   2.2.2.2 Land use development and property value .......................... 50
   2.2.2.3 Labour market and employment changes .......................... 55
   2.2.2.4 Social effects .................................................................. 57
2.3 The synergistic effect of key contributing factors ..................... 64
2.4 Coordination of different stakeholders ....................................... 68
2.5 Case studies .............................................................................. 71
2.5.1 General comparison between selected cases ............................ 71
2.5.2 Review of the cases ............................................................. 74
2.5.3 Lessons drawn from the cases ............................................... 82
2.5.4 The case study of Chongqing ................................................ 83
   2.5.4.1 Chongqing’s development ................................................ 83
   2.5.4.2 Land development process in Chongqing ........................... 97
   2.5.4.3 Spatial strategies of rail transit planning in Chongqing .............. 99
Chapter 3. Methodology ....................................................................................... 105

3.1 Research steps .......................................................... 105
3.2 Research framework .......................................................... 107
3.3 Research design specific to research questions .................. 108
3.4 Data collection of indicators of change .............................. 111
3.5 Methods for exploring spatial variation of direct impacts (research question 1) 112
   3.5.1 Methodological review of global and local models for public transport use analysis 112
   3.5.2 Data source .............................................................. 115
   3.5.3 Analytical techniques (research question 1) ................................. 117
      3.5.3.1 Logistic regression .................................................. 117
      3.5.3.2 Spatial autocorrelation test: Moran’s I ......................... 121
      3.5.3.3 Geographic weighted regression ............................... 123
3.6 Catchment area: definition used in this research ............... 132
   3.6.1 Literature review of the definition of catchment area .......... 132
   3.6.2 Catchment area definition for different analyses – rules and limitations ........ 136
3.7 Methods for exploring spatial variations of indirect impacts (research question 2) ................................................... 142
   3.7.1 Methodological review of existing literature and implications for this study .......... 142
   3.7.2 Data acquisition .......................................................... 144
   3.7.3 Analytical techniques (research question 2) ................................ 145
      3.7.3.1 Comparative study: defining research areas .................... 145
      3.7.3.2 Multilevel regression model .................................... 148
3.8 Methods of exploring social equity of indirect impacts (research question 3) 151
   3.8.1 Methodological review of MANOVA and discriminant analysis for group comparison 151
   3.8.2 Sampling, questionnaire design and data ........................................... 152
3.8.3 Analytical techniques (research question 3) ............................................................. 157

3.9 A statement on data quality and the resulting limitations of model-based analyses 160

3.10 Qualitative analysis ............................................................................................... 163

Chapter 4. Direct travel impact of the transit system ........................................... 167

4.1 Introduction ............................................................................................................ 167

4.2 Description of the statistics .................................................................................. 169

4.2.1 Travel mode choice .......................................................................................... 173

4.2.2 Travel distance ................................................................................................ 176

4.2.3 Car ownership ................................................................................................ 182

4.2.4 Property type ................................................................................................ 184

4.2.5 Non-Hukou holders ...................................................................................... 188

4.3 Results of global logistical regression model .................................................... 192

4.4 Examining spatial autocorrelation ...................................................................... 198

4.5 Geographic weighted regression analysis ......................................................... 203

4.5.1 The coefficient of ‘travel distance’ ................................................................. 204

4.5.2 The coefficient of ‘distance to the nearest rail transit station’ ....................... 207

4.5.3 The coefficient of ‘age’ .................................................................................. 211

4.5.4 The coefficient of ‘car ownership’ ................................................................. 215

4.6 Discussion ............................................................................................................ 218

4.7 Conclusion ........................................................................................................... 219

Chapter 5. Exploring geographic variations in demographic, economic and physical outcomes of rapid rail transit developments ........................................... 223

5.1 Introduction ........................................................................................................... 223

5.2 Research areas and data ...................................................................................... 225

5.3 The secondary impacts of rail transit across different locations .................... 227

5.3.1 Land development ........................................................................................ 227

5.3.1.1 The impact on land development at the city scale ................................. 227

5.3.1.2 Integrated transport and land development at the local scale ............ 232
5.3.2 Population change ........................................................................................................ 246
  5.3.2.1 Population density ................................................................................................ 246
  5.3.2.2 Demographics: age structure ............................................................................. 249
  5.3.2.3 Demographics: household size ......................................................................... 252
5.3.3 Employment change ................................................................................................... 256
5.3.4 Business activities .................................................................................................... 260
5.3.5 Income change .......................................................................................................... 263
5.4 Exploring the relationship between average income level and other indicators of development ....................................................................................... 265
5.5 Discussion ..................................................................................................................... 271
5.6 Conclusion ..................................................................................................................... 272

Chapter 6. Exploring Equity Dimensions of Rail Transit Impact ....................... 277
6.1 Introduction ..................................................................................................................... 277
6.2 Definition of income groups ......................................................................................... 279
6.3 Exploring social equity issues revealed spatially in the survey ............................. 281
6.4 Exploring changes in travel mode share among different income groups .... 287
6.5 Differential impact by income group ........................................................................ 292
6.5.1 The perceived rail transit effects on an individual's local neighbourhood .... 292
6.5.2 The perceived rail transit effects on individuals' lives ....................................... 297
6.5.3 Comparing perceived effects on the neighbourhood and individuals ........ 300
6.6 Discussion ..................................................................................................................... 304
6.7 Conclusion ..................................................................................................................... 305

Chapter 7. Key actor interviews ......................................................................................... 309
7.1 Introduction ..................................................................................................................... 309
7.2 Research findings .......................................................................................................... 311
7.2.1 Disconnected planning strategies and diverse power and interests ............... 312
  7.2.1.1 The dilemma of integrating land use and transport: How development is harnessed in Chongqing .......................................................... 312
  7.2.1.2 Rail transit development in Chongqing: lessons learned from other cities'
experiences ........................................................................................................................................... 317

7.2.2 Gaining a clear impression of the transit system’s effect: properly evaluating impact 321

7.2.3 A lack of an assessment system of benefit distribution ........................................................... 331

7.2.3.1 Identifying the power and interest of different stakeholders ............................................. 331

7.2.3.2 Assessing the ‘winners’ and ‘losers’ and protecting the vulnerable .................................... 333

7.2.3.3 Coordinating different stakeholders’ power and responsibilities ....................................... 335

7.3 Conclusions .................................................................................................................................. 341

Chapter 8. Conclusions ...................................................................................................................... 347

8.1 Current Debate .............................................................................................................................. 347

8.2 Differences in context between the Western experience and China ........................................ 350

8.3 Key findings in answering research questions: ........................................................................ 354

8.3.1 Research findings relating to research question 1 .................................................................. 354

8.3.2 Research findings relating to research question 2 .................................................................. 356

8.3.3 Research findings relating to research question 3 .................................................................. 358

8.4 Thesis contributions .................................................................................................................... 360

8.5 A critique of the methodology ................................................................................................... 364

8.6 Reflections on future research ................................................................................................... 367

8.7 The key priorities for policy makers in Chongqing ................................................................... 370

Appendices ........................................................................................................................................ 377

Appendix 1: Chongqing urban household travel survey 2014 ....................................................... 377

Appendix 2: Transport attitude survey ............................................................................................. 379

Appendix 3: Interview questions for stakeholders .......................................................................... 387

Appendix 4: Interviewee list .............................................................................................................. 390

References ........................................................................................................................................... 391
List of Figures

Figure 2.1: Specification of the source-effect-impact-receptor chain for social impacts of transport. The receptor part consists of ‘impact on individual’, ‘differences between groups’ and ‘social (in)justice’. Sources: (Geurs et al., 2009) .............................................................. 61

Figure 2.2: Case study 1: Canary Wharf, London ................................................................. 74

Figure 2.3: Case study 2: Pudong, Shanghai ........................................................................ 76

Figure 2.4: Case study 3: West Kowloon, Hong Kong .......................................................... 78

Figure 2.5: Case study 4: La Défense, Paris ......................................................................... 80

Figure 2.6: Case study 5: Zuidas, Amsterdam ..................................................................... 81

Figure 2.7: The location of Chongqing Municipality within China and the administrative ...... 84

Figure 2.8: The main urban area of Chongqing. Source: Chongqing's Urban Planning ....... 85

Figure 2.9: The central urban area of Chongqing ................................................................... 86

Figure 2.10: Chongqing rail transit Line 3, opened in 2011. Source: https://www.flickr.com/photos/chenlin3632/9052365040 ........................................................ 87

Figure 2.11: Population change and population growth rate in Chongqing’s main urban area 2007-2015. Source: Chongqing Urban Traffic Annual Report 2015 (Chongqing Transport Planning Institute., 2016) ....................................................................................................... 90

Figure 2.12: Changes associated with GDP sectors and GDP growth rate of Chongqing’s main area 2007–2015. Source: Chongqing Urban Traffic Annual Report 2015 (Chongqing Transport Planning Institute., 2016) ........................................................................................................ 92

Figure 2.13: Changes in passenger traffic volume of the bus system in Chongqing’s main urban area 2007–2015. Source: Chongqing Urban Traffic Annual Report 2015 (Chongqing Transport Planning Institute., 2016) ........................................................................................................ 94

Figure 2.14: Changes in passenger traffic volume of the rail transit system in Chongqing’s main urban area 2007–2015. Source: Chongqing Urban Traffic Annual Report 2015 (Chongqing Transport Planning Institute., 2016) ........................................................................................................ 95

Figure 2.15: Changes in the total number of private cars in Chongqing’s main urban area 2007–2015. Source: Chongqing Urban Traffic Annual Report 2015 (Chongqing Transport
Figure 3.1: Research steps

Figure 3.2: Research framework

Figure 3.3: Twenty-five transport zones in the city of Chongqing. The study region included zone 1, zone 2, zone 10, and zone 11 (dark grey).

Figure 3.4: A spatial kernel. Source: (Fotheringham et al., 2003)

Figure 3.5: GWR with fixed spatial kernels. Source: (Fotheringham et al., 2003)

Figure 3.6: GWR with adaptive spatial kernels. Source: (Fotheringham et al., 2003)

Figure 3.7: Reference regions, station catchment areas and areas not affected by stations

Figure 3.8: Comparison between rail station catchment areas and reference area

Figure 3.9: Statistical comparison of diverse fields

Figure 3.10: Key research aspects of questionnaire studies

Figure 3.11: Two facets to explore in the questionnaire study

Figure 3.12: Defining social groups

Figure 4.1: Descriptive analysis: travel mode choice. Higher saturation (of purple colour) and larger radius of a data-point indicate a larger proportion of people in that grid who chose rail transit as their mode of travel. The value on the colour-bar represents the average score in each grid, between 0 and 1 (arbitrary units). 1 means all the people in the grid choose transit, 0 means no-one choose transit.

Figure 4.2: Descriptive analysis: travel distance. Higher saturation (of blue colour) and larger size of data-points indicates a longer travel distance. Travel distance values on the colour-bar are in units, metres.

Figure 4.3: Descriptive analysis: car ownership. The saturation (of yellow colour) and size of data-points show the categorical levels of car ownership. The larger yellow points indicate two or more cars; the smaller darker yellow points indicate one car; and the smallest dark grey points indicate no cars.

Figure 4.4: Descriptive analysis: property type. Larger, blue points represent luxury properties; smaller, light-purple points represent ordinary properties; the smallest dark purple points represent old properties.

Figure 4.5: Descriptive analysis: Non-Hukou status. The saturation (of pink colour) and size of
points indicate the categories of non-Hukou status. The larger pink points represent non-Hukou holders, and the smaller grey points represent Hukou holders. ................................. 191

Figure 4.6: Residual map of the binomial logistical model ................................................................. 199

Figure 4.7: Distance based K-nearest neighbours, when K = 4 ................................................... 200

Figure 4.8: Contiguity based neighbours with Queen's rule .......................................................... 202

Figure 4.9: Coefficient (B in Table 4.8) of the independent variable travel distance in predicting choice of rail transit as mode of travel. The coefficient represents the change of logit of the outcome variable (travel mode choice) associated with a 1 km change in travel distance. Bright yellow indicates a higher (more positive) value of coefficient than dark red. ............................................................................................................................................. 205

Figure 4.10: Coefficient of the independent variable distance to nearest transit station in predicting rail transit as choice of mode of travel. Presented as per Figure 4.9, but for 1 metre change in distance to nearest transit station. Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values. ......................... 209

Figure 4.11: Coefficient of the independent variable age in predicting choice of rail transit as mode of travel. Presented as per Figure 4.9, but for a 1 year change in age. Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values............................................................... 213

Figure 4.12: Coefficient of the independent variable car ownership in predicting choice of rail transit as mode of travel. Presented as per Figure 4.9, but for a one unit change in the categorical variable ‘car ownership.' Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values....................................................... 217

Figure 5.1: Land development in the whole city region .................................................................... 229

Figure 5.2: Land development in the central city ........................................................................... 234

Figure 5.3: The building to the right with the train line passing through it is Liziba Building at Rail transit station Line 2. Source: http://news.skykiwi.com/world/dl/sh/2014-08-01/183539.shtml ................................................. 235

Figure 5.4: The train passed through the Liziba Building. Source: http://chuansong.me/n/413798443078 ............................................................... 236

Figure 5.5: Entrance to the rail transit Line 1 and 2, through the ground floor of the building.
The ground outside the building is occupied by the vendors ......................................................... 238

Figure 5.6: Residential buildings next to the Qingguishangcheng property development .... 238

Figure 5.7: Xinganxian Building above Lianglukou station at the junction of Line 1 and Line 2. 
Source: http://www.panoramio.com/photo/105594774 .......................................................... 240

Figure 5.8: Shidaitianjie Project at Shiyoulu rail transit station in the old city area.......... 242

Figure 5.9: Communities nearby. The established residents sit outside their residential buildings in an ordinary afternoon. ....................................................................................... 243

Figure 5.10: Communities nearby. Shops along the streets after a rain shower. .......... 243

Figure 5.11: Zhongyu Project at Jiazhoulu rail transit station. Source: Jiazhou Commercial Centre Plan (2013) ................................................................................................................ 245

Figure 5.12: Population density in research areas: comparison of different locations. Source: Chongqing census data, 2007-2013 ........................................................................................................ 248

Figure 5.13: Percentage of people below 16 years old. Source: Chongqing census data, 2007-2013 ............................................................................................................................. 251

Figure 5.14: Percentage of people above 60 years old. Source: Chongqing census data, 2007-2013 ............................................................................................................................. 251

Figure 5.15: Percentage of people between 16 and 60 years old. Source: Chongqing census data, 2007-2013 .................................................................................................................... 252

Figure 5.16: Single-person household percentage for each area. Source: Chongqing census data, 2007-2013 ........................................................................................................................................ 254

Figure 5.17: Two-to-three person household percentage. Source: Chongqing census data, 2007-2013 ....................................................................................................................................... 255

Figure 5.18: Multi-person household percentage. Source: Chongqing census data, 2007-2013 ........................................................................................................................................ 255

Figure 5.19: Employment density in research areas: comparison of different locations. Source: Chongqing census data 2007-2013 ........................................................................................................... 257

Figure 5.20: Employment/residential population balance: comparison of different locations. Source: Chongqing census data 2007-2013 .................................................................................... 259

Figure 5.21: Locally-employed population number in Daping Sub-district (DPSD). Source: Chongqing census data 2007-2013 ........................................................................................................ 260
Figure 5.22: Annual increased numbers of firms registered (per 10,000 population) in Longxi Sub-district. Source: Chongqing census data, 2007-2013 .............................................................. 261

Figure 5.23: Annual increase in number of self-employed entrepreneurs in Longxi Sub-district. Source: Chongqing census data, 2007-2013 ........................................................................ 262

Figure 5.24: Income level: comparison of different locations. Source: Chongqing census data 2007-2013 ............................................................................................................................. 263

Figure 6.1: Perceived transit effect on community harmony and importance of community harmony to individuals: comparison of different locations. The perceived effect ranges from -2 to 2, while the importance to individuals is from 0 to 2. Source: Primary survey data (Lixun Liu) .................................................................................................................... 283

Figure 6.2: Perceived transit effect on local employment increase and importance of local employment increase to individuals: comparison of different locations. The perceived effect ranges from -2 to 2, while the importance to individuals is from 0 to 2. Source: Primary survey data (Lixun Liu) .................................................................................................................... 285

Figure 6.3: Perceived transit effect on property price rising and the impact on individuals: comparison of different locations. Source: Primary survey data (Lixun Liu) ........................................... 286

Figure 6.4: Canonical discriminant functions of perceived importance of transit effects on the local neighbourhoods ........................................................................................................... 297

Figure 6.5: Canonical discriminant functions of perceived impacts or importance of transit effects on the individual ........................................................................................................ 300

Figure 6.6: Function 1 variables plotted against income group .................................................. 302

Figure 6.7: Function 2 plotted against income group ................................................................. 303

Figure 7.1: Answers from different stakeholders to the question: what do you think the most significant impacts of the rail transit investment are? The y-axis shows the mean number of mentions (number of mentions divided by number of individuals in that professional group). .......................................................................................................................... 323

Figure 7.2: Answers to the questions: What are the most important factors in influencing investment decisions? The y-axis shows the mean rating of importance for each professional group. .......................................................................................................................... 326

Figure 7.3: the urban planner’s perspective on the impact of rail transit investment .......... 327
Figure 7.4: the transport planner’s perspective on the impact of rail transit investment ...... 328
Figure 7.5: Results of the question: The importance of the factors for development and
regeneration in the rail transit impacted areas ................................................................. 330
Figure 7.6: Power and interest evaluation of different stakeholders: average score from
interviewees’ answers .................................................................................................... 333
List of Tables

Table 2.1: General comparison between the cases ......................................................... 73
Table 2.2: Comparison of economic and transport indices of main urban areas among
Transport Planning Institute., 2016)................................................................................... 89
Table 2.3: Changes in GDP and its sectoral compositions of Chongqing’s main urban area
Planning Institute., 2016).............................................................................................. 91
Table 2.4: Travel mode share of residents in terms of trips in the main urban area of
(Chongqing Transport Planning Institute., 2015) .............................................................. 93
Table 2.5: Main research findings in the literature of the impacts of rail transit investment and
perceived ‘knowledge gaps’............................................................................................. 102
Table 3.1: Data source for indicators of change ................................................................ 112
Table 3.2: Variables of indirect impacts in comparison method................................................ 145
Table 3.3: Gender proportion comparison: census data and survey data. Source: 2013
Chongqing census data and 2014 Attitudinal survey data ............................................ 156
Table 3.4: Age proportion comparison: census data and survey data. Source: 2013
Chongqing census data and 2014 Attitudinal survey data ............................................ 156
Table 3.5: Migrant proportion comparison: census data and survey data. Source: 2013
Chongqing census data and 2014 Attitudinal survey data ............................................ 157
Table 3.6: Car ownership comparison: citywide travel survey data and survey result. Source:
2014 Chongqing travel survey data and 2014 transport attitude survey result................. 157
Table 3.7: Table of interviewees...................................................................................... 165
Table 4.1: Description of variables for model, for all users................................................ 171
Table 4.2: Percentage of people’s commuting travel mode grouped by region. Source:
Citywide household panel travel survey 2014 ................................................................. 176
Table 4.3: Left: Percentage of travel distance categories grouped by region. Right: Average
travel distance for users of all travel modes and for the rail transit users, grouped by region.

Source: Citywide household panel travel survey 2014 ................................................................. 180

Table 4.4: Percentage of transit use in different travel distance categories grouped by region.
Source: Citywide household panel travel survey 2014 ........................................................................ 181

Table 4.5: Percentage of transit use grouped by household car ownership. Source: Citywide household panel travel survey 2014 ..................................................................................... 184

Table 4.6: Percentage of transit use grouped by different property types. Source: Citywide household panel travel survey 2014 ..................................................................................... 188

Table 4.7: Coefficients of the binary logistical regression model with seven variables ......... 194

Table 4.8: Coefficients of the binary logistical regression model with significant variables .. 195

Table 4.9: Moran's I statistics of residuals of binomial logistical regression for all the users 201

Table 5.1: Summary of reference regions and case study areas. Source: Chongqing census data, 2007-2013 .................................................................................................................... 226

Table 5.2: Population density in research areas: comparison of different locations. Source: Chongqing census data, 2007-2013 .................................................................................................................... 248

Table 5.3: Employment density in research areas: comparison of different locations. Source: Chongqing census data 2007 -2013 .............................................................................................. 258

Table 5.4: Income level: comparison of different locations. Source: Chongqing census data 2007-2013 ............................................................................................................................. 264

Table 5.5: Tests of fixed effects: a linear trend of growth ................................................................. 267

Table 5.6: Coefficient estimate: a linear trend of growth ................................................................. 268

Table 5.7: Tests of fixed effects: a quadratic trend of growth ......................................................... 268

Table 5.8: Coefficient estimate: a quadratic trend of growth ......................................................... 269

Table 6.1: Income group definition ........................................................................................ 280

Table 6.2: Spatial distribution of household annual income level from 2014 attitudinal survey. Source: Primary survey data (Lixun Liu) ........................................................................................................... 281

Table 6.3: Household income groups and current travel mode share. Source: Residents’ perception survey in rail transit station catchment areas 2014 by the author ....................... 289

Table 6.4: Current travel mode share of previous private automobile users (car, taxi or company special bus) divided by different categories of household income. Source: Residents’
Table 6.5: Current travel mode share of previous public travel mode users (bus or walk) divided by different categories of household income. Source: Residents' perception survey in rail transit station catchment areas 2014 by the author.

Table 6.6: Multivariate tests of perceived transit effects on the local neighbourhood.

Table 6.7: Eigenvalues of discriminant functions of differentiating income groups.

Table 6.8: Significance of discriminant functions on differentiating income groups.

Table 6.9: Structure matrix: discriminant analysis of perceived transit effects on the local neighbourhoods.

Table 6.10: Multivariate tests of perceived importance and impacts of transit effects on individuals' lives.

Table 6.11: Structure matrix: discriminant analysis of perceived impacts or importance of transit effects on individuals' lives.

Table 7.1: Table of the question: Please give a score of the importance of the factors for development and regeneration in the rail transit impacted areas.
Chapter 1. Introduction

1.1 Inspiration for this research

The structure and function of modern ‘global cities’ are influenced by economic, technological and social factors. Together, these affect both the relationship between cities and the internal structure within individual cities (Hall, 2001). Within this context, a key contributing force over the 20th century has been globalisation. Another fundamental factor has been the rise of the ‘information economy’, which is the shift of advanced economies from goods production and handling to information processing (Hall, 1988, Castells, 1989). The prevailing forces in the post-industrial era have overlaid a new order of space — of economic and information flows in the global system — on top of the original “space of places” (Hall and Pain, 2006), and lead to the emergence of a highly complex “space of flows” (Castells, 1989); thus reconfiguring previous geographical relationships. The associated economic and technological revolutions have placed new requirements on geographical locations, in order for them to be attractive to people and businesses. Physical geography is no longer as important as the knowledge and skill levels of the population, or there being access to high quality transport and communications infrastructure (Hall and Pain, 2006).

In response to the economic restructuring changes of the information age, two main forces — ‘concentration’ and ‘dispersal’ — have had spatial implications on the urban form (Hall and Pain, 2006). The principle of access to information governs the

---

1 A ‘global city’ refers to one large and important enough to be considered a node in the global economic system.
2 ‘Concentration’ is often defined as the process in which an increasing proportion of a country’s population is concentrated in urban areas. ‘Dispersal’ is associated with decentralisation or urban sprawl; it describes the expansion of human populations away from central urban areas, usually into low-density and usually car-dependent communities.
new locational rationale, under the force of concentration. The importance of face-to-face contact still remains — encouraging agglomeration\(^3\) in major cities, where information is generated and easily exchanged (Sassen, 2001), as well as requiring convenient travel within major cities, which often function as transportation nodes (Cervero, 1998, Hall and Pain, 2006). Thus these big cities are not only centres for financial services, major companies and governments, but also attract clusters of other specialised business services and associated functions, which generate demand for transportation and communication (Porter, 1998, Sassen, 2001). The other countertrend brought on by the information age has been dispersal (Cervero, 1998). Smaller towns and cities tend to cluster around one or more larger central cities: physically separate but functionally networked; drawing economic strength from a new functional division of labour, and also exchanging information which bypasses the central city (Christaller, 1966).

As a result, the two forces of concentration and dispersal have produced a variety of urban and suburban landscapes and posed significant changes to transport (Cervero, 1998, Hall, 1999). The cities where there is an ‘agglomeration economy’ appear to be undergoing a process of simultaneous ‘concentrated de-concentration’ at different geographical scales (Bontje, 2001, Bontje, 2003, Schuyt and Taverne, 2004). Over a wide city region, there is a trend for dispersal, and re-concentration at particular nodes (Christaller, 1966). However, this de-concentration of both housing and employment away from big cities is not leading to greater self-containment of settlements: instead it stimulates travel between nodes. As a result, cities experience the serious problems of car traffic associated with the ‘automobile age’. So-called ‘sub-global’ cities (below global cities in the hierarchy) also tend to have problems associated with congestion and de-concentration (Hall, 1995a), as well as problems relating to environment issues. Furthermore, there is a need to consider

---

3 In urban economics, ‘economies of agglomeration’ means the benefits that firms obtain by locating near each other.
the sustainability of both development and regeneration: working towards the more sustainable cities of the future (Banister, 2008).

To address sustainability concerns, a main solution seems lie with measures to reduce car use and to provide effective public transport (Thomson, 1978). Integrated land use and transport planning strategy is key to this, in order to provide people with attractive, safe alternatives to using the car (e.g. pedestrian-friendly city centres with safe bike routes and convenient public transport links). A rich range of literature has been published on this subject (Breheny, 1992, Breheny, 1995, Hall et al., 1993, Frank and Pivo, 1994, Cervero and Gorham, 1995, Banister et al., 1997, Ewing and Cervero, 2010). However, this literature largely focuses on planning strategies, whereas relatively few successful example case studies have been published. There is generally a consensus on the need for higher densities, mixed uses and the planning of development form around the public transport network (Banister and Hickman, 2006, Banister, 2007, Hickman and Banister, 2007). However, there is still some dispute as to whether, and how, to implement a strategic planning framework to reduce automobile use (Gordon and Richardson, 1989, Echenique et al., 2010). The dissenting views largely arise from the classical transport economist’s viewpoint — perceiving that organisation of urban areas should be left to the market rather than involving public intervention. It is argued that designing and structuring sustainable cities should not only consider physical factors, but also demographic, economic, social and spatial factors (Hall, 1995a).

When dealing with transport problems, it is important to consider both demand-side and supply-side factors. Demand-side measures seek either to reduce, or shift, travel demand. By creating an urban environment of compact, mixed-use neighbourhoods that are conducive to use of public transit, these strategies aim to provide sufficient ridership demand to support public transport services (and intensive rail services in particular). On the other hand, supply-side initiatives aim to provide facilities and services to accommodate people’s wishes to travel; for
example, providing rail transit system improvements as alternatives to highway expansion. There is thus a reciprocal relationship, where the urban environment shapes the organization and delivery of rail transit services, but also rail transit investment and services alter and reshape the urban environment they serve. The demand-side and supply-side responses complement each other, and are consonant with the broader objectives of sustainable development. Therefore they should be embodied in urban development strategies (Cervero, 1998).

Within the context of urban sustainability, the principle of ‘sustainable concentrated de-concentration’ has been put forward (Hall and Ward, 1998, Bontje, 2003, Schuyt and Taverne, 2004). In this, it is suggested that growth should be guided onto selected development corridors along strong public transport routes, or as clusters of urban development around train stations and key motorway interchanges, rather than there being continuous urbanisation. The effect of rail transit systems on guiding such development have been widely studied over the past century.

Comparisons between cities, with and without regional rail systems, suggest that rail investment has some clustering effects, leading to a more polycentric metropolitan form than would have existed if no rail transit system been built (Cervero and Landis, 1995). So-called ‘transit-oriented development’ (TOD) was proposed by Peter Calthorpe in US (and the ideas of Breheny and Rookwood, in the UK, are similar). In this, settlements of different scales are strung like beads on a string along public transport corridors, which range from bus routes to heavy rail systems. Walking-scale suburban developments are proposed to be established around public transport stops, with jobs and services clustering at the nodes (Owens, 1992, Calthorpe, 1993, Breheny, 1992, Breheny and Rookwood, 1993, Breheny, 1995, Hall and Ward, 1998). This can assist remote areas, by reducing the need for long distance commuting using the public transport system (Kloosterman and Musterd, 2001). For example, integrated land use and transport planning strategies have been developed in the Netherlands to enhance the role of public transport, aiming
to reduce traffic and cope with pressure from growth. The Dutch ‘ABC’ location policy suggests that residences, work areas and amenities be concentrated to produce the shortest possible journey distance, ideally by public transport (Hall and Ward, 1998).

To support the aims of both regeneration and development, public rapid transit systems are continuing to be built or upgraded in cities around the world. There are examples where rail lines have been built in advance of new development, and have provided convincing evidence that transit can shape cities and regions. Rapid transit infrastructure continuously interacts with the developing urban form, particularly in supporting sustainable objectives. Most such developments were carried out in an era before the ascendancy of the automobile: prior to the 1930s in America, and the 1970s in Europe. However, even then, the positive impacts of rail transit — such as increased employment — are dependent on there being existing growth and development in an area; for example, increasing job opportunities more generally. There are also issues as to whether people are willing to move to planned residential sites, and where these are, relative to their work-place (Hall, 1995a, Feitelson and Rotem-Mindali, 2015). Finally, although public transport was probably most influential before the automobile era, there is a modern renaissance in public transport, which is beginning to have very large developmental impacts on modern cities.

In summary, the prevailing forces in the post-industrial era have overlaid a new order of space in the global system — one of ‘economic and information flows’ — on top of the original ‘space of places’. More locally, these forces seem to lead the urban form to exhibit both concentration and dispersal. Environmental issues arise particularly in cities with transport congestion. Supporting sustainable urban development through mass public transport needs to consider not only physical factors, but also demographic, economic and social concerns (Feitelson and Rotem-Mindali, 2015). An effective solution is always contextually sensitive.
General aim of this thesis

This thesis aims to explore the impact of rail transit on development and regeneration in modern car-dominated metropolises, with a particular focus on rapidly-developing Chinese cities, where rail transit services have been newly introduced. The specific research questions are presented later, in Section 1.3.

The research presented here is carried out within the context of (and taking inspiration from) the broader literature in the sustainable urban development field, as discussed above.

1.2 Public transit in China: context and gaps in the literature

Many rail transit systems are being built or upgraded, especially in rapidly-developing cities in China (and other countries in east-Asia), with the aim of redeveloping and regenerating particular neighbourhoods.

There are both direct and indirect impacts associated with investment in transport infrastructure. The direct impacts mainly relate to improvements in accessibility to transport (Banister and Berechman, 2003), which can provide the benefits of cheaper distribution of goods and an expansion of the labour market area (Townroe, 1995). In locations of particularly poor existing accessibility, or uncompetitive areas just opened to competition, a regional connection added by transport investment tends to have an impact on both regional and local development (Hall, 1995a, Vickerman, 1995, Vickerman, 2008). However, in an already dense and congested network (except where there is a major change in connectivity) the change in accessibility doesn’t have a significant long term impact (Hall and Banister, 1995, Banister, 1998, SACTRA, 1999, Llewelyn-Davies et al., 2004). Aside from this direct
impact, transport investment can potentially also lead to economic, land use, environmental and social changes. These are the so-called ‘secondary’, or ‘indirect’, benefits of transport investment on the wider aspects of urban development. It is these secondary benefits that are frequently cited as likely to impact urban economic regeneration, and are often used to justify specific investment (Townroe, 1995). But a key question is whether one can define the specific dimensions of these indirect benefits to urban development.

There is some emerging evidence on relationships between urban structure and transport in China (Shen, 1997, Cervero and Day, 2008, Wang and Chai, 2009, Wang et al., 2011, Pan et al., 2009, Pan et al., 2013, Zhao, 2010). However there is less work, to my knowledge, on the relationship between transit investment in China, and its economic and social impacts. For all studies, it seems that contextual issues are important — hence it is not clear that findings generalise well between different cities. Empirically, the challenge is to isolate a range of factors to observe the impact of rail transit, and to show temporal and spatial changes.

Research methodologies vary across studies, and it has been difficult to isolate impacts, to clearly establish causality, and to draw general conclusions that can be used in practice. The details of the context appear critical. Transport investment is only one of the factors affecting development change; but it is a very important factor. In a rapidly-growing Chinese city, where the evidence is particularly scarce, the availability of ex-post (after the event) assessment is usually very limited; and any ex-ante assessment (before the event) of the developmental impacts of transit investment can often be a step into the unknown, as there is little evidence to base projections on.

There is an emerging body of evidence suggesting that the regeneration effects triggered by urban transit systems exert different types of impact, not only on geographic locations, but also on different income groups; hence there are different
‘winners’ and ‘losers’ from investments, and there is a social equity dimension to the spatial impact of such systems. In the literature, the social impacts of transport investments are quite poorly understood, even though disparities in social equity are likely to arise, due to modifications in accessibility and to the built environment. In China, social equity issues are of great importance, as there is much focus given to social cohesion (The Central Committee of the Communist Party of China and The State Council of the People’s Republic of China., 2014). Changes to the development form, the use of buildings, the value of land and property, and employment opportunities, are all likely to have diverse impacts on different population cohorts. Transport provision can often fail to meet people’s specific, or even minimum, needs, in terms of their social characteristics, skills, financial status, preferences and attitudes. When there are disproportionate numbers of benefits or burdens of an initiative for particular areas and/or social groups, this can lead the emergence of actual (or, at least, perceived) inequity.

Understanding this spatial variation in the demographic and socio-economic impacts of transit investment can be challenging, as many of the impacts are indirect and are likely to be lagged by some time period. One way to conceive of this spatial variation is to view it through the lens of spatial inequity. Total investment has accounted for almost half of China’s gross domestic product (GDP) growth rate over the last five years4, and is increasingly required to sustain economic growth objectives (Qing, 2012). Massive spending on infrastructure has hugely improved connections within and between cities. Since 1992, China has spent 8.5% of its national income on infrastructure per year, far more than Europe or America (2.6%), or India (3.9%) (The Economist., 2015a). However, according to the Chinese Prime Minister’s report at the annual session of the National People’s Congress on March 5th, 2016, the Chinese government has called for a lower rate of growth in fixed-asset investment (The Economist., 2016a). Beyond the headline GDP growth

4 https://www.quandl.com/data/ODA/CHN_NID_NGDP-China-Total-Investment-of-GDP
figures, the socio-economic, demographic and built-environment impacts of urban transit investment are dramatic across many Chinese cities, but these impacts vary spatially with different population cohorts.

1.3 Research aims and questions

This research aims to understand how investment in urban rail transit might affect urban development in cities in China; how the impact of rail transit differs spatially and across income groups; how the dimensions of (in)equity that arise can be assessed; and how societies might develop an appropriate strategy for future investment that coordinates and balances the diverse aspirations and needs of stakeholders.

Research question 1:
What direct impacts are associated with metro investment in China, and how do these differ spatially, and by population group, within cities?

Research question 2:
What wider (indirect/secondary) impacts are associated with metro investment — including demographic impacts, employment changes and land development — and what is the strength of the relationships between investment and these impacts?

Research question 3:
What social equity/inequity impacts are associated with metro investment, in terms of actual and perceived impacts on the neighbourhood and on individuals?
1.4 Thesis structure

The remainder of this thesis is structured as follows:

Chapter 2: Literature review
A critical examination of the research field is provided, exploring: the effect of rail transit at the city level and the local level; and the spatial and social equity dimensions of transport; deriving an understanding of any ‘knowledge gaps’ in the literature.

Chapter 3: Methodology
A research framework is introduced, which can be used to assess the direct and indirect impacts of transit investment, and a methodology for examining the social distribution of impacts. The datasets used and statistical analysis methods employed are also introduced.

Chapter 4: Direct travel impacts of transit systems
The distributional and equity dimensions of people’s travel mode choice are examined across space and time. Logistic regression and geographic weighted regression (GWR) models are used to explore how new rail transit systems, and other influential factors, contribute to people’s travel mode choice; how this varies over space; and how to explain these variations, given the local context.

Chapter 5: Exploring geographic variations in demographic, economic and physical outcomes of rail transit developments
The wider impacts of transport are examined across space and time — including impacts on the economy, employment, population and land development. Longitudinal descriptive analysis is used to compare the diverse impacts of rail transit among different locations, and the effect of other influential factors, such as the local economic environment and policies. A multi-level regression model is used
to explore how the average income level of people in different locations has changed over time, before and after transit opening, and to explore the influence of other associated variables.

Chapter 6: Exploring the equity dimensions of rail transit impact

The impacts of rail transit on development and regeneration are examined, to explore how they differ across income groups, and to assess the equity dimensions that arise. MANOVA (multivariate analysis of variance) and discriminant function analysis (hereafter referred to simply as ‘discriminant analysis’) are used to understand whether the new transit developments in Chongqing have been to the benefit of all citizens, by examining the ways in which people from different socio-economic groups perceive the impacts of new transit developments on their neighbourhoods and on themselves.

Chapter 7: Key actor interviews

Qualitative interviews of different stakeholders in the transit development process are used to examine the underlying obstacles to rail transit investment, and the proposed integration of transport and land development. Implications and recommendations for the institutional and political systems involved are also discussed.

Chapter 8: Discussion and conclusions

Thesis contributions and key research findings from the results sections are presented, as well as a reflection on the methodology used in this thesis, and thoughts on future research.
Chapter 2. Literature Review

2.1 Introduction: growth in China

2.1.1 Growth-oriented planning and urban rail investment in Chinese cities

Since the ‘reform era’ and opening of the market in the 1970s, China has steadily adopted a market-oriented approach. In 1994, a new tax-sharing system was introduced by the Chinese government. In this system, tax resources of the central and local government were separated. Only 25% of value added tax (VAT) was allowed to be retained by local government. Also, all extra budgetary revenues and revenue from the sale of land could be kept by the municipal government (Wu, 2015). With the financial pressures of balancing local revenue and expenses for public and social services, local governments have resorted to land development as a vital means of generating revenue. In this way, land development has become a mechanism for facilitating growth. Due to this incentive, local governments have participated directly in land and infrastructure development. This entrepreneurial-like behaviour of local governments explains why infrastructure investment has been heavily subsidized since the mid-1990s (Jessop and Sum, 2000, Wu et al., 2015).

Since these 1970s reforms, the proactive role of planning has been demonstrated to have been an important factor in strengthening the economy, as well as in shaping the financial market. Planning in China can therefore be said to be growth-oriented, whereas the distribution of generated benefit to the whole society is rather limited.

---

5 China’s reform era was a period starting in the late 1970s/early 1980s, when reformists within the Communist Party of China carried out economic reforms.
and the consideration and coordination of the needs of stakeholders is generally poor. Political support, at the highest level, for planning fosters confidence among political leaders, as well as among investors. Planning has proven to be the primary tool for municipalities to attract new industrial and residential developments, and indispensable for long-term economic success. Production of ‘strategic plans’ by local political leaders has been a key method for promoting their particular areas. This is having a clear effect on the urban form in China. Urban planning has played a crucial role in opening up opportunities for the expansion of suburbs for large-scale development. This often involves the conversion of agricultural land to urban land, with the associated, necessary demolition. Urban planning targeted at a particular location can indicate its future prosperity, and due to the government’s investment and favourable policies, this can lead to an increase in local land value. Specifically, the government improves the land by providing infrastructure and other public amenities (Wu, 2010, Wu et al., 2015, Wu, 2015).

In 2012, the Chinese central government announced a stimulus of about ¥800 billion (bn) CNY (Chinese Yuan Renminbi; about $127 bn USD), to be used over the next three to eight years for building twenty-five subways and elevated rail lines across China, with the aim of increasing mobility for the population in a rapidly urbanising nation. By 2014, twenty-two cities had begun operating eighty-three rail transit lines in China. The vast majority of these lines were newly-built since 2000 (China Research and Intelligence Co. Ltd., 2015, Cao and Pan, 2016). In China’s three largest metropolitan areas — Guangzhou, Shanghai, and Beijing — there are more than 5 million passenger rides each day; even more than similar networks in New York or Paris. It is planned that by 2020, China will have forty cities, with metros extending to around 7,000 kilometres in total distance (Freemark, 2012).

In a comparison of the program initiated by the Chinese Ministry of Transport (MoT) in 2011, to fund more than thirty cities, with the proposals in the book Transit Metropolis (Cervero, 1998), Zhou (2016) argues that, although the MoT program has
similar motivations for developing transit as Cervero described, the former actually offers more extensive technical standards and performance measures. However, it overlooks the integration of transit with land use development, housing options and pedestrian infrastructures. Collective effort from different government entities is therefore recommended to promote the integrated development of transit and land use in the future (Zhou, 2016, Cao and Pan, 2016).

Although the high ridership of the newly-constructed lines has not yet brought operational profitability to these systems, and these rail transit systems require heavy operational subsidies, Chinese officials recognize that their investments (in addition to offering an important economic stimulus) provide positive externalities that outweigh the subsidies that will be required to maintain the systems. By setting fares low, the rail lines are able to attract higher ridership and passengers from across the income spectrum. Even in the densest, most packed city centres, rail transit systems allow largely congestion-free mobility (The Economist, 2015a). According to People’s Daily (the largest official news group in China), the number of private automobiles in China doubled between 2011 and 2015, reaching 124 million — an average of 31 cars per 100 households. It is hoped that spending on new rail transit systems will encourage a large percentage of the population to remain or become public transit users, rather than switching to private cars, even when people’s income increases (Freemark, 2012).

Sufficient evidence has been provided in other developing countries that deficiency in governmental investment in urban rapid transit networks has effectively failed their populations, by offering them little alternative to automobile use, and thus encouraging pollution and road congestion. For example, the severe traffic congestion in Manila, the Philippines, is said to result from the city government’s failure to build an extensive, high-volume public transport system, and their inability

---

to regulate the hundreds of private bus companies (The Economist., 2016b). These are considered by the Chinese government to be lessons for (and situations to avoid in) China’s big cities.

### 2.1.2 Social changes in Chinese society: Labour force and employment

In contemporary Chinese society, the difference between urban and rural household income has greatly increased. Drawn from official data, China’s Gini coefficient” (Lucas et al., 2016) went from less than 0.3 in the 1980s, making it one of the world’s most equal countries, to nearly 0.5 today, making it one of the least equal countries (Sicular, 2013, The Economist., 2016e). This increasing gap has been accompanied by an increase in overall social inequality, and in inequality between different social groups inside cities. A ‘new poor’ have been created both from the working poor of rural migrants and the laid-off workers of the city (Solinger, 2006, Wu, 2015).

The Hukou (户口), or ‘household registration’ system in China has a dichotomy between urban and rural systems. Hukou was introduced in the 1950s, in order to prevent a rush of migrants from the vast countryside to the cities, because of a fear that this rural migration might destabilize the cities of the still-young Republic. Under state socialism, social welfare provision in the city was associated with one’s affiliation with a workplace. The urban Hukou system determines that a person can enjoy subsidised public services, such as health care and education in urban areas, which rural Hukou holders are excluded from. The rural migrants who are ineligible for state cover have had to rely on the market provision of public services (Wu, 2015). However, since the 1990s, migration has become the impetus for a

---

7 The Gini coefficient is a statistical measure of inequality. 0 is perfectly equal; 1 is very unequal. The UK’S Gini Coefficient was 0.3 in 2012, while for the US it was 0.4 in 2012. http://data.worldbank.org/indicator/SI.POV.GINI?end=2014&start=2014&view=bar
manufacturing boom in China (The Economist., 2015b). This migration is viewed as the biggest movement of humanity that the planet has seen in the past three decades. Rural to urban migration has officially caused the urban population to expand by an additional 500 million people. Over half of that number is now officially ‘urban’, while the other 200 million (or more) do not have the benefits of urban Hukou (The Economist., 2015a). The pernicious impact of the Hukou system, nowadays, has aggravated a huge social divide in China’s cities, and curbed the free flow of labour (The Economist., 2015b).

Except for the rural migrants, there is another large underprivileged population in Chinese society: the laid-off employees of state-owned enterprises (Wu, 2015). In China, the state-owned enterprises (SOEs), with their political backing, have traditionally had far easier access to finance, and dominate a series of sectors, from energy to transport. These privileges, along with heavy subsidies from central government, carry with them the obligation to help maintain social stability by refraining from laying off workers. However, with industrial restructuring, SOEs don’t have infinite resources. Loss-making industries, which face being eliminated in the industrial upgrading and transformation process, are shedding workers constantly. After being laid off, the social welfare of the previous workers is transferred from their former workplaces to local governments.

In 2015, the service-sector accounted for more than half of China’s GDP, and the output of this sector is continuing growing. With the expansion of this sector, which is more labour-intensive than industry, more jobs are generated. However, many of the service-sector jobs are destined for younger people with higher education. It is reported that opportunities to acquire jobs as higher-level service-sector workers or lower-level restaurant servers are still both plentiful. But for those who lose jobs in the industry sector, it is extraordinarily difficult to adjust from physical labour to higher-skilled activities (The Economist., 2016d).
2.2 Identifying and measuring the impacts of rail transit

Stimulated by the economic trends of globalisation, and the decentralisation of residence and employment, travel demand in the automobile age is ever rising. This results in serious traffic problems, as well as environment issues. With limitations on urban space and land-use, travel intensity is increasing at a faster rate than car capacity can increase in cities. If the centre of the city is only served by road traffic, both economic and social costs escalate enormously (Thomson, 1978). Automobile-directed patterns of growth also consume many more resources than well-functioning rail-oriented development (Cervero and Landis, 1995). Furthermore, cities are increasingly calling for solutions that can provide a sustainable future (Banister, 2008). Any solution to the cities’ problems should be based on a stable, practicable equilibrium between these different forces of re-concentration and dispersal, which have their spatial implications on the urban structure (Thomson, 1978). The solution to great cities’ transport and environmental problems is widely recognized to lie in measures to reduce car-use, and to provide effective public transport (Calthorpe, 1993, Cervero, 1998, Bertolini et al., 2009, Cao and Pan, 2016). Mass urban rail systems are thus widely considered as a sustainable tool, which can make more efficient use of land and provide transport capacity (Pan and Zhang, 2008, Cervero and Day, 2008, World Bank., 2010, Duncan, 2010).

It is also widely accepted that the primary benefit of transport infrastructure investment is in improving accessibility (Banister and Berechman, 2003), and changes in accessibility dictate the benefit that infrastructure investment has for the local economy (SACTRA, 1999). The benefit derives from the cheaper distribution of goods and an expansion of labour market area. With public transport investment specifically, there are also benefits from relief of road traffic congestion, along with increased access to certain areas which lack other transport links (Townroe, 1995).
Except for the primary benefit of improved accessibility, there are secondary benefits for wider aspects of urban development. In fact, it is also widely recognized that many transport decisions would not have been made if only the direct transport benefit had been considered. Broader employment and development benefits help justify investment in rail systems (Banister and Berechman, 2003). It is these secondary benefits — and the stimulation of urban economic development and regeneration in particular — that are frequently put forward as incentives for transport investment (Townroe, 1995). However, it is still not clear how best to define or measure the various dimensions of impact that secondary benefits may have on urban development and regeneration. It could be argued that this framing of primary and secondary impacts downgrades the importance of the developmental impacts. For example, in some contexts these developmental impacts might be more important than a large number of small time savings.

In exploring these secondary impacts, much of the literature on transport generally seems to value the stimulation of growth in the areas surrounding rail transit stations simply by measuring the impacts on land value and the potential regeneration effect. However, it is also critical to measure changes in standard of living/quality of life when assessing the regeneration impact of transport. It is suggested that the interpretation of impacts cover a broader set of sub-themes: economic aspects (including employment, inward investment and output measures, such as productivity); urban attractiveness and the built environment; and social aspects (Llewelyn-Davies et al., 2004).

New transport routes tend to reinforce the established transport axes, but also powerfully transform the relative positions of different centres along them. However, even when there are significant effects from rail investment, previous research suggests that rail systems can both strengthen downtown cores, whilst also reinforcing decentralization trends, by improving accessibility to areas more distant
from the city. With reference to cases in North America, new rail investment has helped tackle the decline in the city centre of Washington, D.C. However, it has also widened the disparity between the central and peripheral areas (Cervero, 1998). Past work suggests that rail transit investments do not create real economic growth but rather redistribute growth. Research on Philadelphia’s Lindenwold line and Washington Metrorail suggest that regional rail systems have been a force towards decentralisation of both population and employment (Berechman and Paaswell, 1983, Llewelyn-Davies et al., 2004). Rather than influencing the total amount of growth, rail transit has channelled the distribution of growth, by shifting it from one corridor to another (Cervero, 1998).

It is likely that the relationships between transit investment and development are different in the Chinese and US context, and even in Europe. The development density in China is much higher, and the control of planning permission is much stronger — hence more can be made of the transport and development relationships. The US research tends to demonstrate weak relationships between transit investment and developmental ‘impact’, but in China there is much more potential to shape the development around the transit stations — hence the relationships may be much stronger.

The research presented in this study, on the effect of rail transit in Chinese cities, is carried out with due consideration of these concerns. A spatial framework of impact should firstly be drawn. As the literature suggests, at the macro level, effects on the economy can be identified and measured. At the meso level, the impacts relate more to agglomeration economics and labour market effects, with some additional environmental consequences. At the micro level, the impacts are primarily determined by the land and property market effects (Banister and Thurstain-Goodwin, 2011). By referring to these results in previous literature, the research explores the effect at the local level.
2.2.1 Rail transit’s direct impact on travel

The major contribution of public transport investment to a society lies in the shifts brought about in both its economic value and its people’s behaviour. Shifts in a society’s economic value relate to changes in capital flows and transportation of goods, while shifts of people’s behaviour relate to both automobile use and energy consumption (Cervero, 1989, Cervero, 1996a, Cervero, 1996b, Cervero and Duncan, 2006, Handy, 1993, Næss, 2009). It is argued that public transport’s contribution to shifts in travel behaviour have greater significance than shifts in other aspects of behaviour (Townroe, 1995). However, given the aim of reducing car use, a common question is to what extent rail transit systems can promote public transport use in preference to automobile use. Empirical studies have provided both positive and negative answers, or indicated unnoticeable impacts in some cases.

A positive impact was seen in a study comparing commuting patterns between two kinds of communities: ‘transit-based’ communities (communities with convenient access to public transit) and ‘automobile-biased’ communities (those designed to facilitate car use) in the San Francisco Bay Area. The former had 70% more transit trips and 120% more pedestrian trips than the latter (Cervero, 1989, Cervero and Gorham, 1995, Cervero, 1996a). Data from a survey of employees in Canary Wharf (London) also indicated that most of the new commuting trips associated with increased employment used public transport, with 80% of the total arrival trips from increased employment taken by Dockland Light Rail (DLR) or Jubilee Line Extension (JLE). However, the reported level of use of the JLE by newcomers to the area who moved into newly-built residences was 73%, compared to only 37% by the established residents of the area (Lane et al., 2004).

Another significant case study is Stockholm’s rail transit system. Stockholm is a good example of a transit-supportive urban structure. The experience of Stockholm has demonstrated how a region can adapt from a pattern of expansion to the
suburbs and concentration in the centre, into a system of rail-served satellite sub-centres, with successful integration of the satellite communities along developmental corridors, via superior quality regional rail services. Under Markelius’s General Plan of 1945–1952, the Tunnalbana System was designed to be built in advance of demand, before establishing the satellite sub-centres, which then functioned as ‘counter-magnets’ to attract people and businesses away from central Stockholm. Afterwards, the rail-served new towns, connected by the Tunnelbana system, have co-developed as powerful rail transit (and other land use) nexuses. The commuting pattern is one of incredibly well balanced two-way traffic flows, with directional splits of around 45:55. Only a small proportion of the total employees working in the new towns actually live there. Far more employees live in Stockholm and commute ‘in reverse’. This reflects the close economic dependency of Stockholm’s satellites on the rest of the region. The ‘modal split’ of commuters in Stockholm has one of the highest proportions of transit use in Europe. About half of all workers commute by train or bus: nearly twice the proportion found in other bigger rail-served European metropolises. Of those who go to work in central Stockholm, from the new towns, three out of four take rail transit. While of those who travel to work in the new towns from the central city, about 60% commute by transit, making it one of the highest rail transit shares in the world. Internal commuting within the communities also tends to be mostly by foot and bicycle (Cervero, 1998, Hall, 2013).

On the other hand, experiences in some big cities have indicated that — even with well-built transit systems and well-designed urban environments — there are still great flows of long distance commuter cars in the outer suburbs. Decentralised residence and employment have led to huge growth in suburb-to-suburb car commuting (Hall et al., 1993). For example, in the case of Berlin, at the edge of the city, long-distance automobile commuting extends far beyond the reach of the public transport system and into the city’s new outer suburbs (often 70-80 km away from the centre). Car dependency there is as high as that found in suburbs in the

44
United States (US) of America. In the case of the Frankfurt region, even though public transport has a respectable share of nearly 41% of all trips within and between cities, public transport use only captures just under 27% of the suburb-to-city trips and only 15% of suburb-to-suburb trips (Hall, 1995a).

Transport systems in big cities often exhibit patterns of congestion in peak hours but reduced ridership in off-peak hours. The great gulf between the demand during peak hours and off-peak hours suggests an unbalanced transport demand, which results from the disintegration between land use and transport in the city (Thomson, 1978). Therefore, the key to a more holistic solution is to integrate the planning of transport systems in the city with the wider planning of how land will be regenerated, or used for new development.

Evidence from US suggests that the impact of rail transit on more remote communities has been modest. It is argued that rail transit can have an impact on travel behaviour, only if the employment and residential locations both have good accessibility to public transport. This means that building housing near rail transit stations does little to lure commuters onto trains and buses, unless at the other end of the trip (the workplace) public transit is similarly convenient (Cervero, 1989, Cervero and Gorham, 1995, Cervero, 1996a). This, however, may be a very US-specific result, and certainly in China the higher population densities across cities mean that rail transit systems will be very well used.

Furthermore, the impact of rail transit improvements on people’s mode of travel is argued to be differentiated by people’s social and economic status. Evidence from the JLE in London showed that the newly built line had different impacts on established residents and newcomers. The former made relatively few changes to their travel behaviours and made limited use of the transit, while the latter were more likely to make greater use of the transit, despite also having higher rates of car ownership (Lane et al., 2004).
There is great disparity between different cities in the impact of rail transit on travel patterns. This disparity has much to do with factors such as the particular urban form of a city, the established travel behaviours of its people, and the corresponding local policy framework. Successful examples suggest that people's travel behaviours significantly shift to rail transit use, only when community-based planning and design conducive to transit use and accessibility to employment and other opportunities for different groups are promoted alongside rail transit investment. Only with the implementation of an appropriate policy framework to address all these factors can transit-oriented urban development really begin to take form (Cervero, 1998).

US case studies show minimal impact of transport on development, which may be related to the dispersed development patterns there. In the UK, comparatively more impacts are shown, as population and building densities are higher and developments are planned around the public transport network. However in China, since densities are higher still, the estimated impacts are likely to be higher. Moreover, the Chinese case has its own unique political and economic aspects. The particular approach to planning, with government taking a very proactive role, has a strong influence on the outcomes of such projects. Projects can be implemented quickly and development shaped effectively around the public transport network.

A previous study has been carried out in a similar context of highly compact development, namely Singapore. This study investigated the impact of planners' and developers' decisions on the density of high-income households in areas around rapid transit stations. It was found that the developers intentionally increased the density of housing units in developments around stations, and this consequently attracted the upper- and upper-middle class residents who could afford these properties. By comparing two travel survey results before and after the opening of a transit line, a change was shown; with a lower levels of travel by car and higher
levels of transit use after opening (Zhu and Diao, 2016). These findings indicate the importance of the specific planning approach used in Singapore, which promotes high-density development.

### 2.2.2 Rail transit’s indirect impacts

Aside from the direct transport benefit of rail transit, broader employment and development benefits also justify investment in rail systems (Banister and Berechman, 2003). These indirect impacts have economic, land-use, employment and social aspects. These include economic growth effects, produced by business activities, agglomeration and increased productivity, as well as attractiveness to inward investment; land development effects, including changing land use and increased property values; labour market effects, including changes in labour market catchment areas, labour costs and local employment; and wider social effects, including on social equity.

#### 2.2.2.1 Economic performance

It is widely accepted that transport developments can affect the economy by lowering production and distribution costs, improving labour productivity, and stimulating private investment and technological innovation (Llewelyn-Davies et al., 2004). The level of improvement in relative accessibility following transport investment is frequently used as a measurement criterion, as accessibility to transport can reduce costs and support productivity by increasing the accessible pool of labour and raw materials (Vickerman et al., 1999, Vickerman, 2008).

As the UK Standing Advisory Committee on Trunk Road Assessment (SACTRA) report (SACTRA, 1999), suggested: the main mechanism by which transport has an impact on economy is by changing the cost of movements. The aspects by which transport improves economic performance include:

- Reorganization or rationalization of production, distribution and land use;
• Effects on labour market catchment areas and hence on labour costs;
• Increase in output resulting from lower costs of production;
• Stimulation of inward investment;
• Unlocking inaccessible sites for development;
• Triggering growth, which in turn stimulates further growth.

Large amounts of investment into transport are usually supported by the belief that the public investment will generate economic growth. Therefore, infrastructure investment is often targeted at those locations where the greatest return is expected. That is likely to be in the regions with the most buoyant economic conditions, which attract more investment and influx of labour (Banister and Berechman, 2003).

However, in the developing world, where the existing transport network is sparse and of lower quality, new investment of transport can make a substantial impact on accessibility — opening up new markets and areas for development, as well as improving access to jobs, health, education and other amenities. In this way it help improve life quality, reduce poverty and promote growth (Banister and Berechman, 2003). In contrast, inappropriately designed transport strategies and programs may result in aggravation of the condition of the poor, by ignoring people's changing needs of access to opportunities (World Bank., 1996, Gwilliam, 2002). Evidence in developing countries demonstrates that infrastructure can produce major benefits in economic growth, poverty alleviation and environmental sustainability. However, these only occur under the condition that services are provided that respond effectively to individuals’ needs.

As suggested by the World Bank’s report, a 1% increase in the total infrastructure stock is matched by a 1% increase in GDP across all countries. The rates of return on transport projects in developing countries are about twice the levels expected in developed countries (15% compared to 8%) (World Bank., 1994, Banister and Berechman, 2003). The effect of transport investment in depressed or emerging
regions is thus justified. In depressed areas, the impacts of transport can be clearly identified, and causal relationships between transport investment and development can be inferred.

Previous literature has suggested that the most obvious economic impact of rail transit is on inward investment, with new industrial and commercial concerns attracted to the local area. These transfers are suggested to be frequently accompanied by further incremental investment, with a rise in the productivity in both labour and capital. The impacts on an agglomeration economy will also broaden and multiply, with one development potentially leading to another (Townroe, 1995). However, studies have suggested that the impact resulting from improvement of transport doesn’t add to the total economy, but rather has a redistributive effect. It is suggested by some studies that most of the relocation decisions are made from within the same local area. They are considered as a transfer within a wider region but not a real resource gain (Boddy et al., 1986). It is also argued that the role of transport in locational competitiveness and attractiveness of firms will be mitigated by the advent of a high technology, service-based economy and flexible labour markets (Banister and Berechman, 2003).

There are also benefits from improvement in customer accessibility, but like inward investment, the gain is argued to actually be a spatial redistribution of purchasing power, switched into the local area from other parts of the city (Townroe, 1995). As suggested in its case study, the JLE might not add to the total volume of economic activity in London, but may actually direct economic activity to areas needing regeneration, at the same time as relieving the pressure on the established area (Lane et al., 2004). This can be fairly easily contested — the building of the Docklands seems to be much more than a substitution. Instead its main objective was to provide additional space for financial services beyond the constrained city of London. It is also recognized that large transport investment in a city may have an impact on business activities overall, but probably an extremely small effect on
individual businesses. For an individual case, some may gain, while most remain unaffected, or gain indirectly, and some even lose. Nevertheless, cumulatively across the city, this gain will be substantial (Townroe, 1995).

However, in China, unprecedented rail transit investment in the larger cities in the last decade has greatly improved the accessibility of neighbourhoods to mass public transport stations. Evidence of urban rail transit’s impact on local economic activities and consumer amenities is found in numerous studies. A larger market for local retail business is found around the transit stations. Research on the influences of urban rail transit systems on the development of catering business in Beijing suggests that the opening of transit stations has increased the number, diversity and consumer demand of catering services, with proximity to a new station increasing the effect. Nevertheless, the effect also varies between locations: in suburban neighbourhoods the effects are larger than in urban neighbourhoods. The impact also varies by service type: for example, fast food services have a larger increase than sit-down services (Zheng et al., 2016, Cao and Pan, 2016).

2.2.2.2 Land use development and property value

The impacts on land and property resulting from major transport investment can be the most visible manifestation of growth. It is even argued that the real resource gain from new transport investment comes from the stimulus to property construction or upgrade, which directly results from the changes in land and property value (Llewelyn-Davies et al., 2004). The incentives for land development investment from transit development are twofold: firstly, rail transit proves to be the most competitive mode of transport in large cities; secondly, the station areas enjoy the highest development allowances; and these two factors complement one other (Bertolini et al., 2009).

When people’s desire for locational advantages, to minimize travel time/distance, is satisfied by improved accessibility, brought about by new rail transit, the impact of
transit on land use then takes place. Real estate developers are fully aware of this pattern. The process takes place when offices and upscale businesses outbid other activities, and then ancillary businesses follow, which gives rise to urban form change. The quality of change can be enhanced through desirable urban design. This process results in locational advantages, which in turn increases demand, and land value increases as a result. A limit in supply, caused by planning regulations, can also lead to land value increase. Besides, the upgrading of the urban environment near transport stations (stimulated by rail construction) also helps to promote value. The up-market developments and consequent property value increase may in turn bring about regeneration (Cervero, 1998). In this sense, the improved accessibility provided by transit investment can facilitate new development, infill development, and adaptive reuse of old buildings (Cao and Pan, 2016, Cao and Porter-Nelson, 2016).

However, it is argued that the rising land and property value associated with gentrification can have adverse impacts on the local, established residents and can drive them away from an area (Lane et al., 2004). The desire is that the new opportunities, especially newly created employment, are available to all, and that the benefit of regeneration should improve the quality of the whole urban environment for local residents, employees, customers and visitors to the area (Lane et al., 2004). However, in areas with relatively high existing accessibility, it is argued that the change in accessibility brought about by new transit investment is limited. Thus the transit's contribution to land development may not be significant (Guiliano, 2004, Cao and Pan, 2016).

A study on the effect of the Bay Area Rapid Transit (BART) system (San Francisco, California, USA; opened 1972) on the value of single family homes showed that nearby properties did enjoy a value premium (Cervero and Landis, 1995). Another frequently cited example is Toronto's Yonge Street Line. Following its opening during the early 1960s, research showed that one half of high-rise apartments and 90% of
office constructions in the whole of Toronto were established within a five-minute walk of the new train stations (Cervero and Landis, 1995). Research on five new suburban rail stations in Washington D.C., showed that office projects immediately adjacent to the rail transit stations commanded up to 10% more in rent than buildings two blocks away, and that commercial offices in the area impacted by the railway had higher rent premium than those served by freeways (Cervero and Landis, 1995). However, it is also suggested that the type of transit technology, and spatial extent of the transit system, have some bearing on rates of revenue capture. For light rail transit (LRT), the impact seems to have little influence on the property value (Cervero, 1994, Cervero and Landis, 1995, Duncan, 2010).

Often regarded as a significant case, research shows the Jubilee Line Extension (JLE) in London, UK, has been a catalyst for a series of developments. As a result of improvements to local accessibility, there was significant increase in land value and property prices, rate and density of land development and redevelopment, and maintenance of properties and townscape (Llewelyn-Davies et al., 2004). The chronic infrastructure deficiencies in the Isle of Dogs (an area within a meander of the River Thames in the former Docklands area of East London, now dominated by the Canary Wharf office complex) had cast bad publicity and poor perceptions on the area as a business location, which lead to the Canary Wharf Estate suffering poor fortunes in the early 1990s. In the mid 1990s (along with an overall improvement in the property market), the opening of JLE greatly changed people’s attitudes, attracting companies and people. Canary Wharf has since become a highly desirable business district as well as a residential location. The increased transport capacity JLE promised was considered as a major reason underlying the boom in the Docklands. Although the period when JLE opened was during a period of property market recovery and economic buoyancy — exerting pressure to accommodate London’s development demands — the JLE almost certainly hastened the trend for development. Without the JLE, much of the increased economic activity would have probably happened elsewhere, rather than in these
formerly run-down areas of East London (Mejia-Dorantes and Lucas, 2014), and the
critical mass of development which took place there would have probably been of a
different character and at much lower density (Lane et al., 2004).

In a longitudinal comparison, after the authorisation of the JLE in 1993, residential
construction in the corridor doubled from under 1,000 units per annum, in the period
Furthermore, in a latitudinal comparison, since JLE was approved, commercial
property values have increased faster in the JLE station catchment areas than in the
reference area. There is a similar trend for residential development: from 1991
(before the line opened) to 2001 the population in the JLE corridor rose from
161,159 to 211,392 (Mejia-Dorantes and Lucas, 2014). Meanwhile, the visual
attractiveness and quality of townscape in the JLE corridor has been improved, both
directly or indirectly motivated by the JLE (Llewelyn-Davies et al., 2004). Although it
can’t be ignored that the JLE corridor contained some of the largest development
opportunities in Inner London, in terms of vacant and derelict land, the developable
lands were already available prior to 1993, when JLE was authorized, and it was
partly this authorisation that led to the development opportunities being taken up. To
this day, the changes in land development and property value are still ascribed to
the enabling or encouraging impact of the JLE (Lane et al., 2004). The influx of new
residents to the catchment areas, who were often younger professionals with higher
purchasing power, due to a much higher income, was a particular stimulus for
property development. It convinced the developers that the incoming population
would be willing and able to afford to occupy newly-built properties in previously
unattractive areas (Lane et al., 2004).

Development in China exhibits a much more compact pattern, thus the results found
in transit impact studies have shown clear differences from the ‘Western’

---

* The term “Western countries” or “Western world” is interchangeably used with the term “developed
experience. A study examining rents of apartments in Shanghai, to explore the effect of rail transit, found a significant rental premium effect. It showed that a community’s proximity to the nearest metro station tended to be positively correlated with the average asking rent of a two-bedroom, one-bathroom apartment (Wang et al., 2016). In a study investigating the impacts of LRT and mass rapid transit (MRT) in Wuhan (武汉, Hubei [湖北] province, China), housing sales prices were also found to be increased with proximity to rail transit, but the effects varied across different transit lines, and thus exhibited locational dependency. Furthermore, results showed that in Wuhan, the influence area extended to 700 m for light rail transit and 900–1000 m for metro rail: a result much larger than the conventionally accepted value of 400–500 m, which is commonly used for planning (Xu and Zhang, 2016).

In exploring the effect of rapid transit on land development, it is argued that most studies overlook the role of government intervention in this process. Planning and policy intervention can both influence the choice of station siting and the availability of developable land (Guiliano, 2004, Cao and Pan, 2016). The development effect triggered by new transit stations can be ascribed largely to station location selection, which can be heavily influenced by the government in order to maximize development potential. Using Shenzhen (深圳, Guangdong [广东] province, China) as an example, a study suggests that MRT planning has shifted away from orienting transit provision towards established communities — where traffic congestion is severe and land rents are high — to favouring under-developed areas (Yang et al., 2016, Cao and Pan, 2016). These development-oriented government initiatives are largely due to the proactive roles taken by the local government to promote areas, and the prevalent mechanisms for financing infrastructure in China. These policy factors inevitably influence the impacts of rail transit on land development and countries”. These countries are generally considered to share certain fundamental political ideologies, including those of liberal democracy, the rule of law, human rights and equality.
should not be ignored in research analysis. Nowadays, it is the planning system that ‘creates’ the facilities and development in a market economy (Wu, 2015, Wu et al., 2015).

2.2.2.3 Labour market and employment changes

The impact of transport development on the size of the accessible labour market, and the potential increase in employment, is often used to justify transport projects, although some previous research studies have reported ambiguous or even contradictory results, suggesting that the effect was either negligible or significant. Moreover, some scholars have also pointed out an apparent increase in employment may actually be re-distributive rather than generative of new employment (Boddy et al., 1986), and may therefore result in negative social costs, by removing sources of employment (Boarnet and Crane, 2001).

Usually a gain for the labour market includes both supply-side and demand-side factors. On the supply side of the labour market, accessibility improved by rail transit investment can benefit a variety of people. Existing employees can enjoy easier journeys for work trips; job seekers (new entrants and those changing career) may consider the accessibility of the location; established local residents may enjoy expanded employment opportunities offered by the public transport; and newcomers to the area may base their choice of residential location on their ability to use the rail transit system to commute to their work place. On the demand side of the labour market, rail investment can benefit employers. For firms that plan to expand their labour force, or have just moved to a new location, rail transit investment opens a larger labour pool from which employers can recruit. In general, new rail transit brings about a new pattern in the relationship between employment location and residential location (Townroe, 1995).

Interestingly, the study of BART’s impact in the first twenty years after it opened shows that population has grown 20% faster in the non-BART served corridors than
in the BART corridor. BART thus appears to have done little to channel population growth (at least during the study period). Employment growth also occurs more in non-BART served corridors rather than the BART corridor. However, in terms of occupation breakdown, BART has had a primary influence on the FIRE (finance, insurance, and real estate) sectors. BART seems to have enticed businesses that hire larger shares of professional, technical and administrative/clerical workers to the BART-served areas, when compared to matched freeway interchanges (Cervero and Landis, 1995).

Data on the JLE indicates that it has had a significant impact on employment. From the time JLE opened, there has been a substantial employment increase in the JLE corridor, with a considerably faster growth rate than the reference area of Inner East London. This employment increase is perceived as having resulted from the improved accessibility provided by JLE. There is an expansion of the recruitment area for companies, as well as the employment area for local residents (Lane et al., 2004). Prior to line opening, unemployment in the JLE corridor was much higher than the average for London as a whole, as well as there being higher levels of lone parents, ethnic minorities and other socially disadvantaged populations. However, in the first 12 months after the JLE opened, across all station catchment areas, employment increased at twice the London rate, especially in Canary Wharf. The increase in amount of employment was accompanied by a change in occupation pattern. The percentage of residents working in managerial, professional and technical sectors increased rapidly, and caught up with that of the reference area. However, there are still some undeveloped catchment areas that didn’t grow: namely North Greenwich and West Ham, where there is still predominantly social housing and relatively few development opportunities.

In contrast to the significant number of employment opportunities the JLE has brought, it is argued that the JLE has not contributed much towards reducing high levels of long-standing local unemployment in the catchment areas. Local people
have only benefited by a limited amount from the increased employment. The proportion of employees from the local established population remained at around one fifth, and there was no significant change in the local employment rate. In pre-and post-opening surveys of companies in the JLE corridor, the percentage of local recruitment had declined from 22% to 19%, but recruitment outside the M25 London-circular ring-road had greatly increased, from 10% to 18%. It is clear, therefore, that JLE provided convenience for companies to recruit employees from long distance, rather than from local areas (Lane et al., 2004).

2.2.2.4 Social effects

An appraisal framework covering three sustainability dimensions — economic, ecological and social — was first developed by institutions including the World Bank in the 1990s, to assess the sustainability impacts of specific funding proposals (Serageldin et al., 1994). Later on, these three dimensions were increasingly addressed in transport policy appraisal systems in countries such as the UK and the Netherlands (Geurs et al., 2009). The UK, for example, has Web-based Transport Analysis Guidance (WebTAG), which is a multi-criteria based system of appraisal, addressing economic, environmental and social objectives (Department for Transport, 2014). Supportive planning policies are critical to ensure wider social and environmental requirements are met (Hajer, 1995). It is suggested that projects with lower levels of economic return have to be balanced against holistic regional development benefits. There are also increasing concerns over equity, with arguments that particular provision has to be made for those without access to cars or sufficient public transport (Banister and Berechman, 2003).

Numerous authors have emphasized that cities are not equal, and resources are distributed unequally. Typically, this issue has been framed in terms of space/location in the city, but there is increasing focus on inequalities related to social factors, such as gender, ethnicity, sexuality, and age (Fainstein, 2010), and how spatial and social factors may actually re-enforce one another to worsen
In the academic discourse, spatial equality is concerned with the allocation of resources and provision or burdens. Spatial inequality means that the population of one territory does not receive as much per head than another territory, or is required to contribute more (Hay, 1995). It is argued by Harvey (2010), that when the principles of social justice are applied to geographic situations, a spatial organization and the pattern of regional investment should fulfil the needs of the population. The degree of justice (or injustice) is thus evaluated by discrepancies between needs and actual allocations. By referring to demographic indicators, it is suggested that the most appropriate distribution between areas is “according to the needs of the population of each area” (Davies, 1968). This idea is expanded by later scholars: that provision should be proportionate to need (Boyne and Powell, 1991). It was argued by Hay (1995) that more concern should be cast on more exact specifications of both the needs and the form of provision, and whether the provision is available to the disadvantaged groups in a society.

Therefore, besides these three key dimensions discussed above (economic, environmental and social), which are traditionally regarded as impacts of transport systems and policy interventions, another, distributional dimension should now be considered. As certain disadvantaged groups can be negatively affected by distribution in all three primary dimensions, the distributional effect is argued to be an independent dimension worth discussion, rather than just an issue affecting each of the three dimensions separately (Jones and Lucas, 2012). Therefore, the distribution dimension directly points to the equity issue, and makes it clear that there are trade-offs affecting equity in any dimension. In attempts to operationalise sustainable development and sustainable transport programs, these trade-offs should be balanced (Feitelson, 2002).
In this context, issues of social equity associated with transport can be raised, which are widely considered to be the cumulative implications of these distributional impacts. However, before stepping directly into the discussion of transport-related social equity issues, it is necessary to do the following: firstly, disentangle the process by which transport investment generates its social impacts, be they benefits or burdens; secondly, explore how these social impacts differ among different population groups, given a particular transport disadvantage or even transport-related social exclusion; and thirdly, how the issue of social inequity can arise from differentiated impacts, and can potentially lead to social injustice.

In order to sustain the new forms of network that are a feature of the new digital and mobile world, people have to undertake sufficient travel (Hall and Pain, 2006, Urry, 2012). What is important is not the travel per se, but the connections generated and maintained by this travel. And access to interactions in social networks is argued to be very unevenly distributed, making it a growing source of inequality. It is evident that, compared to the increasingly longer distances that more well-off people are willing/able to travel to sustain their networks, those who for various reasons are unable to travel regularly, are at a disadvantage in making and sustaining their networks (Urry, 2012).

The term ‘social exclusion’ refers to a decline in participation in normal processes of society and is associated with increasing deprivation among particular social groups (Burchardt et al., 1999, Kenyon et al., 2002, Bocarejo S and Oviedo H, 2012). Transport-related social exclusion has been explored more recently in the UK and Europe, by identifying specific conditions related to the transport component of exclusion, often by using survey methodologies (Church et al., 2000, Department for Transport, 2002, Social Exclusion Unit., 2003, Lucas, 2006, Lucas, 2012, Cebollada, 2009, Bocarejo S and Oviedo H, 2012). Mobility-related social exclusion, in particular, has happened as a result of inadequacy of means to travel, and reduced accessibility to opportunities (Burchardt et al., 1999, Kenyon et al., 2002, Bocarejo S
and Oviedo H, 2012). Therefore, the way in which entities access and appropriate the capacity for socio-spatial mobility needs to be considered, in order to consider the potential for transport-related social exclusion. Access to different forms of mobility is constrained by spatial distributions of population, transport supply and relevant transport policies. Furthermore, the competence to recognize and appropriate (interpret and act upon) access is greatly influenced by the skills and abilities of the population, which in turn are closely related to the socio-economic status of population groups (Kaufmann et al., 2004, Cass et al., 2005, Lucas, 2012). Transport disadvantage can be understood as the outcome of a shortfall at any point in this series of criteria (Lucas, 2012, Schwanen et al., 2015).

Therefore, if one only considers transport provision, or physical accessibility of transport facilities, one is not able to fully appreciate or understand transport-related social exclusion. What makes the situation significantly worse is when these disadvantages interact (directly or indirectly) with other population attributes, such as socio-economic characteristics; the need for, cognitive knowledge of and aspiration to do activities; and opportunities for interaction. Whether differentiated by income, gender, race, ethnicity, age, geographical region, or otherwise, groups are unlikely to be affected evenly by specific transport policies or investments.

Existing appraisals provide little guidance on the evaluation of the distribution of benefits from transport investment among population groups, especially for specific population segments (Geurs et al., 2009). Figure 2.1 shows how transport investment generates its social impacts and can result in social inequity. Social impacts of transport can exert both positive and negative influences on people’s preferences, well-being, behaviour or perception, and these impacts can occur at multiple levels: either as individuals, or collectively as groups, social categories or at the level of the whole society. Individual sensitivity to social effects from transport is variable. People belonging to a certain social category tend to bear similar impacts. Different levels of social impact of transport aggregate across different
demographic dimensions. When an effect exceeds the sensitivity level of individuals, and has aggregated effects on a particular population group, it can lead to inequity of social impacts.

As shown in Figure 2.1 if different levels of social impact are unacceptable, according to the values and standards of society, it tends to brings about problems of social injustice (Geurs et al., 2009). Social justice in transport is described in broad terms as “the fairness in the physical distribution of goods, accessibility for people, affordability of all types of services and distribution of other gains (such as increases in land and property prices)” (Beyazit, 2011). In this view, justice is closely related to distribution in the interests of equality (Lucas, 2006, Lucas, 2012, Martens et al., 2012, Mullen et al., 2014). Injustices in urban transport are conventionally conceptualised, and often explored, in the dimensions of: valuation in transport time; distribution of space; and exposure to negative externalities of transport, such as accidents and air pollution (Gossling, 2016), while less frequently
mentioned, is the distribution of indirect impacts of transport.

In essence, social equity of the indirect effects of transport is argued to be a function of its land use effects, and the relationship between the users who benefit from the use of a transport system and the population that bears the environmental cost. Transport’s market-driven effects on land use and development play a role in changing the land value and urban environment around the stations, and dynamically changing the demographic pattern there. (Feitelson, 2002). However, proximity to a transport network can have both positive and negative effects. Residents can benefit from accessibility enhancement that transport provision brings, while conversely being more likely to suffer from exposure to environmental pollutants, noise and accidents. For example, income-deprived neighbourhoods are often found to be exposed to higher concentrations of pollution (Agyeman et al., 2002, Mitchell, 2005, Schweitzer and Zhou, 2010). The most disadvantaged condition is where local communities derive no benefit from the transport investment but are negatively impacted by severance effects, such as living environment degradation, being driven away by rising living costs, or even property damage caused by construction (Jones and Lucas, 2012). Feitelson considers how to explore the distribution of benefits amongst different groups, and suggests a proper comparison between the typology of rail users versus those otherwise affected (Feitelson, 2002). If the affected are not users of the transport facility, transport investment’s indirect effects may give rise to social inequity issues.

Previous literature has certainly indicated that the benefits of a rail transit system in the city are distributed disproportionately in terms of geographic location and population groups (Feitelson, 2002). It is suggested that negative effects are often concentrated within particular geographic locations, such as areas of existing deprivation (Agyeman et al., 2002, Mitchell, 2005, Schweitzer and Zhou, 2010). Therefore it can be argued that research should not only focus on geographic inequity, but also address aspects of unequally distributed benefits and
accumulated social impacts across population groups. A large amount of recent research on spatial distributional effects have expanded to include socio-demographic effects (Jones and Lucas, 2012). Evaluation of these effects is always highly dependent on the moral values, standards and norms of the context in the society in question (Lucas et al., 2016). Therefore it is necessary to consider together the geographic space and societal stratification in equity research, and carry out research to explore the implications across geographic locations and population groups.

It is important to mention that some approaches in widespread use for evaluating transport investment are often biased towards particular aspects of the transport provision, such as journey time savings or operational efficiencies, while they overlook whether the transport investment promotes equality of opportunity and social inclusion, such as the distribution effects of such investment decisions (Lucas et al., 2016). For example, the widely used cost-benefit analysis (CBA) generally ignores the distributional effects of transport decisions, such as how they affect different regions and social groups. Even ‘multi-criteria analysis’ (MCA) does not inherently identify the spatial or social distribution of impacts. Alternative approaches are needed to evaluate transport investment that specifically aims to redistribute transport resources towards currently disadvantaged population groups and deprived areas (van Wee, 2012, Lucas et al., 2016). Considerable efforts have been made to provide appropriate measures of the social and distributional impacts of transport projects and associated policies (Department for Transport, 2002, Social Exclusion Unit., 2003, Hurni, 2005, Preston and Rajé, 2007, Mackett et al., 2008, Paez et al., 2009, Currie et al., 2009). Apart from these, it has also been argued that a lack of influence for local people on decision-making and governance — for instance, being locked out of the planning process — also plays a great part in social inequity of transport and needs to be taken into consideration (Schwanen et al., 2015).
2.3 The synergistic effect of key contributing factors

Although positive economic growth from transport infrastructure investment has been evidenced by numerous case studies, the argument that transport investment will bring about economic growth requires that other complementary resources are also present. Any assumption that transport investment will bring about a high return of economic growth only risks simplifying the political and economic arguments for investment, and overlooking the regional variations and the actions of individual firms and people in their own decisions (Banister and Berechman, 2003), and it is important to consider this *ex ante* when assessing transport investment.

Research studies into the impact of regional rail, in the European context, indicate that it is difficult to distinguish the effect from a multiplicity of other effects, such as: the general regional economic dynamism and industrial mix; the relationship between population and employment centres; and the existing level of transportation investment (Hall, 1995a). Meanwhile, public transit development in North America also demonstrates that, besides transport investment, a number of other conditions are necessary for rail transit to exert a strong and lasting influence on urban form and land use, namely: stringent land-use controls such as complementary zoning; taxation policies; a healthy regional economy; the availability of land amenable to development; a hospitable physical setting; and policy for relative automobile restraints. Some demographic changes, such as the influx of migrant populations, can also contribute to development (Cervero, 1984, Llewelyn-Davies et al., 2004).

A rich range of literature has shown that transport is not a sufficient precondition for development, and it can, in fact, be a constraining factor. Other factors, including the local economy, planning policy, land availability, inward investment and market value of abutting area, are also highly influential on the impact of transport (Banister and Berechman, 2003, Banister and Thurstain-Goodwin, 2011). Supportive
measures, such as strong local economies, supportive planning policies and availability of attractive development sites should also be in place for the positive effects of transport investment to be realised (Hall and Hass-Klau, 1985).

Firstly, positive economic externalities are the most important condition; even prerequisite. Only when these externalities are positive can new transport investment have an impact. These include agglomeration and labour market economies, a good quality labour source, and underlying dynamics in the local economy (Banister and Berechman, 2003). Experiences in a number of cities (e.g. light rail investment in US ‘rust belt’ cities, like Buffalo, Illinois) have proved that, with weak regional economies, transit can only exert negligible land use impacts (Cervero, 1984). In contrast, investment tends to be very beneficial to a location with good economic environment, as in the case of the Japanese Shinkansen high-speed network (Guerra and Cervero, 2011). The impact of transport investment seems to be particularly great when the investment occurs just prior to an upswing in regional growth (Cervero, 1998). That is to say, transport development can favour the locations which are able to take direct advantage of it (Hall and Hass-Klau, 1985).

It is argued that once a complex transport network is established, the local economic conditions are the key driver of further growth (Llewelyn-Davies et al., 2004). Studies of the impact of rapid rail transit in seven German cities and six British cities in 1985 showed that the influence of rail transit investment on the local economy is quite limited. For cities with serious problems of economic contraction and emigration of people (e.g. Glasgow, Scotland), while there was a general increase in planning applications for retail and office space, there was no detectable increase in housing property values or shopping trips. No positive improvement was seen in employment or population figures either. Some British cities showed a rise in office rents after transit opening comparable to those cities that did not have transit.
Some German cities (e.g. München, Hannover, Nürberg) did have an increase in passengers, but some (e.g. Essen) still suffered similarly dramatic losses of passengers on public transport systems as those cities (e.g. Dortmond) which did not have transit investment. With regard to retail turnover, some cities (e.g. Dortmund, Bremen) without rail investment performed as the same as some cities with investment (e.g. Köln, München), and even showed a bigger increase than some cities with investment (e.g. Essen, Nürberg).

In terms of economic impact, one of the only positive outcomes was München, which demonstrated improved economic performance. During the period when the rail transit was opened, there was already a strong increase in employment in the urban cores, especially in the service sector. Subsequent to the transit opening, a strong increase in office development and property values was seen. Strong population increase was also observed around the areas with rapid rail access. Also significant was the decline in car pollution and road traffic. The research suggests that if the city is already in a downward economic spiral, these forces far outweigh the benefits in accessibility that rail investment brings about. Transportation alone can achieve little; it can only facilitate urban change (Hall and Hass-Klau, 1985).

Moreover, political factors also play a significant role. These include the source of finance, level of investment (local, regional, national), site marketability, other supportive policies and processes (legal, organizational and institutional), and any necessary complementary policy actions (grants, tax breaks, and training programs) (Banister and Berechman, 2003). Additional policies related to land use are also required (Breheny, 1991). Marketability of sites can provide available land resources. Supportive mixed-use policies encourage land use variety. Policy measures to discourage automobile uses and parking are also crucial (Curtis, 1996, Cervero, 1998).
As in the case of the JLE in London, planning permission can promote the high-density development triggered by JLE (Lane et al., 2004). In Stockholm, behind the success of the transit-oriented development lay two fundamental factors, without which the development would not have been possible. One was the availability of land. The lands were purchased by the city council decades before to reserve for future expansion. It was this public ownership of land that made it possible for Stockholm to develop land for integrated transit development. The other factor was the socialisation of public services. This included not only the provision of public transport but also the provision of public housing, which could contribute to the establishment of communities around transit hubs (Cervero, 1998).

The investment factor includes the availability of funds, their scale, timing, location, and the network effect of the investment (Banister and Berechman, 2003, Guerra and Cervero, 2011). However, investment intentions are largely influenced by locational attractiveness. Previous research shows that when some countries attempted to implant new innovative complexes in urban areas that previously lacked them (e.g. UK), the investment still relied on there being some existing economic and educational nodes, such as technological universities, existing industrial bases and a trained labour force (Hall, 1995a).

In addition, some other factors are also regarded as prerequisites for a positive impact from rail transit investment, such as the availability of land, and hospitable physical settings. Former transportation conditions are also a factor that exerts an influence (Hall, 1995a, Cervero, 1998). The scale of the transport investment and existing transportation condition in the specific location will influence the impact of the investment. In locations of particularly poor accessibility, or uncompetitive areas just opened to competition (Vickerman, 1995, Vickerman et al., 1999, Vickerman, 2008), a regional connection added by transport investment can exert a positive impact on both regional and local development, especially at the interchange nodes. However, as efficiency and productivity increase, while economies become more
developed, the link between growth in transport investment and economic growth may be reduced (Banister and Berechman, 2003). In an already dense and congested network (except where there are major changes in connectivity) the change in accessibility resulting from new investment alone seems to be not enough to have a sufficient scale or duration of impact on the local economy (Hall and Banister, 1995, Guiliano, 2004, Cao and Pan, 2016). Especially in a mature economic environment, with an already sustainable rate of growth, the impact from transport investment tends to be modest (Banister, 1998, SACTRA, 1999, Vickerman et al., 1999).

2.4 Coordination of different stakeholders

Development promoted by rail transit around transit stations is the result of the cooperation between different actors that have decisive roles. The crucial issues are how the different actors can be enticed to the areas impacted by rail transit, and how the environment can be made functional for actors with different interests (Curtis et al., 2009). A diverse range of stakeholders, with a variety of interests, are typically involved in transportation investment, and a strategic planning framework should aim to coordinate these disparate intentions, especially with issues relating to power and influence (Flyvbjerg, 1998).

When looking into the process of transit investment decision-making, research shows that investors will generally only respond to transit investment proposals if there are already development intentions in place. It is also suggested that investment location decisions are influenced by factors such as complementary local business, government grants and incentives, labour supply, access to markets, and availability of land. These are often more influential factors than simply the reduced transport cost provided by convenient transport links (Llewelyn-Davies et al., 2004). In a survey exploring the attitude of business establishment decision
makers to the South Yorkshire Supertram, ‘access to public transport’ was only reported as important for decision making by 22% of respondents, whereas more importance was given to the suitable land and buildings (72%), general road access (67%) and cost of land and buildings (63%) (Townroe, 1995).

Therefore, greater attention should be paid to the different concerns of the participating stakeholders. Stakeholders who are responsible for development include different levels of administration: state, regional governments and local government; transit agencies; and market actors (developers, investors, and end-users) (Curtis et al., 2009). In the process of cooperation, they may have divergent interests and demands:

1. State and regional governments’ main concerns are the available funds and state polices for planning and implementation.

2. Transit agencies’ main concerns are the use of public transport, the balance between satisfying short term parking demands around transit stations and promoting long term land development, and the capture of value from the private sector.

3. Local government and communities’ primary concerns are economic: namely an increase in employment, improved vibrancy of the district, reduction in household transport expenditure, and an increase in property tax generated from increased property values. Secondly, they also have major environmental concerns, namely: the preservation of open space; reduced greenhouse gas emissions and energy consumption; reduced automobile dependence and traffic congestion. Finally they have social concerns, namely people’s quality of life, appropriate benefit distribution and urban attractiveness.

4. Private developers’ main concerns are the length of the approval process of development application, the major risks of investment, the amount of subsidies, and the market condition (internal rate of return) (Curtis et al., 2009).

In coordinating the concerns of these diverse stakeholders, there is a need to
establish a framework for cross-sector and cross-agency collaboration. As proposed in successful transit-oriented development (TOD) cases, this kind of framework at the implementation stage contains: a strategic planning framework asserting the development density and mix; a strategic transport plan; a statutory planning base, preferably with a specialized development agency (such as a redevelopment authority); and a public and private funding mechanism (Bertolini et al., 2009). This framework establishes the platform for integrating the factors of investment, policy, and transport strategy.

Previous redevelopment experiences have suggested that, if public entities share both the upstream risks and downstream rewards with private investors (including a commitment on redevelopment costs and financial incentives) as a way of combining public and private funding, it can prove highly attractive for private capital to revitalize deteriorated areas (Curtis et al., 2009). An institutional capacity with effective inter-departmental linkage also proves crucial, because there are often separations between different government levels (federal, state, regional, and municipality) and sectors (transport and land use) (Curtis et al., 2009). In the US, a successful case of leveraging public transport investment through joint development initiatives was Washington’s Metrorail, which has involved a number of successful revenue sharing deals. Research on suburban rail stations in Washington D.C. showed that the presence of joint development projects increased rents about 15% above those office projects which were not jointly developed (Cervero and Landis, 1995).

Other successful examples of cooperation between governments and private developers include the market-driven mechanism used in Tokyo and the state-driven mechanism in Singapore. Tokyo has indirect strategic planning and limited statutory planning. Public actors shape the general conditions of planning and private actors are involved in both transit and property investment. This relies on market, rather than planning mechanisms, where market forces have strong
incentives towards TOD. In contrast, Singapore has strategic planning departments covering both urban planning and rapid transit planning. Public sectors invest in both transport and housing, while private actors invest in commercial properties near the stations (Bertolini et al., 2009).

2.5 Case studies

2.5.1 General comparison between selected cases

In order to explore the relationship between rail transit investment and development, experiences from previous cases should be studied. Five representative examples of rapid rail development are chosen, and these cases are reviewed in this section. The opportunity and risks in these cases are compared. Important issues such as the rail transit’s impact, the different intentions of the various stakeholders, and the coordination mechanisms between different influential stakeholders are explored. The aim is to take lessons from these examples, and to subject these examples to both ex ante and ex post evaluations in future work. By reviewing these cases, the key evaluation criterion of rapid rail investments are proposed at the ex ante stage of a specific investment and can be embodied into the new line design. This also feeds into the ex post analysis needed before the next round of transport investment. The lessons learned from these cases will help enlighten the research presented later in this thesis.

The cases reviewed in this section are:

- La Défense in Paris, France;
- Canary Wharf in London, UK;
- Zuidas in Amsterdam, Netherlands;
- Pudong New Area (浦东新区) in Shanghai (上海), China;
- West Kowloon (西九龍) in Hong Kong (香港), China.
Generally, the five cases share a number of similarities but also retain unique individual features:

1. A new business district: competing and shifting function from the conventional city core.
   The five cases are all purpose-built business areas. They are detached from the conventionally city centre but exhibit strong trends to compete with or shift the economic function from the centre.

2. The purpose of development: regeneration and mixed use.
   Among the five cases, Canary Wharf, Pudong, and La Défense are constructed directly on a former declined area, thus bear the task of regenerating the area, (especially in the case of Canary Wharf). In some cases, like Amsterdam Zuidas and West Kowloon, the government led the residential program of mixed development from the beginning.

3. The investors’ intentions and cooperation mechanisms
   The cases illustrate the intentions of different developers. For example, Canary Wharf is mainly an enterprise zone. Some cases even have a public-private partnership with the private sector sharing the cost of infrastructure development, e.g. West Kowloon and Zuidas.

4. Rail transit investment
   Some cases, such as Zuidas and West Kowloon, are accompanied by a public transport system, planned even before the area’s development. West Kowloon is a completely rail transit-oriented development. However, in other cases, public transport systems are constructed as a supplement after the development, such as in Canary Wharf. This area suffered from stagnant development in the early 1990s because of restricted public transport provision. The opening of the JLE afterwards greatly contributed to the flourishing of Canary Wharf.
<table>
<thead>
<tr>
<th></th>
<th>La Défense</th>
<th>Canary Wharf</th>
<th>Zuidas</th>
<th>Pudong</th>
<th>West Kowloon</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Development Purpose</strong></td>
<td>Business district with aim of mixed use</td>
<td>Enterprise zone</td>
<td>Mixed-use development zone</td>
<td>Special economic zone, including Pilot-Free Trade Zone</td>
<td>Compact mixed-use development</td>
</tr>
<tr>
<td><strong>Total Area (hectares)</strong></td>
<td>560 ha</td>
<td>195 ha</td>
<td>270 ha</td>
<td>142967 ha</td>
<td>340 ha</td>
</tr>
<tr>
<td><strong>Core Area</strong></td>
<td>159 ha</td>
<td>95 ha</td>
<td>NA</td>
<td>170 ha</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Current Development</strong></td>
<td>3,300,000 m² offices, 600,000 m² residential usage, 200,000 m² retail</td>
<td>1,300,000 m² Office and retail space</td>
<td>Aiming to grow to 4,200,000 m² (38% offices, 29% residential and 33% amenities)</td>
<td>9,770,000 m² floor area</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td>180,000 daily workers</td>
<td>94,500 employees</td>
<td>Aiming: 80,000 employees</td>
<td>Lujiazui core area: 150,000 employees</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Residents</strong></td>
<td>25,000 permanent residents and 45,000 students</td>
<td>27,500 residents</td>
<td>Aiming: 25,000 permanent residents, 30,000 students</td>
<td>5,187,200 inhabitants</td>
<td>Public and private housing program to accommodate 100,000 people</td>
</tr>
</tbody>
</table>

Table 2.1: General comparison between the cases
2.5.2 Review of the cases

Case Study 1: Canary Wharf, London

Canary Wharf (the red area in Figure 2.2) is an area located in the Isle of Dogs Enterprise Zone in the Docklands area of East London — once home to the busiest port in the world. The British government adopted various policies to redevelop the badly declined area. A milestone was the creation of the London Docklands Development Corporation (LDDC) in 1981, with the Isle of Dogs Enterprise Zone status being granted in 1982. In 1987 the Canadian company Olympia & York (O&Y) began to conduct a major office development on the Isle of Dogs. Unfortunately, upon opening, the London commercial property market collapsed and this halted development for several years. Enormous financial commitment to the project caused O&Y’s bankruptcy in 1992. However, three years later, in 1995 an international consortium, backed by the former owners of O&Y and other investors, bought the scheme back again. With a general recovery in the property market, and continuing demand for office accommodation, Canary Wharf’s revival
re-commenced. The Canary Wharf project has since established a second major financial centre in London.

The Docklands historically has had poor transport connections. The Canary Wharf developers had, for a long time, recognized that transport links were essential to the success of the project. In 1979, the first stage of the Jubilee line was opened, with the intention to stretch further to southeast London, but the rising costs and low level of development in Docklands led to the project’s postponement. The eventual opening of the Jubilee Line Extension (JLE) in 1999 played a critical role in promoting the flourishing of Canary Wharf, along with the recovery of the property market. As Hall (1988) has argued, "no other case has shown as great an impact of rail transit as Canary Wharf", both in terms of reversing the developer’s bankruptcy and the revival of the area resulting from the opening of the new metro line. It can’t be denied that it was partly the refusal of the UK government to initially supply transportation infrastructure that contributed to O&Y’s failure, which emphasised the importance of the transportation in later development (Hall et al., 1999).

Firstly, the opening of the JLE in 1999 has been a catalyst for land development and redevelopment. In the extraordinary case of the Isle of Dogs, the Estate development proceeded rapidly from 557,000 sq.m in 1997 to 1.5 million sq.m in 2003 (as compared to the slow increase from 502,000 sq.m in 1991). The higher rates of development being reached in Canary Wharf helped to generate sufficient confidence for increased levels of development interest, and resulted in other areas surrounding the estate being proposed for major development (Lane et al., 2004).

Secondly, figures indicate that the JLE has, in general, had a significant favourable impact on levels of employment. Employment approximately doubled in 2002, since the opening of JLE in 1999. This increase in the employment was perceived to be because of the accessibility the JLE provided, so that firms could recruit from a wider commuting area, and long-distance commuters could travel more easily to
specifically take employment in Canary Wharf. In this sense, the JLE has been successful in redirecting employment to areas needing regeneration. This increase has, in turn, attracted high profile companies to the area (Lane et al., 2004, Butler, 2007).

Case Study 2: Pudong, Shanghai

Pudong New Area (the red area in Figure 2.3) in Shanghai, located along the east side of the Huangpu River, is just opposite the historical city centre of Shanghai, in Puxi (浦西). The special economic zone of Pudong was officially set up in 1993. Now, Pudong New Area is the largest centre of commerce and finance in mainland China. At the western tip of Pudong is located the Lujiazui (陆家嘴) Finance and Trade zone. The number of foreign capital banks, fund management companies and insurance companies here constitutes half of the total number in China. The rail transit in operation in Shanghai had a total distance of 600km in 2014, and there are now six
metro lines passing through the Pudong area. The earliest line commenced its service in 1999 — the same year that Shanghai Pudong international airport opened its doors.

Firstly, rail transit has had a major impact on modes of travel, trip frequency, time and purpose. In a study (Pan et al., 2009) on the influence of the rail transit in Shanghai around stations of three lines in 2000, 2002, 2003, modes of travel exhibited a major shift from bus to metro after the metro opened. The share of bus use changed from 63.3% to 17.4%, and the corresponding share of metro use changed from 0% to 52.9%. The stated purpose of passengers' trips also changed, with 'work' increasing from 20% to 36.5%, and 'personal business' increasing from 3.29% to 10.9%, with a corresponding decrease in use for 'recreation'. There was also an increased travel frequency for downtown visits. There were a number of reasons, including fare deductions, increased direct links to destinations and convenience for transfers (Pan et al., 2009).

Moreover, rail transit investment has functioned as a catalyst for land development, both in terms of urban regeneration and new area development. A case study of Xinzhuang station (莘庄站), at the southeast end of Line 1, showed that there was a major trend towards more commercial and office use replacing residential use in the station impact area, just between 2000 and 2003. This suggested that rail transit does have an influence on the change of the land use patterns. A comparison between the land use patterns around stations on three lines in Pudong, and the current pattern in the centre of Shanghai as reference area, shows that the former has a higher proportion of commercial and public facilities use (Pan and Zhang, 2008).

Furthermore, rail transit investment has stimulated integrated development, with consideration of the needs of various different developers and the government. For example, the development of People’s Square station, at the interchange of Line 1
and Line 2, uses a compact development pattern around the station, attracting the interests of various stakeholders. The development shows the willingness for participation of various stakeholders, with institutional supports as a bonus. The development mechanism of the rail impact areas does reflect the increasingly important role of the private sector in China in making land use decisions (Pan and Zhang, 2008, Cervero and Day, 2008).

Case study 3: West Kowloon, Hong Kong

West Kowloon (the red area in Figure 2.4) is a stretch of land in Hong Kong, reclaimed in the late 20th century. The reclamation project was carried out as a part of a core airport development program: a government-driven plan aiming to develop the west of Hong Kong. Hong Kong’s rail transit development took place over two generations. The first consisted of four lines, completed by the end of the 1980s. The second generation included the opening of the fifth airport line in 1998,
which includes both the Tung Chung Line (東涌線) and Airport Express Line (機場快線). Along with moving the airport from the city centre to Lantau Island (大嶼山), the construction of the airport line was part of the overall urban development plan of a new zone in West Hong Kong.

The West Kowloon MTR station is an important node of the airport line. It is also the station of the Guangzhou-Shenzhen-Hong Kong express rail link (广深港高速铁路). The West Kowloon project is located on the station site. It is zoned for mixed use with commercial, residential and leisure development. The core of the project is the Union Square station, which includes commercial projects, an international commerce centre, and residential towers that sit atop Kowloon MTR station. The development was directly stimulated by the rail transit line, with flight check-in possible within the city. It is a dense development with an especially high plot ratio of 12:1 (Tiry, 2003, Xue et al., 2010). The strategy of the Mass Transit Railway Corporation (MTRC, 香港鐵路有限公司) is to pursue income from real estate development over the stations. It demonstrates collaborative participation between MTRC and private sectors (Tiry, 2003, Xue et al., 2010).
La Défense (the red area in Figure 2.5) is now Europe’s largest purpose-built business district. It is located at the western extremity of the 10 km long historical axis of Paris. The first generation of skyscrapers in the area began to slowly replace the old constructions in the late 1950s. Then, the second and third generations of skyscrapers appeared in the early 1970s and 1980s. After stagnation in new development in the mid-1990s, La Défense is once again expanding. In 2006, a development plan was confirmed by EPAD (Établissement public pour l’aménagement de la région de la Défense, the La Défense Management & Development Office) to be carried out around 2015, with four main axes of regeneration of out-dated skyscrapers, allowing new building, improving the balance between offices and residential housing and making transport easier. La Défense today concentrates a great part of the employment in the Paris region, while the government tries to balance tertiary sector employment in the whole region (Hall, 1984). In 1970, the RER (Réseau Express Régional) ‘A’ route was opened from La Défense to Étoile. The journey time was cut spectacularly by the RER, but it soon reached saturation due to a considerably high passenger flow. In 1992, Line 1 of the
Paris Métro was extended to La Défense. Now 85% people working in La Défense use public transport. As the hub of numerous public rail transport infrastructures, including the Métro, the RER, the SNCF (Société nationale des chemins de fer français) train and the tram, La Défense is less than 15 minutes from the heart of Paris. The exceptional level of transport service continues to contribute to the success of the business district (Bollotte, 1991).

Case study 5: Zuidas, Amsterdam

As a major new development zone in the Netherlands, Zuidas (the red area in Figure 2.6) lies in a district between Amsterdam-Zuid and Buitenveldert, with the highest average disposable income in the Amsterdam region. The international station in the district is connected to Amsterdam Schiphol Airport, and takes only a few minutes by train. The initial development of Zuidas began with firms seeking convenient space outside the crowded core of Amsterdam, with easy automobile access. Given concerns about promoting social housing to peripheral business developers, the
development of Zuidas, starting in 1987, was converted from a single-use large office development to include mixed uses of commerce, housing and recreation (Pharoah and Apel, 1995). Zuidas is a transport hub with train, metro, tram and bus. The new international rail station includes HSL (high speed line) services to Brussels and Paris and ICE (Intercity-Express) services to Köln and Berlin. It will become Amsterdam's main international station. Now, the development of Zuidas has caused a shift of the economic centre away from the historical core. It has also caused a change in the character of the inner city, with a functional shift towards entertainment, tourism and small business. However, as with the Stratford City development in London, there are problems with citizen involvement, because relatively few people actually live there (Fainstein, 2008). The planned commercialisation mechanism involves a public and the private partnership. The private sector is playing a larger role in providing infrastructure, such as financing the rail and highways, and is receiving development rights in the newly created space in return (Fainstein, 2008).

2.5.3 Lessons drawn from the cases

1. All the cases have exhibited obvious impacts from rail transit investment. Especially in Canary Wharf (excluding deliberate zoning factors), land use development, employment and economic performance have shown extremely significant growth, directly caused by the rail transit investment. Cases such as West Kowloon, Hong Kong and Shanghai have shown dense development mainly around the rail transit stations. A favourable shift in travel mode share towards rail use is apparent in all the cases. However, the social equity issues arising from rail transit investment can never be ignored (as shown in the case of Canary Wharf), but there is very limited research available on the social effects in these cases.

2. The impact in each case is influenced comprehensively by many other factors. After the reviewing these cases (especially cases with a longer period of existence,
such as La Défense and Canary Wharf) it again needs to be noted that the transport factor is never the only influence. Other factors, such as the economic environment, investment and policies also work together to contribute to the result.

3. *The cases can be viewed as examples to show how to integrate the different intentions of various stakeholders.*

Especially in Hong Kong, there has been rich experience of a collaborative development mechanism between the public and private sectors. This kind of cooperation trend has also been shown in Zuidas, Amsterdam. Policies to promote public-private partnerships have also proved attractive to investors in other cases. The experience of coordinating diverse needs and motives can benefit understanding and planning of similar projects in the future.

### 2.5.4 The case study of Chongqing

#### 2.5.4.1 Chongqing’s development

The city of Chongqing (重庆) is used as the case study for this thesis. It is an economic centre located on the upper Yangtze River (长江), in the region of Southwest China (西南) (Figure 2.7). As of the 2014 Census, the main urban area (as shown in Figure 2.7) has a residential population of 8.2 million (8.2m). Although Chongqing’s main urban area only spans 5,473 km$^2$, its administrative area is more comparable to a province: it spans over 80,000 km$^2$, much of which is rural. The total population is around 30m (million) people. Around 12m of its residents are villagers; another 18m live in the main urban area and other widely scattered towns.
The urban area runs approximately north to south; sitting in a syncline between two mountainous folds: Zhongliang Mountain to the west, and Tongluo Mountain to the east (Figure 2.8). The development of the urban area to the west and east has historically been confined by these natural topographical barriers. However, in recent years, with several tunnels constructed through the mountains, new developments have also been possible on the other sides of the two mountains.
Figure 2.8: The main urban area of Chongqing. Source: Chongqing’s Urban Planning Bureau 2005
The old city centre in Chongqing is located at the junction of the two rivers. With the development of the airport in the early 1990s, development has been witnessed at astonishing speed, turning the previous farmlands on the north of the river into a prosperous new city centre within just 20 years (Figure 2.9).
Currently in Chongqing, four lines of the public transit Metro network are in operation (lines 1, 2, 3 and 6), with a total length of 202 km. The first line was opened in 2004. Three new lines were added — two in 2011 and one in 2012 (Figure 2.9), and there is now an extensive Metro network. According to the Municipal Government’s plan, by 2020, the public transit network will consist of six radial lines and one circular line, with a total length of 480 km. This compares to 402 km on the London Underground network (2013). Hence another issue is apparent: the speed and scale of development in China is extremely rapid, and it will take Chongqing just 15 years to develop a Metro network as extensive as that in London, which took 150 years.

![Figure 2.10: Chongqing rail transit Line 3, opened in 2011. Source: https://www.flickr.com/photos/chenlin3632/9052365040](image)

A comparison between several large cities in mainland China (sorted according to their population in the main urban area) is provided in Table 2.2, including Chongqing (Chongqing Transport Planning Institute., 2016). All of these cities have rail transit systems. Different indices are given, which reflect the nature of the main urban area of each city. The population of Chongqing’s main urban area is
comparable to that of Wuhan or Nanjing, and considerably lower than Beijing, Shanghai, Guangzhou or Shenzhen (each with populations over 10 million). The overall length of track in Chongqing’s rail transit network ranked it fourth among the mainland cities in 2014, behind Beijing, Shanghai, and Guangzhou.

Within Chongqing’s main urban area, GDP per capita was ¥76,800 CNY in 2014. Road density in Chongqing’s main urban area is 0.68 km/km², compared with Beijing’s 0.39 km/km² and Shanghai’s 0.77 km/km². These figures are still far behind countries with more developed road transport. For example, the UK’s road density was 1.72 km/km² in 2007 (a figure for the whole country, including rural areas). The number of vehicles per capita in Chongqing in 2014 was 140.5 per 1,000 people; much lower than the equivalent UK statistic of 519 per 1,000 people.

---

9 After Nanjing opened its Line3 in 2015, Chongqing becomes the fifth.

10 http://www.nationmaster.com/country-info/stats/Transport/Road-density/Km-of-road-per-100-sq.-km-of-land-area

11 http://www.nationmaster.com/country-info/stats/Transport/Road/Motor-vehicles-per-1000-people
<table>
<thead>
<tr>
<th>Indices</th>
<th>Unit</th>
<th>Beijing</th>
<th>Shanghai</th>
<th>Guangzhou</th>
<th>Shenzhen</th>
<th>Wuhan</th>
<th>Nanjing</th>
<th>Chongqing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>thousand</td>
<td>21,520</td>
<td>24,260</td>
<td>13,080</td>
<td>10,630</td>
<td>10,338</td>
<td>8,216</td>
<td>8,190</td>
</tr>
<tr>
<td>Land area</td>
<td>km²</td>
<td>16,410</td>
<td>6,341</td>
<td>7,434</td>
<td>2,020</td>
<td>8,494</td>
<td>6,587</td>
<td>5,473</td>
</tr>
<tr>
<td>Population density</td>
<td>Per km²</td>
<td>1,311</td>
<td>3,826</td>
<td>1,759</td>
<td>5,262</td>
<td>1,217</td>
<td>1,247</td>
<td>1,496</td>
</tr>
<tr>
<td>Gross Domestic Product (GDP)</td>
<td>billion yuan</td>
<td>¥2,133.1</td>
<td>¥2,356.1</td>
<td>¥1,670.6</td>
<td>¥1,600.2</td>
<td>¥1,007.0</td>
<td>¥882.1</td>
<td>¥628.9</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>thousand yuan</td>
<td>¥100.0</td>
<td>¥97.0</td>
<td>¥128.0</td>
<td>¥149.0</td>
<td>¥98.0</td>
<td>¥108.0</td>
<td>¥76.8</td>
</tr>
<tr>
<td><strong>Road</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total length of the urban roads</td>
<td>km</td>
<td>6,426</td>
<td>4,852</td>
<td>N/A</td>
<td>6,368</td>
<td>N/A</td>
<td>7,424</td>
<td>3,730</td>
</tr>
<tr>
<td>Urban road density (Urban road length/land area)</td>
<td>km/km²</td>
<td>0.39</td>
<td>0.77</td>
<td>N/A</td>
<td>3.15</td>
<td>N/A</td>
<td>1.13</td>
<td>0.68</td>
</tr>
<tr>
<td><strong>Motor vehicle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of motor vehicles</td>
<td>thousand</td>
<td>5,591</td>
<td>3,042</td>
<td>2,504</td>
<td>3,140</td>
<td>1,820</td>
<td>2,062</td>
<td>1,151</td>
</tr>
<tr>
<td>Number of motor vehicles per 1,000 population</td>
<td></td>
<td>259.8</td>
<td>125.4</td>
<td>191.4</td>
<td>295.4</td>
<td>176.0</td>
<td>251.0</td>
<td>140.5</td>
</tr>
<tr>
<td><strong>Bus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of buses</td>
<td>thousand</td>
<td>23.7</td>
<td>16.2</td>
<td>13.7</td>
<td>14.8</td>
<td>7.8</td>
<td>8.3</td>
<td>8.6</td>
</tr>
<tr>
<td>Passenger traffic volume</td>
<td>billion*person per year</td>
<td>4.77</td>
<td>2.67</td>
<td>2.61</td>
<td>2.26</td>
<td>1.48</td>
<td>1.06</td>
<td>1.96</td>
</tr>
<tr>
<td><strong>Taxi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of taxies</td>
<td>thousand</td>
<td>68</td>
<td>51</td>
<td>22</td>
<td>17</td>
<td>17</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Passenger traffic volume</td>
<td>billion*person per year</td>
<td>0.67</td>
<td>1.04</td>
<td>0.78</td>
<td>0.44</td>
<td>0.38</td>
<td>0.31</td>
<td>0.61</td>
</tr>
<tr>
<td><strong>Rail transit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total network length</td>
<td>km</td>
<td>527</td>
<td>578</td>
<td>260</td>
<td>178</td>
<td>97</td>
<td>179</td>
<td>202</td>
</tr>
<tr>
<td>Passenger traffic volume</td>
<td>billion*person per year</td>
<td>3.38</td>
<td>2.83</td>
<td>2.28</td>
<td>1.04</td>
<td>0.36</td>
<td>0.5</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Figure 2.11 shows the population change within Chongqing’s main urban area from 2007 to 2015. There was a steady increase in population during this period. However, the growth rate dropped from a peak of 7.38% in 2010, to 1.93% in 2015. This suggests that, while the urbanisation trend continues, its speed has been slowing.

![Population change in Chongqing’s main urban area](image)

Table 2.3 and Figure 2.12 show changes in GDP, and its sectoral composition in Chongqing’s main urban area. From 2007 to 2015, GDP increased more than three times, from ¥181.24bn to ¥686.18bn CNY. There was a rapid increase from 2008 to 2011, with GDP growth rate remaining above 20% each year. In 2012, GDP growth rate slowed quite dramatically, down to around 10%, where it has roughly remained since. In the first half of 2016, GDP growth rate in the whole city region was 10.6%
— 3.9% higher than the national average level. As shown in Table 2.3, the tertiary sector has gradually become the largest part of GDP, with the share held by the primary and secondary sectors continuing to decrease.

<table>
<thead>
<tr>
<th>Year</th>
<th>GDP</th>
<th>GDP growth rate</th>
<th>Primary sector</th>
<th>Primary sector proportion</th>
<th>Secondary sector</th>
<th>Secondary Sector proportion</th>
<th>Tertiary sector</th>
<th>Tertiary sector proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>181.24</td>
<td>6.18</td>
<td>3.41%</td>
<td>87.89</td>
<td>48.49%</td>
<td>87.17</td>
<td>48.10%</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>224.93</td>
<td>24.11%</td>
<td>6.56</td>
<td>2.92%</td>
<td>115.31</td>
<td>51.26%</td>
<td>103.06</td>
<td>45.82%</td>
</tr>
<tr>
<td>2009</td>
<td>298.63</td>
<td>32.77%</td>
<td>6.82</td>
<td>2.82%</td>
<td>132.76</td>
<td>44.46%</td>
<td>159.05</td>
<td>53.26%</td>
</tr>
<tr>
<td>2010</td>
<td>359.67</td>
<td>20.44%</td>
<td>7.52</td>
<td>2.09%</td>
<td>167.63</td>
<td>46.61%</td>
<td>184.52</td>
<td>51.30%</td>
</tr>
<tr>
<td>2011</td>
<td>448.26</td>
<td>24.63%</td>
<td>8.74</td>
<td>1.95%</td>
<td>199.41</td>
<td>44.49%</td>
<td>220.77</td>
<td>49.25%</td>
</tr>
<tr>
<td>2012</td>
<td>498.17</td>
<td>11.13%</td>
<td>9.96</td>
<td>2.00%</td>
<td>231.19</td>
<td>46.41%</td>
<td>257.02</td>
<td>51.59%</td>
</tr>
<tr>
<td>2013</td>
<td>553.30</td>
<td>11.07%</td>
<td>10.21</td>
<td>1.85%</td>
<td>255.23</td>
<td>46.13%</td>
<td>287.86</td>
<td>52.03%</td>
</tr>
<tr>
<td>2014</td>
<td>628.90</td>
<td>13.66%</td>
<td>10.24</td>
<td>1.63%</td>
<td>251.64</td>
<td>40.01%</td>
<td>367.02</td>
<td>58.36%</td>
</tr>
<tr>
<td>2015</td>
<td>686.18</td>
<td>9.11%</td>
<td>10.79</td>
<td>1.57%</td>
<td>263.23</td>
<td>38.36%</td>
<td>412.16</td>
<td>60.07%</td>
</tr>
</tbody>
</table>


http://jtj.cq.gov.cn/tjsj/sjjd/201607/t20160715_423998.htm
Statistics relating to the travel mode share of residents in the main urban area are exhibited in Table 2.4. Walking always takes a dominant role. This pattern is partly caused by the topography of Chongqing. Residential and employment locations were historically confined by the mountainous topography of the main urban area. Most people therefore walk from their home to the working place. The pattern is also caused by historical industrial planning policies in the city. Construction in the main urban area was organised according to a pattern of several ‘clusters’. Within the clusters, residential areas were located around the industries, for convenience and efficiency of production. It should be noted that there is no specific category for bicycle as a mode of transport in Table 2.4. Due to the mountainous topography, and the lack of cycle lanes, very few people ride bicycles in Chongqing.
From 2002 to 2010, the share held by walking dropped from 62.7% to 47.5%, with the expansion of the city. Many people now travel outside the original clusters, thus the shares held by bus, taxi and car have all increased. After the rail transit lines 1, 3 and 6 were opened (in 2011 and 2012), the share held by rail transit increased from 0.6% to 5.8%. From 2010 to 2014, the proportion walking remained almost the same, while the share held by buses and taxis dropped, and the share held by cars still increased from 11.5% to 15.8%. However, in those who switched to rail transit or private cars, it is not clear which travel mode they were previously using. In this thesis, I explore this issue further through a survey of changes in travel patterns in certain study areas (Section 6.4).

<table>
<thead>
<tr>
<th>Year</th>
<th>Walk</th>
<th>Bus</th>
<th>Rail transit</th>
<th>Taxis</th>
<th>Car</th>
<th>Other</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>62.7%</td>
<td>27.6%</td>
<td>0</td>
<td>4.4%</td>
<td>4.7%</td>
<td>0.6%</td>
<td>100.0%</td>
</tr>
<tr>
<td>2010</td>
<td>47.5%</td>
<td>32.8%</td>
<td>0.6%</td>
<td>6.7%</td>
<td>11.5%</td>
<td>0.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>2014</td>
<td>46.3%</td>
<td>26.8%</td>
<td>5.8%</td>
<td>4.8%</td>
<td>15.8%</td>
<td>0.5%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 2.4: Travel mode share of residents in terms of trips in the main urban area of Chongqing. Source: Chongqing Urban Traffic Operation Condition Annual Report 2014 (Chongqing Transport Planning Institute., 2015).

Figure 2.13 shows the changes in the yearly passenger traffic volume of the bus system in Chongqing’s main urban area. The absolute passenger traffic volume increased from 2007 to 2014, with a slight drop in 2015. However, the growth rate continued decreasing from 2008 to 2014, and even dropped below zero (−2%) in 2015.
In comparison, passenger traffic volume on the rail transit system has increased at a faster rate than the bus network. As shown in Figure 2.14, there was an increase of 176.4% in 2011, with the opening of rail transit line 1 and 3, and 103.2% in 2012, with the opening of Line 6. After that, the passenger traffic volume kept increasing with the continued opening of the extensions of these lines in 2013 and 2014. However, the growth rate has gradually slowed (from the bump in 2011) to 22.3% in 2015.
When looking at the number of private cars in the main urban area (Figure 2.15), the growth rate remained above 20% between 2007 and 2014. After reaching a level of 30.2% in 2009, the growth rate slightly decreased from 2009 to 2013. There was a sudden increase in the rate in 2014, to 30.4%, but it dropped again to 17.6% in 2015. This suggests that, although the amount of car ownership in China is still increasing (and will likely continue for some time), the trend is gradually moving towards saturation of private car demand.
With economic growth in China gradually slowing down, all of the above changes have shown a trend towards saturation. However, the GDP growth rate is still high (6.9% in 2015) in comparison with some developed countries (for instance: UK, 1.4% and US, 1.8% in 2015\textsuperscript{13}), and of course the absolute GDP value is considerable. Meanwhile, the urbanisation rate in China reached only 56% by 2015. Therefore, compared to other developed countries (for example, UK, 83% and US, 82% in 2015\textsuperscript{14}), there is still much space for development.

This research thesis addresses the impact of Chongqing’s rail transit systems, and aims to explore the short-term outcomes of this transport provision, in terms of both direct and indirect impacts. However, it will also consider how these short-term

\textsuperscript{13} http://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZG
\textsuperscript{14} http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS
outcomes may interact together to generate long-term economic, urban and social effects (Jones and Lucas, 2012).

### 2.5.4.2 Land development process in Chongqing

As has been discussed, planning in China plays a role in shaping and driving economic development in cities. It is argued that the rationale of growth-oriented planning (including transport planning in China) provides strong evidence that planning can support growth, by its nature and associated activities. A wide belief exists among governments, planners, investors and citizens that development can, and should, be planned (Wu et al., 2015). Given this consensus, favourable spatial planning strategies play an important role in attracting industries such as manufacturing, residential and commercial development — thus increasing the local economic output.

The tax-sharing system that exists between the central government, municipal governments and the land market in China provides the necessary conditions and financial incentives for local government to pursue land development. Meanwhile, monopolistic land ownership by the state makes municipal authorities the only provider of land. The municipal governments in China are endowed the right of compulsory land reservation by the state (Wu, 2015), and they are given the right to use the land as a collateral to raise capital through the private market (Wu et al., 2015). In Chongqing, land is reserved for use as collateral to the banks for loans, and to finance public facilities such as infrastructure construction in the city. The revenue gained from such ‘land banking’ makes up a great proportion of local finance. When the land price rises, the government sells the land to the private market, pays back the bank and also gains from the revenue generated in the process.

In the current framework of land policy in China, there are two legitimate ways of land leasing: one is *land assignment*, while the other is *bid, auction and listing*. The
latter involves three stages. The first is building demolition and land preparation. The preparation of farmland, wasteland, or built-up areas requires budget allocation from the government. In this process, the action of municipal governments ranges from the provision of necessary infrastructure, to fiscal incentives, to promotion of grand development visions for attracting investors and developers. Secondly, the audit department of the government set the base price of the land. Finally, the land goes through the bid, auction and listing process. The bidding process is the crucial point when the appreciation of land value is realized. Before bidding, the government will reveal the urban plan index of the land, such as the public transport provision, industry planning, permitted plot ratio, and constructive area. The developers participating in the auction need to estimate the land value according to the given information.

The social changes in Chongqing are different from many other cities. There is an aim to keep economic expansion going, while ensuring that the huge social changes unleashed by growth do not perpetuate inequalities. Chongqing’s efforts to achieve this have gone further than many other cities in China. It has involved three main initiatives. First, the government has promised to build 40m square metres of housing by 2020 to rent to the urban poor, including rural migrants. Chongqing sets the rent at about 60% of the market price of comparable commercial properties. This contrasts with other local governments, who are reluctant to spend money on housing migrant workers. Secondly, the government plans to give full urban status (Hukou) to 10m migrants. Between 2010 and now, around 4m rural migrants have opted to switch their Hukou status to ‘urban’. Thirdly, the government has announced changes to the urban planning system, to allow land left behind by rural migrants to be traded for use in building new houses and offices. The initiative is considered as a breakthrough in China: the central government still officially disapproves of selling farmers’ property (The Economist., 2016c).
2.5.4.3 Spatial strategies of rail transit planning in Chongqing

Currently in China, forty-one cities have already submitted their metro system plans to the National Ministry of Construction and the State Council to examine and approve. The procedure of rail transit system planning varies between cities in China, but the general process is similar. In the rail transit system development process, different levels of government, as well as different sectors are involved, such as the Urban Planning Bureau, the Development and Reform Commission, the Construction Committee, the Transport Committee, and the Land and Resources Commission, at both the municipal and local levels.

The earliest stage of the procedure is preparing the urban rail network plan, which is part of ‘Urban Master Planning’. The rail network plan should then be handed to municipal expert committee to examine. This committee include experts from the Construction Committee, the Transport Committee, and the Development and Reform Commission. The Development and Reform Commission is in charge of project approval; the Construction Committee is in charge of construction of the rail transit systems; the Transport committee is in charge of the operation of the system. The next stage is the public engagement procedure. At this stage, public opinions are welcome. After public engagement, the plan is reported to the municipal government and the municipal people's congress, and opinions are welcomed. Finally, the plan is reported to the Ministry of Housing and Urban-Rural Development and the State Council of the central government to examine and approve.

Once the plan is approved, next comes the construction procedure. The Municipal Construction Committee is in charge of drafting the construction plan. It is then reported to the National Development and Reform Commission for approval. The construction plan presents, in detail, which lines are to be constructed and when. After the construction plan is approved, the Municipal Development and Reform Commission is responsible for setting up the project. In recent years, the procedure
has been simplified so that the construction plan doesn’t need to be reported to the central government for approval, but just to the municipal government. After the project is set up, the Municipal Transit Corporation is responsible for preparing a feasibility report for the transit project. In parallel to the feasibility report, two other assessment reports are also prepared. These are the landscape and environmental assessment reports, which are prepared by the Municipal Environmental Bureau, and require investigations and resident surveys. Because of the ever-worsening environmental risks in China, these two reports receive particular attention from the government. There are rare situations in which the government tries to have public involvement. If there is strong opposition from the public, the design, the plan, and the engineering systems could all be changed. For example, in the rail network plan in Chongqing, some sections have been changed from over-ground to underground, because residents nearby worried about noise. This change involved a high additional cost in construction.

Integration of land use and transit development requires a series of governmental actions such as land acquisition and preparation, demolition and allocation, and transport construction. Besides, it also includes a set of procedures carried out by the developers, including gaining the land development rights, conducting regulatory and construction planning, financing rounds, and revenue and tax recapturing. A large quantity of coordination work goes on among different levels of governments, including municipal and local governments, and different governmental sectors, such as the Municipal Development and Reform Commission, and other agencies dealing with building, transport, planning, land and resources, and finance.
2.6 Conclusion

This literature review helps to give a comprehensive understanding of the impacts of rail transit investment, by covering transport, demographic, economic, spatial and social aspects. Social inequity issues relating to the distribution of the effects of rail transit have also been discussed in the process. Among the cases reviewed, results of empirical research on the impact of new rail transit systems vary a lot between cities. In fact, results can vary dramatically between different locations of the same city, and even different parts of a single line.

Table 2.5 shows some of the main research findings in this area, considering the direct and indirect impacts that are typically examined. The research gaps include how transit investment may impact on travel behaviour, economic performance, land development and property values, labour market and social equity.

It is clear that many other factors are simultaneously influencing the impact of rail transit. As to what extent the transit can contribute to development, research difficulties exist in quantifying development directly caused by the transit project in isolation. Therefore, more important than discerning the net effect of rail transit, is the identification of the synergistic factors involved. Diverse needs still exist among different stakeholders, and require coordination. Only with a comprehensive understanding of the whole picture, can a package of measures be combined to produce the most desirable result.
Table 2.5: Main research findings in the literature of the impacts of rail transit investment and perceived 'knowledge gaps'

<table>
<thead>
<tr>
<th>Direct impacts</th>
<th>Research gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limitation and condition</strong></td>
<td></td>
</tr>
<tr>
<td>The scale of transport investment and the existing transportation condition in the specific location influence the impact of the new investment. In locations of particularly poor accessibility, or areas just opened to competition, the regional connection added by the transport investment can exert significant impact (Vickerman, 1995, Vickerman et al., 1999, Vickerman, 2008).</td>
<td></td>
</tr>
<tr>
<td>People's travel behaviours can only significantly shift towards rail transit use when community-based planning and design are conductive to transit use, and when accessibility to employment and other opportunities are promoted together with the rail transit investment (Cervero, 1998).</td>
<td></td>
</tr>
<tr>
<td><strong>Transport impact</strong></td>
<td></td>
</tr>
<tr>
<td>By improving accessibility, rail systems can strengthen downtown cores. They have been a force towards decentralization of both population and employment, but they can widen disparity between the central and peripheral areas (Berechman and Paaswell, 1983, Llewelyn-Davies et al., 2004).</td>
<td>• How does the impact of rail transit on peoples’ travel behaviour vary spatially and across population groups?</td>
</tr>
<tr>
<td>Regional rail has adapted the region of Stockholm into a form with rail-served satellite sub-centres, integrated along developmental corridors, producing the highest modal share of rail transit for work trips in Europe (Cervero, 1998, Hall, 2013).</td>
<td>• What are the social equity implications of spatial-social variation in rail transit’s direct impact?</td>
</tr>
<tr>
<td>An employee survey in Canary Wharf showed 80% of the total arrival trips associated with increased employment fall into the category of rail transit (Lane et al., 2004).</td>
<td></td>
</tr>
<tr>
<td>Rail transit had different impacts on established residents and newcomers to an area. The former made relatively few changes to their travel patterns, while the latter were more likely to make greater use of rail transit (Lane et al., 2004).</td>
<td></td>
</tr>
<tr>
<td><strong>Indirect impacts</strong></td>
<td></td>
</tr>
<tr>
<td>The impact on inward investment and employment increase may be re-distributive rather than generative (Boddy et al., 1986, Boarnet and Crane, 2001).</td>
<td>• To what extent can rail transit investment influence decisions on business location and inward investment intentions?</td>
</tr>
<tr>
<td>In the areas with relatively high accessibility, the change in accessibility brought about by transit investments is limited, and thus the transit’s contribution to land development may not be significant (Guiliano, 2004, Cao and Pan, 2016).</td>
<td>• How does the rail transit system influence the perspectives of different stakeholders?</td>
</tr>
<tr>
<td><strong>Economic performance</strong></td>
<td></td>
</tr>
<tr>
<td>The aspects by which transport improves economic performance include: reducing production and distribution costs; improving labour productivity; increasing the accessible pool of labour and raw materials, and stimulating inward investment (SACTRA, 1999, Llewelyn-Davies et al., 2004).</td>
<td></td>
</tr>
<tr>
<td>In the developing world, where existing public transport is sparse and of lower quality, new investment in transport improves physical access to resources and the market, helps improve quality of life, reduce poverty and promote growth (Banister and Berechman, 2003).</td>
<td></td>
</tr>
<tr>
<td>The impacts on an agglomeration economy broaden and multiply, with one development potentially leading to another (Townroe, 1995).</td>
<td></td>
</tr>
<tr>
<td>Urban rail transit has an impact on local business activities and consumer amenities (Zheng et al., 2016, Cao and Pan, 2016).</td>
<td></td>
</tr>
<tr>
<td><strong>Land development and property values</strong></td>
<td></td>
</tr>
<tr>
<td>New development, infill development, adaptive reuse of old buildings and upgrading of the urban environment are demonstrated to be</td>
<td>• What are the impacts of the newly built rail</td>
</tr>
</tbody>
</table>
facilitated near new transport stations (Cao and Pan, 2016, Cao and Porter-Nelson, 2016), with changes in land and property value which directly result from the improved accessibility provided by transit investment (Llewelyn-Davies et al., 2004).

Various evidence shows that proximity to rail transit increases property prices, rents and development rates, e.g. in cases of BART, Toronto’s Yonge Street Line, Washington D.C, Singapore, Beijing and Wuhan’s rail transit (Cervero and Landis, 1995, Zhu and Diao, 2016, Wang et al., 2016, Xu and Zhang, 2016).

The JLE brought about a significant increase in land value and property price, rate and density of land development and redevelopment, and maintenance of properties and townscape (Llewelyn-Davies et al., 2004).

Planning and policy intervention by government can both influence the choice of station siting and the availability of developable land (Guiliano, 2004, Cao and Pan, 2016). It is the planning that ‘creates’ the development in a market economy when there is a planning system like that in China.

**Labour market**

New rail transit brings about a new pattern of relationships between employment locations and residential locations, by opening up a larger labour pool for employers to recruit from, and by improving accessibility to an expanded employment area for a variety of people (Townroe, 1995).

Rail transit has been successful in redirecting employment to areas needing regeneration and changing the image of the areas, which in turn tends to attract high-profile companies to the area. A substantial employment increase in the JLE corridor resulted from an expansion of the recruitment area and potential customer engagement area for companies (Lane et al., 2004).

The increase in employment levels due to rail transit is accompanied by a change in occupation pattern. Businesses that hire a higher proportion of professional, technical and administrative/clerical workers were attracted to the areas served by BART (Cervero and Landis, 1995), and a similar situation occurred in the JLE corridor (Lane et al., 2004).

The JLE has not contributed much to reducing the high level of long-standing local unemployment in its catchment areas. Local people have only benefited to a limited extent from the increased employment (Lane et al., 2004).

**Social equity effect**

More concern should be placed on more exact specifications of both the form of transport provision and the needs of disadvantaged groups in the society (Davies, 1968, Boyne and Powell, 1991, Hay, 1995).

A distribution dimension exists alongside other dimensions of transport impact (economic, ecological and social dimensions). The distribution dimension directly points to the social equity issues associated with transport investment (Feitelson, 2002, Jones and Lucas, 2012).

When the effect exceeds the sensitivity level of individuals, and has aggregated effects on a particular population group, it can be considered a true inequity of social impact. If different levels of social impact are deemed unacceptable, according to the values and standards of society, it tends to bring about issues of social injustice (Geurs et al., 2009).

Research on the relevance of social impacts should not only focus on geographic inequity, but also address aspects of disproportionate distributed benefits and accumulated social impacts across population groups (Feitelson, 2002, Jones and Lucas, 2012).

A lack of influence on decision-making and governance (e.g. locking the public out of the planning process) also plays a great part in social inequity of transport (Schwanen et al., 2015).

<table>
<thead>
<tr>
<th>How do the impacts on development vary over space?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the distribution of benefits of employment from transit development?</td>
</tr>
<tr>
<td>To what extent can the local residents benefit from the increased employment?</td>
</tr>
<tr>
<td>How do the individuals occupying different socio-economic positions in the city perceive the impacts of new transit developments differently?</td>
</tr>
<tr>
<td>What are the equity dimensions that arise from transit development?</td>
</tr>
<tr>
<td>Which policies and planning interventions might be introduced to achieve greater equity in impacts?</td>
</tr>
</tbody>
</table>
Chapter 3. Methodology

3.1 Research steps

The previous literature review helps to develop an understanding of current trends in the field, such as the background of rail transit development, rail transit’s potential impacts on regeneration, and the social equity issues that may arise in the process. The research presented in this thesis was carried out according to the following stages (Figure 3.1):

- Defining research fields and research questions
  Based on the extensive literature review, the research field was defined as the impact of rail transit on regeneration and development. Research questions were then put forward.

- Developing a research framework
  Then, the research framework was established to answer the research questions, as shown in Figure 3.2. This firstly presents the mechanisms by which rail transit has an impact on urban development, as well as how it is itself influenced by other factors. Secondly, it presents the steps needed to explore spatial-social variation in the direct and indirect impacts of rail transit investment, and how to access the social equity dimensions.

- Research design
  Both quantitative and qualitative approaches were utilised in this research. Quantitative analysis was used to explore each research question, followed by an explanatory study of the key actors' perspectives and attitudes.
• **Data collection**

Data for this study came from three data sources, which were selected to allow measurement of the impact of rail transit. Data that would act as indicators of change over time were collected from local authorities, including: population data, employment data, income data and local business activities. Data regarding residents' travel patterns and socio-economic background characteristics were extracted from an official city-wide travel survey (2014, Chongqing Urban Planning Bureau). Data regarding residents' attitudes were gathered using a survey specifically designed by the author for this study.

• **Statistical analysis**

Analysis tools were employed to investigate the relationship between public transport investment and its impacts. These tools included logistic regression, geographic weighted regression (GWR), descriptive analysis, multilevel regression, multivariate analysis of variance (MANOVA) and discriminate analysis.

• **Sequential explanatory research**

Further to the quantitative analysis, qualitative explanatory research was also conducted using sequential interviews. The diverse intentions of different stakeholders were explored, and how they might have influenced the impact of transport investment. The supplementary qualitative analysis investigated the potential causes of the exhibited effects that the quantitative approach might not have been able to sufficiently explain.

• **Drawing conclusions**

Conclusions were drawn based on the results of the statistical analysis and supplementary qualitative analysis.
3.2 Research framework

As has been addressed in the literature review, generally the main output from transport infrastructure investment is network accessibility improvement, while there may also be secondary benefits for wider aspects of urban development. This study aims to understand how transport investment affects different realms of urban (re)development; how the effect of transport investment is affected by other factors such as policies; how we conceptualize the distributional dimension of transport investment effects (which directly points to social equity); and how we might develop an appropriate strategy to integrate transport and land development. Therefore, the methodology framework was organized in correspondence with the research questions, as shown in Figure 3.2 (below).
3.3 Research design specific to research questions

This research adopted a combination of both quantitative and qualitative approaches. Generally speaking, it took an explanatory approach, in which qualitative data was connected to quantitative data. In this study, different methods were used at different stages to deal with the specific research questions. The research analysis was carried out according to the following structure:

1. Identifying indicators of change

For any appraisal of the impact of a transit system there must be an identification of indicators of change. In this study, travel behaviour, economic impact, social-economic impact and land development were identified as the indicators of change to be researched and measured over time. As explained in the literature review, travel convenience was considered as a direct impact, while the others were considered to be indirect. The direct impacts and indirect impacts were explored separately.
2. Identifying influential factors

The likely macro influential factors on urban development were considered, such as the economic environment, policies, investment and other influences. As suggested by previous literature, the effect of rail transit is influenced by other factors, which can make results vary greatly between cities. The aim of highlighting these factors is to reveal that the impacts on urban development can be the result of the synergistic effect of transit investment and other supporting innovations that are introduced in parallel, such as supplementary policies and investments. The importance of these other supportive measures is also explored in this study.

3. Identifying the city areas for study and time-scale over which impacts occur

After the indicators of change are identified, it is necessary to assess the extent to which any change in these indicators is due to the transit system. In this study, a comparative method was used to assess this. Rail station catchment areas and reference and control areas were therefore defined. The comparison between the catchment areas and both reference and control areas was performed with the intention of ruling out other contextual influences, and viewing the effect of rail transit in isolation. In order to examine the effect of time, data was collected at four time points: two before opening and two after opening of the new rail transit system. Furthermore, comparative analysis between the effects in different transit station catchment areas was used to explore the effects of introducing other supportive planning interventions.

The process of assessing the impacts of the transit system was divided into two parts: direct and indirect impacts.

4. Analysis of spatial-social variations of direct impact

I first assessed the direct impact of rail transit (the impact on transport itself), in order to address the first research question (see Chapter 1). Logistic regression and
geographic regression analysis were used to assess how transit’s direct impact on people’s travel convenience was itself influenced by other locational and social economic variables and how this influence varied spatially. Data for this analysis was extracted from an official citywide travel survey (Appendix 1: Chongqing urban household travel survey 2014).

5. Analysis of spatial-social variations of indirect impacts
The next step was to assess the indirect impacts, in order to address the second research question. Indirect impacts were firstly explored with descriptive analysis on different locations. Spatial variations of the impacts are revealed by comparison. A multilevel regression model was then used to assess whether the changes in population and employment in the local area have broadly contributed to the quality of living (measured by average income level) of people there. Next, the distribution of the beneficial effects — as a measurement of transit related social equity — was assessed by measuring people’s opinion of the rail transit’s impact on themselves and their neighbourhoods, using a bespoke survey. MANOVA and discriminant analysis were then used to explore the variations of opinions between different population groups.

6. Analysis of sequential qualitative study
A qualitative approach, using interviews and follow-up was used in order to further explain the results found from the quantitative analysis. Interviews were carried out to explore how the different powers and interests of stakeholders influenced: the process by which the transit investment generated its effects; the level of ‘value capture’; and the use of integrated transport and land development.

The following sections in this chapter explain these methods in more detail.

15 Value capture measures are often used in urban mass transit projects to internalise external benefits of land value increment, with the aim of lightening the burden of financing.
3.4 Data collection of indicators of change

In order to explore the impact of the transit system on urban development and regeneration, the first step is to identify the impact dimensions. Impact is divided into the five dimensions below, including the direct impacts and indirect impacts. In order to assess these different dimensions, particular indicators of change are identified for each. The data source of the chosen indicators of change is presented in the following sections (each limited by the availability of data).

1. Transport
   Indicator(s): Travel mode share

2. Land use characteristics
   Indicator(s): Land development and population

3. Economic impact
   Indicator(s): Employment and business activities

4. Social economic characteristics
   Indicator(s): Income level, household size and age structure

5. Social equity
   Indicator(s): Distribution of impacts spatially and across the population

Measurements of each subdivision of impacts, and the relevant data sources are listed below in Table 3.1.
### Dimensions of Change: Measurement/Data sources

#### Transport statistics

- **Travel mode**
  - Travel mode split: bus, trail transit, car, walk, others *(Citywide travel survey)*

- **Travel distance**
  - Travel distance of daily first outbound trip from residential location to destination *(Citywide travel survey)*

- **Travel time**
  - Travel time of daily first outbound trip from residential location to destination *(Citywide travel survey)*

- **Trip origin and destination**
  - Trip origin and destination of daily first outbound trip from residential location to destination *(Citywide travel survey)*

- **Trip purpose**
  - Trip purpose of daily first outbound trip from residential location to destination *(Citywide travel survey)*

#### Land use characteristic statistics

- **Population**
  - Residential population size *(Census Data from local government)*

- **Population density**
  - Residential population density *(Census Data from local government)*

- **Land development**
  - Built-up land *(Statistics from city planning bureau)*
  - Land for sale *(Statistics from city planning bureau)*
  - Construction land *(Statistics from city planning bureau)*

#### Economic performance statistics

- **Employment**
  - Working-age population in employment *(Census Data from local government)*

- **Employment density**
  - Employment density *(Census Data from local government)*

- **Local employment**
  - Local employment rate *(Census Data from local government)*

- **Business accumulation**
  - Number of firms and self-employed entrepreneurs located *(Census Data from local government)*

#### Social - Economic characteristic statistics

- **Income**
  - Household annual income *(Census Data from local government)*

- **Car ownership**
  - Household car ownership *(Citywide travel survey)*

- **Age structure**
  - Residents’ age *(Citywide travel survey)*

- **Household size**
  - Household size *(Census Data from local government)*

- **Gender**
  - Gender *(Citywide travel survey)*

---

Table 3.1: Data source for indicators of change

### 3.5 Methods for exploring spatial variation of direct impacts (research question 1)

#### 3.5.1 Methodological review of global and local models for public transport use analysis

Many studies employ multivariate statistical analyses to explore the interrelationships among variables that may predict people’s public transport use.
Global models based on multiple regression analysis (Messenger and Ewing, 1996, Kuby et al., 2004, Cervero, 2006, Cervero et al., 2010, Taylor et al., 2009, Souche, 2010, Pan et al., 2009, Pan et al., 2013) are a complementary approach to estimating transit use-related variables as a function of station environment and transit service features. These predictor variables can reveal the impact of urban planning on transit use, which are particularly relevant in transit oriented development (Cardozo et al., 2012).

There has been an increasing amount of research identifying the non-transport effects of rapid transit facilities, such as property market effects. The main approach has been to use a hedonic pricing model (HPM). The HPM estimates the implicit value of attributes of differentiated goods, such as housing, by regressing the attributes on the price of the good. Therefore, HPMS have strength in revealing the benefits of rapid transit on the land market (Lancaster, 1966, Rosen, 1974, Duncan, 2010, Higgins and Kanaroglou, 2016). However, the main difficulty with an HPM is the means by which it handles spatial data. The issue of spatial dependency in an HPM is an important concern. Distance thresholds are normally used in HPMS to determine the impact of independent variables. This often makes the result differ from that with other model estimates (Banister and Thurstain-Goodwin, 2011). The inherently spatial nature of data sets in HPMS potentially leads to biased estimates and unreliable test statistics (Du and Mulley, 2006). In response to these problems, other spatial econometric methods are used, which recognise the spatial dependencies by incorporating a spatially-lagged dependent variable, error term, or both, to model such effects. However, local spatial analytical methods, such as geographically weighted regression (GWR) have been developed to address the potential spatial dependency and model spatial heterogeneity (Higgins and Kanaroglou, 2016). Thus in this study it was decided that GWR was the best approach to model the relationship between the dependent and independent variables over space. How GWR can model spatial heterogeneity is explained later.
Local models, such as spatial proximity regression, GWR, and hierarchical linear models, are used to examine the key factors affecting public transport use locally (Chow et al., 2006, Kobayashi and Lane, 2007, Blainey, 2010, Gutiérrez et al., 2011, Pulugurtha and Agurla, 2012, Cardozo et al., 2012). Among these local models, GWR has already been applied to diverse topics, including health, crime, transport and urban space. In the field of transport, GWR models have also been used to explore the spatial variation of variables, such as car ownership (Clark, 2007), accessibility (Paez, 2006), land use (Du and Mulley, 2006) and public transport use (Chow et al., 2006, Blainey, 2010, Cardozo et al., 2012, Chiou et al., 2015). Blainey (2010) examined the relationship between passenger numbers and the characteristics of local railway station environments. Cardozo et al. (2012) incorporated GWR into direct station-level ridership forecasting models. Chiou et al. (2015) used a global and local regression model (GWR), to identify the key factors that affect public transportation usage in Taiwan. In evaluating spatial justice, GWR has had a great number of applications in evaluating environmental justice, with regards the risks from diverse kinds of pollution (Mennis and Jordan, 2005, Gilbert and Chakraborty, 2011, Gebreab and Roux, 2012, Jephcote and Chen, 2012), but very limited applications in transport-related justice.

In the literature, two main approaches — individual and collective — are applied to examine public transport use. Individual approaches are conventionally based on data from questionnaire surveys of travellers. The individual approach examines the effects of a series of variables on people’s travel mode choice. The commonly adopted explanatory variables include travel time, travel cost, social-demographics and trip characteristics (e.g. trip distance, walking distance) of travellers. The individual approach has the advantage over the collective approach when studying associations between individuals’ mode choice change and the improved public transport service, which is useful for evidencing decisions regarding public transport investment.
Though the individual approach is frequently used in conventional regression models (Pan et al., 2009, Pan et al., 2013, Le Loo et al., 2015), most of the literature using GWR has adopted the collective approach (Chow et al., 2006, Du and Mulley, 2006, Paez, 2006, Blainey, 2010, Cardozo et al., 2012, Chiou et al., 2015), with analysis carried on data aggregated to the zone level. This is partly because the commonly-adopted explanatory variables in the individual approach are costly to collect data on, as they require many transport surveys over a large area. Furthermore, raw data of household travel records before aggregation are very difficult to get access to, and datasets with geographic locational information are especially sparse. In the Chongqing urban household travel survey 2014 (described below), data were collected by the surveyors using a tablet loaded with a specially developed ‘app’ (software application). Individual information was thus recorded in the dataset, along with geographic locational information of the residence. Therefore, the spatial information in the dataset used in this research provides a unique opportunity to adopt the individual approach to applying a GWR model.

### 3.5.2 Data source

The association between people’s travel-related variables and socio-economic characteristics, and choice of rail transit for travel, was modelled using data from a citywide travel survey (Appendix 1: Chongqing urban household travel survey 2014), which took place three years into the operation of Line 1, 3 and 6. This survey sampled households in the main city region (as defined in the Introduction chapter). The city was divided into twenty-five transport zones as shown in Figure 3.3. The sample size of each zone was based on its population size. The whole survey contained a sample of 80,000 persons, in 28,000 households, in the main city region (representing a 1% sampling of the total population).
Figure 3.3: Twenty-five transport zones in the city of Chongqing. The study region included zone 1, zone 2, zone 10, and zone 11 (dark grey).

For this study, data for the central city impacted zones were extracted for analysis from zone 1, zone 2, zone 10, and zone 11 (the grey areas in Figure 3.3) — yielding a dataset of 5,111 persons. Next, data from people below 18 years of age were excluded, in order to focus the analysis on people’s commuting patterns. Thus a final dataset amounting to 3,642 persons was used for the analysis in this chapter. The following logistic regression and GWR analysis were carried out on this sample. A detailed description of the data is provided in Section 4.2.
3.5.3 Analytical techniques (research question 1)

In answering the first research question, the aim was to explore what factors influence people choosing rail transit; that is to say, what factors significantly differentiate those people who choose rail transit from those people who choose other travel modes. Binomial logistic regression was first employed to explore the relationship between the choice of travel mode and a number of explanatory variables. The form of the model used is shown in Equation 1. The explanatory variables used were travel distance, distance between residential location and the nearest rail transit station, age, property type, gender, car ownership and official residential permission (Hukou).

\[
Travel \ mode \sim \ Travel \ distance \\
+ \ Distance \ to \ nearest \ station \\
+ \ Age + \ Car \ ownership + \ Gender \\
+ \ Property \ type + \ Hukou
\]  

(1)

Following binomial logistic regression, geographic weighted regression (GWR) was then used to explore the spatial non-stationarity (which is explained later) in the global logistic regression model. GWR is utilised to reveal the spatial variation in model parameter estimates, as a reflection of what is unique about individual places. The GWR model is incorporated into the regression process, allowing the inclusion of spatial characteristics within the existing regression model (Du and Mulley, 2006). Therefore, it helps to more deeply explain the cause of the variation, and better address the research questions.

3.5.3.1 Logistic regression

It is important to first explain the theory of binary logistic regression. In multiple linear regression, the outcome variable \( Y \) is predicted from the equation:

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \epsilon
\]
where \( b_n \) is the regression coefficient of the corresponding variable \( X_n \). For linear regression to be valid, the observed data should have a linear relationship. When the outcome variable is categorical, this assumption is violated. The solution is to transform the data using a logarithmic transformation. Logistic regression is based on this principle: it expresses the multiple linear regression equation in logarithmic terms (called the logit), and thus overcomes the problem of violating the assumption of linearity. In logistic regression, instead of predicting the value of a variable \( Y \), as in multiple linear regression, we predict the probability of \( Y \) occurring given known values of \( X_n \). The logistic regression equation for the probability, \( P(Y) \), of \( Y \) occurring is given by:

\[
P(Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_{i1} + b_2 X_{i2} + \cdots + b_n X_{in})}}
\]

The equation for logistic regression can be presented in several ways, but this version expresses the equation in terms \( P(Y) \). \( e \) is the base of natural logarithm, and the other coefficients form a linear combination, much the same as in simple regression. The resulting value of \( Y \) varies between 0 and 1. A value close to 0 means that \( Y \) is very unlikely to have occurred, while a value close to 1 means that \( Y \) is very likely to have occurred.

Then, to assess whether a model fits the data in logistic regression, the measure ‘log-likelihood’ is used, and is calculated according to the following equation, where \( LL \) is log-likelihood:

\[
LL = \sum_{i=1}^{N} \left[ Y_i \ln(P(Y_i)) + (1 - Y_i) \ln(1 - P(Y_i)) \right]
\]
The log-likelihood statistic is analogous to the residual sum of squares in multiple regression, in the sense that it is an indicator of how much unexplained information there is after the model has been fitted. Therefore a larger value of the statistic indicates a statistical model with a poor fit. The deviance of a logistic model is given by:

\[ \text{Deviance} = -2 \times \text{LL} \]  

Therefore, the deviance is often referred to as \(-2\text{LL}\) and it has a Chi-squared distribution, which makes it easy to calculate the significance of the value. It is useful to compare a logistic regression model against some kind of baseline model to assess the improvement of the logistic regression model. The baseline model is usually the model that gives the best prediction using nothing other than the values of the outcome, and when only the intercept in Equation 3 is included. The new model deviance can then be subtracted from the deviance of the baseline model to see by how much unexplained information is reduced after the new model is constructed.

\[ \text{LR} = (\text{-2LL(baseline)}) - (\text{-2LL(new)}) \]  
\[ \text{LR} \sim \chi^2(df) \]  

and

\[ df = k_{\text{new}} - k_{\text{baseline}} \]  

where the difference is known as the likelihood ratio, LR, and has a chi-square distribution with degrees of freedom (df) equal to the number of parameters, \(k\), in the new model minus the number of parameters in the baseline model. The number of parameters in the baseline model will always be 1, because the constant is the only parameter to be estimated. By using standard chi-square distribution techniques,
knowing LR and df, it can be calculated whether or not the new model is significantly better than the previous model.

Furthermore, we want to know not only how the overall model fits the data, but also the individual contribution of the various predictors. In logistic regression, the z-statistic follows a normal distribution, and can be used to tell whether the coefficient for that predictor is significant in predicting the outcome, Y.

\[ z = \frac{b}{SE_b} \]  

where SE\(_b\) is the standard error of coefficient b. Here, z is known as Wald statistic, and is basically identical to the t-statistic in linear regression, and can be used to ascertain whether a variable is a significant predictor of the outcome.

The value of the odds ratio can be shown to be equal to \( e^{b_a} \) and can be used to interpret the logistic model. To explain the odds ratio, it is necessary to introduce the concept of odds. In logistic regression, the odds of an event occurring are defined as the probability of an event occurring divided by the probability of that event not occurring.

\[ \text{Odds} = \frac{P(\text{event})}{P(\text{no event})} \]  

The odds ratio is the proportionate change in odds. The proportionate change is calculated by dividing the odds after a unit change in the predictor by the odds before that change.

\[ \text{Odds ratio} = \frac{\text{Odds after a unit change in the predictor}}{\text{Original odds}} \]  

Therefore, if we use the version of logistic regression in Equation 3 to calculate the
odds ratio,

\[
P(\text{event } Y) = \frac{1}{1 + e^{-(b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_n X_{ni})}}
\]

and

\[
P(\text{no event } Y) = 1 - P(\text{event } Y)
\]

Substituting \(P(\text{event } Y)\) and \(P(\text{no event } Y)\) into Equation 9 we find that \(\text{Odds}\) equals:

\[
\text{Odds} = e^{(b_0 + b_1 X_{1i} + b_2 X_{2i} + \cdots + b_n X_{ni})}
\]

(12)

With one unit change in \(X_{ni}\), and substitution into Equation 10, we find:

\[
\text{Odds ratio} = e^{b_n}
\]

(13)

3.5.3.2 Spatial autocorrelation test: Moran’s I

The problem of global parameter estimates in a model is that the global values are spatial averages, which can hide a great deal of information about the process being studied (Fotheringham et al., 2003). Some of the unexplained variance in the errors of the global regression model results probably originate from assuming the relationships in the model to be constant over space. This means a stationary process is assumed in the global model, while in fact it might be non-stationary. If such variations in relationship exist over space, then the global regression model is unlikely to be a good model of the real-life situation (Fotheringham et al., 2003).

A traditional method to investigate the spatial non-stationarity of a model is to map the residuals from the regression model on a map in space. However, even if the distribution of the residuals in space is visually non-random (for example, with large positive residuals accumulating in some areas of the old city), one can’t be sure that
spatial non-stationarity necessarily exists in the model.

A spatial autocorrelation test is required to examine it statistically. The first law of geography says: “Everything is related to everything else, but near things are more related than distant things” (Tobler, 1970). This phenomenon is called ‘spatial autocorrelation’ by statisticians. Spatial autocorrelation occurs when the distribution of the values of observations is not spatially random and describes the similarity of nearby observations. Statistical tests of spatial autocorrelation examine whether the observed value of a variable at one location is independent of values of that variable at neighbouring locations. In other words, it is a test of match between locational similarity and attribute similarity.

Spatial autocorrelation is measured by a number of statistics having slightly different formulations, for example, Moran’s I and Geary’s C statistics. In this study the statistic of Moran’s I was used as a test for the presence of spatial autocorrelation, Moran's I is defined as:

\[
I = \frac{N}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2}
\]  

Where \( N \) is the number of spatial units indexed by \( i \) and \( j \); \( y_i \) is the value of a variable for the \( i \) th observation, \( \bar{y} \) is the sample mean of \( y \), and \( w_{ij} \) is an element of a matrix of spatial weights (the choice of spatial weight matrix is explained in the next section). Values of \( I \) range from −1 to 1. Negative values indicate negative spatial autocorrelation and positive values indicate positive spatial autocorrelation. A zero value indicates a random spatial pattern. The expected value, \( E(I) \), of Moran’s I under the null hypothesis of no spatial autocorrelation is

16 http://rstudio-pubs-static.s3.amazonaws.com/9688_a49c681fab974bbca889e3eae9fbb837.html
17 Moran's / is inversely related to Geary's C. Moran's / is a measure of global spatial autocorrelation, while Geary's C is more sensitive to local spatial autocorrelation.
\[ E(I) = \frac{-1}{N - 1} \] (15)

The null hypothesis states that "there is no spatial clustering of the values associated with the geographic features in the study area". When the p-value is small and the absolute value of the Z score is large enough that it falls outside of the desired confidence level, the null hypothesis can be rejected\(^\text{18}\), which means that spatial autocorrelation exists.

### 3.5.3.3 Geographic weighted regression

Geographic weighted regression (GWR) is utilized to provide a solution to the spatially auto-correlated error terms in the global model. GWR allows detailed spatial variations in relationships to be examined and can effectively reveals the pattern in space (Fotheringham et al., 2003).

Taking as a starting point a global regression model, expressed as:

\[ y_i = \beta_0 + \sum_k \beta_k x_{ik} + \epsilon_i \] (16)

GWR extends this traditional regression framework by allowing local rather than global parameters to be estimated; thus the model is rewritten as:

\[ y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \epsilon_i \] (17)

Where \((u_i, v_i)\) denotes the coordinates of the \(i\) th point in space and \(\beta_k(u_i, v_i)\) is a realization of the continuous function \(\beta_k(u, v)\) at point \(i\). Therefore, Equation 16 is a specific case of Equation 17 in which the parameters are assumed to be spatially

invariant, while Equation 17 recognizes that spatial variations occur. GWR assumes that the coefficients are deterministic functions of some other variables: in this case, location in space. Assuming the parameters exhibit some degree of spatial consistency, then values near to the one being estimated should have relatively similar magnitudes and signs. And this assumes implicitly that observed data near to location \( i \) have more of an influence in the estimation of \( \beta_k(u,v) \) than do data located farther from \( i \). That means data from observations close to \( i \) are weighted more than data from observations farther away.

In order to estimate the parameters of the GWR model, firstly consider the classical regression in Equation 16 in matrix form. With \( n \) observations and \( k \) predictors, Equation 16 can be expressed as a set of linear equations:

\[
\begin{align*}
y_1 &= \beta_0 + \beta_1 x_{11} + \cdots + \beta_k x_{1k} + \epsilon_1 \\
y_2 &= \beta_0 + \beta_1 x_{21} + \cdots + \beta_k x_{2k} + \epsilon_2 \\
\vdots \\
y_n &= \beta_0 + \beta_1 x_{n1} + \cdots + \beta_k x_{nk} + \epsilon_n
\end{align*}
\]

These can be written in matrix form as

\[
y = X\beta + \epsilon
\]

where the variables in bold type denote matrices.

\[
y = (y_1, y_2, \ldots, y_n)^T \\
X = \begin{bmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1k} \\
1 & x_{21} & x_{22} & \cdots & x_{2k} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
1 & x_{n1} & x_{n2} & \cdots & x_{nk} \end{bmatrix} \\
\beta = (\beta_0, \beta_1, \beta_2, \ldots, \beta_k)^T \\
\epsilon = (\epsilon_1, \epsilon_2, \ldots, \epsilon_n)^T
\]
Here superscript \( T \) indicates the transpose function; hence \( y \), \( \beta \) and \( \varepsilon \) are ultimately column vectors.

Using maximum likelihood least squares we can estimate vector \( \beta \), which is constant over space and is estimated by:

\[
x^T x \hat{\beta} = X^T y
\]

where \( \hat{\beta} \) represents an estimate of \( \beta \). This is then solved by multiplying by the inverse of \( x^T x \), which is \( (x^T x)^{-1} \),

\[
\hat{\beta} = (x^T x)^{-1} x^T y
\]

The GWR equivalent of Equation 19 is:

\[
y = (\beta \otimes X)j + \varepsilon
\]

where \( \otimes \) is the cross-product, and \( j \) is an all-ones vector of dimensions \( (k + 1) \times 1 \).

If there are \( n \) data points and \( k \) explanatory variables, both \( \beta \) and \( X \) will have dimensions \( n \times (k + 1) \). The matrix \( \beta \) consists of \( n \) sets of local parameters and has the following structure:

\[
\beta = \begin{bmatrix}
\beta_0(u_1, v_1) & \beta_1(u_1, v_1) & \ldots & \beta_k(u_1, v_1) \\
\beta_0(u_2, v_2) & \beta_1(u_2, v_2) & \ldots & \beta_k(u_2, v_2) \\
\ldots & \ldots & \ldots & \ldots \\
\beta_0(u_n, v_n) & \beta_1(u_n, v_n) & \ldots & \beta_k(u_n, v_n)
\end{bmatrix}
\]

The transpose of the above matrix is estimated by:

\[
\hat{\beta}(u_i, v_i) = (X^T W(u_i, v_i) X)^{-1} X^T W(u_i, v_i) y
\]
where $i$ is the index of each row of the matrix in Equation 24, and $W(i)$ is an $n$ by $n$ spatial weighting matrix of the form:

$$
W(i) = \begin{bmatrix}
    w_{i1} & 0 & \cdots & \cdots & 0 \\
    0 & w_{i2} & \cdots & \cdots & 0 \\
    \cdots & \cdots & \ddots & \cdots & \cdots \\
    0 & \cdots & \cdots & \cdots & w_{in}
\end{bmatrix}
$$

(26)

where $w_{ij}$, as an element of $W(i)$, is the weight given to data point $j$ in the calibration of the model for location $i$. The estimator in Equation 25 is a weighted least squares estimator, but rather than having a constant weighting matrix, the weights in GWR vary according to the location of point $i$. The mechanism of calibrating the weighting matrix is explained below (Fotheringham et al., 2003).

GWR works such that a region is described around a regression point and all the data points within this region are then used to calibrate a model. Each data point is weighted by its distance from the regression point. Hence, data points closer to the regression point are weighted more heavily in the local regression than data points farther away. Geographically, the method is to fit a spatial kernel to the data, as shown in Figure 3.4. For a given regression point, the weight of a data point is at a maximum when it shares the same location as the regression point $i$. This weight decreases as the distance between the data point and the regression point increases. The bandwidth is the measure of the distance-decay in the weighting function, and indicates the extent to which the resulting local calibration results are smoothed. Spatial kernels with a small bandwidth have a steeper distance-decay weighting function and produce rougher surfaces than spatial kernels with a large bandwidth, as shown in Figure 3.6. A further explanation of the bandwidth is given below.
In this way, the regression model is calibrated locally by moving the regression point across the region. For each location, the data will be weighted differently across the region and the results of any one calibration at a regression point are unique to a particular location in the region. Therefore, the weighting matrix $W(i)$ in Equation 26 is a weighting scheme based on the proximity of the regression point $i$ to the data points $j$ around $i$. The weighting matrix of Equation 26 has to be computed for each point $i$ and the weights depict the proximity of each data point $j$ to the location of $i$, with points in closer proximity carrying more weight in the estimation of the parameters for location $i$.

The mathematical description of the relationship between the regression point $i$ and the data points around it is summarised below. Basically there are two kinds of spatial kernel: fixed terms (Figure 3.5) and adaptive terms (Figure 3.6). Fixed term kernel functions are fixed in shape and magnitude over space, whereas adaptive term kernels can be different in shape and magnitude in different locations.
One way to specify $w_{ij}$ is as a Gaussian function where the weight of the $j$th data point at the $i$th regression point is calculated by the continuous function,

$$w_{ij} = \exp \left[- \frac{1}{2} \left( \frac{d_{ij}}{b} \right)^2 \right]$$ \hspace{1cm} (27)

where $d_{ij}$ is the Euclidean distance between $i$ and $j$ and $b$ is the bandwidth. The bandwidth at each regression point is assumed to be constant across the study area. If $i$ and $j$ coincide, the weighting of data at that point will be unity and the weighting of other data will decrease according to a Gaussian curve as the distance...
between i and j increases. However, the weights are non-zero for all data points, no matter how far they are from the regression point.

An alternative fixed kernel utilizes a bi-square function where the weight of the jth data point at regression point i is given by,

\[ w_{ij} = \left[1 - \left(\frac{d_{ij}}{b}\right)^2\right]^2 \text{, if } d_{ij} < b \]
\[ = 0 \text{ otherwise} \]  

(28)

This provides a continuous, near-Gaussian weighting function up to a distance b from the regression point, and then zero weights for any data point beyond b.

However, a potential problem that might arise with fixed spatial kernels is that, at some locations of regression points, the data are sparse. The local model is therefore potentially calibrated using very few data points, which gives rise to parameter estimates with large standard errors. To reduce these problems, one can use adaptive (spatially varying) kernels, where the kernels are allowed to vary spatially in size according to variations in the density of the data; with kernels being smaller in regions where the density of data points is high and larger where the density of data points is low. Spatially varying kernels can reduce problems when data in regions are distributed unevenly. Because in regions where data are dense there is more scope for examining changes in relationships over relatively small distances, and where data are less dense, larger distances can be examined.

Several methods for producing spatially varying kernels exist. For example, one is to rank the data points in terms of their distance from each point i so that \( R_{ij} \) is the rank of the jth point from i in terms of the distance j is from i. The closest data point to i has a weight of 1 and the weights decrease as the rank increases according to some continuous function. One expression of this kind of function is:
\[ w_{ij} = \exp(-R_{ij}/b) \quad (29) \]

This method automatically reduces the bandwidth of kernels in regions with large amounts of data. For example in regions where data are scarce, the distance from the regression point \( i \) to the \( j \)th nearest point will be much less than in regions where data are dense.

Another spatially varying weighting method involves a bi-square weighting function which is related to the \( N \)th nearest neighbours of point \( i \). The calibration of the model involves the estimation of \( N \). The weighting function determines the weight of each data point up to the \( N \)th, and all data points beyond the \( N \)th are set to zero. Therefore using this bi-square decaying function to calibrate the weighting matrix, the bandwidth is selected and adaptive, such that there are the same number of data points (\( N \)) with non-zero weights at each regression point.

\[
\begin{align*}
  w_{ij} &= \left[ 1 - \left( \frac{d_{ij}}{b} \right)^2 \right]^2 & \text{if } j \text{ is one of the } N \text{th nearest neighbours of } i, \\
  &= 0 & \text{otherwise.}
\end{align*}
\quad (30)
\]

Specifying the geographical weighting scheme requires the specification of a kernel shape and a bandwidth. As shown from the above discussion, the choice of bandwidth has a large impact on the results of GWR. The bandwidth can be chosen by the user, or selected to minimize the cross-validation (CV)\(^{19}\) approach or the

---

\(^{19}\) The theory of cross-validation involves partitioning a sample of data into complementary subsets, performing the analysis on one subset (called the training set), and validating the analysis on the other subset (called the validation set or testing set). To reduce variability, multiple rounds of cross-validation are performed using different partitions, and the validation results are averaged over the rounds. The goal of cross validation is to define a dataset to "test" the model in the training phase (i.e., the validation dataset), in order to give an insight on how the model will generalize to an independent dataset (i.e., a real problem).
Akaike information criterion (AIC).

The Akaike information criterion (AIC) is a measure of the relative quality of a statistical model for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Hence, AIC provides a means for model selection. It deals with a trade-off between goodness-of-fit of the model and degrees of freedom, by minimizing the AIC. A model with a lower AIC value is a better fit of the data. It is necessary to use a corrected AIC (referred to as $AIC_c$) for finite sample sizes. In GWR, $AIC_c$ is defined as:

$$AIC_c = 2n \log(\hat{\sigma}) + n \log(2\pi) + n \left( \frac{n + tr(S)}{n - 2 - tr(S)} \right)$$

(31)

Where $n$ denotes the sample size, while $\hat{\sigma}$ denotes the estimated standard deviation of the error term of the GWR model. $tr(S)$ is the trace of the hat matrix, which is a function of the bandwidth. The hat matrix $S$ is defined as:

$$\hat{y} = Sy$$

(32)

Where $y$ denotes the observed values, and $\hat{y}$ denotes the fitted values of the data set. The trace is the sum of the values in the leading diagonal of this matrix, usually expressed as $tr(S)$. The trace of $S$ for an ordinary least squares (OLS) regression model is the number of parameters in the model; while in a GWR model, the effective number of parameters is obtained from the expression $2tr(S) - tr(S^T S)$. In fact, inferencing from Equation 23 and Equation 25, $r_i$ is each row of $S$, and can be expressed as:

$$r_i = X_i (X^T W(u_i, v_i) X)^{-1} X^T W(u_i, v_i)$$

(33)
The $\text{AIC}_c$ takes into account the different number of degrees of freedom in different models, so that their relative performances can be compared more accurately. A model with a lower $\text{AIC}_c$ than another is held to be a ‘better’ model. The method of $\text{AIC}_c$ has the advantage of being more general in application than the CV approach, because it can be used in logistic GWR as well as in linear models. Therefore, in this study, the $\text{AIC}_c$ method was utilized to generate the optimal bandwidth.

$\text{AIC}$ can also be used to assess whether GWR provides a better fit than a global model, because it takes into account the different degrees of freedom of the two models.

### 3.6 Catchment area: definition used in this research

#### 3.6.1 Literature review of the definition of catchment area

Transit catchment areas are used by planners and researchers, not only to make predictions about transit ridership and transit impacts (such as socioeconomic and land use impacts), but also to prescribe planning regulations, e.g., relaxing restrictive zoning or carving out TODs for financial plans (Guerra et al., 2012).

However, the definition of the geographical boundary of a station catchment area used in the literature varies from case to case, depending on location and planning practices, and there is no generally agreed rule. For example, an 800 m (metre) radius circle has been widely accepted as a transit station’s catchment area, and this is the spatial extent of most TOD planning in the US. The 800 m (roughly 0.5 mile) distance is loosely based on the distance that people are willing to walk to reach a station within 10 min (Guerra et al., 2012). The 800 m boundary has a lot of evidence to support its use as the effective impacted area (Cervero, 1994, Cervero, 2007). For example, it was found in a study in California, that the transit mode share
of people living within 800 m of a transit station (27%) is four times that of those living in the area between 800 m (0.5 miles) and 4800 m (3 miles) away from a station (7%) (Cervero, 2007).

Despite being widely recognised, many concerns (Weinberger, 2001, Guerra et al., 2012, Xu and Zhang, 2016) have been raised as to whether the 800 m radius is generally an appropriate measure for station-area planning and policy making. It is argued that the definition of catchment area should be subject to local empirical evidence rather than applying ‘rule of thumb’ figures borrowed from other contexts (Xu and Zhang, 2016).

Various approaches have been used in previous literature to explore the appropriate catchment area according to specific context. There are mainly two kinds of approaches. In the first main approach, many studies have tried to explore different types of transit impact by using a series of key walking distance thresholds, e.g., 500 m, 800 m, or 1000 m (Hess and Almeida, 2007, Du and Mulley, 2007, Pagliara and Papa, 2011). These ranges of distances are calculated according to people’s walking time, e.g. 7 min, 10 min and 12 min.

Using such walking distance thresholds to define catchment area is legitimised by considering the principle justification for TOD: measuring/maximising the effect of a transit station in attracting passengers. It is determined by an understanding of how far people are willing to walk to take transit (Guerra et al., 2012). In a research study exploring pedestrian access to LRT stations, O’Sullivan and Morrall (1996) conducted interviews on 1,800 LRT users in Calgary, Canada. For the city of Calgary the average walking distance to suburban stations is 649 m, and the 75th-percentile distance is 840 m. While for a CBD station the average is 326 m and the 75th-percentile distance is 419 m (O’Sullivan and Morrall, 1996). Several other studies have quoted this result as a reference when defining their own catchment areas (Du and Mulley, 2007, Pagliara and Papa, 2011). In studying the impact of the
extension of the Tyne and Wear Metro on the city of Sunderland, UK, Du and Mulley (2007) defined the catchment area as a 500 m radius around the stations, based on a 7 min walk. Pagliara and Papa (2011) also adopted the same radius, of 500 m, in their study on the land use and economic impacts of the urban rail system in Naples.

However, walking distance is highly dependent on the local topography, spatial scale, climate, population density, urban development and pedestrian environment of a specific city. As has been questioned in some studies, the willingness to walk varies from person to person, and many transit users also access stations by car, bike or bus. Therefore one should be cautious when referring to results produced by data gained in another context. Furthermore, the impacts of transit are not limited to the average or even maximum walking distance (Guerra et al., 2012). The transit investment exerts impact on the adjacent area through economic influence, which can’t be measured in terms of simple distance. All of these concerns cast doubt on the validity of using walking distance to define catchment area.

In the other main approach, studies have sought analytical methods for defining the catchment area. Some studies introduced variables (such as population, jobs) into their statistical models to predict diverse impacts, such as transit ridership, land use and property values. These predictive variables are introduced as a set of dummy variables, corresponding to their location within various circular rings of distance (distance bands) around the station. Statistical fits over multiple distance bands are used to set spatial benchmarks of the catchment areas. An appropriate catchment area is defined by considering both the goodness of fit of these models and the farthest distance band of significant predictive variables (Weinberger, 2001, Cervero, 2007, Guerra et al., 2012, Petheram et al., 2013, Xu and Zhang, 2016). Only a few studies determine the catchment area by exploring the decaying changes of impacts with continuous distance change (Lewis-Workman and Brod, 1997, McMillen and McDonald, 2004, Banister and Thurstain-Goodwin, 2011,

Guerra et al. (2012) used regression methods to predict the average of weekday boardings and alightings with station-level variables from a range of distance bands from transit stations. They found, when trying to estimate station-level transit ridership, that different sizes of catchment area had little influence on a model’s predictive power. While for making causal inferences, or prescribing land use policies, their results supported the use of a 400 m radius catchment area for jobs and an 800 m radius for population (Guerra et al., 2012). Another piece of research, carried out by Weinberger (2001), studied the impact of LRT on housing prices. By looking at the distance gradient in isolation, it was shown that properties within 400 m of the LRT were valued similarly; property values decreased (i.e. a negative gradient) between 400 m and 800 m; the gradient was even more negative between 800 m and 1200 m; but there was no further effect above 1200 m. Xu and Zhang (2016) examined the spatial extent to which three transit lines have had an influence on house prices in the city of Wuhan, China. Their results showed that the area of influence extended to 700 m for the light rail transit line, and 900–1000 m for the two metro lines. These findings are greater than the 500–600 m radius that is currently used by the city planning agencies in Wuhan.

However, there is a limitation of this approach with categorical variables, because the kinds of testing bands are limited in number. The distance bands are usually generated using pre-determined intervals of distance from the station, and distance is thus not used as a continuous variable. This results in arbitrary subdivisions and approximate values of dependent variables within one distance band. Models with continuous distance variables can avoid this, but the data often lack sufficient or precise-enough distance information.
3.6.2 Catchment area definition for different analyses – rules and limitations

The choice of catchment area definition used in this research was quite important, as it decided the scale of analysis for both the comparative study and the multi-level approach adopted. However, it was necessarily dependent on the theoretical scale of analysis desired, and the quality of the available data.

Different scales of study area were applied to different analyses in this research. The study area for analysing transport impact, in answering the first research question, was defined to include the whole central city area in Chapter 4, as presented in Section 3.5.2. However, for the purpose of analysing the non-transport impacts, I defined the geographic station catchment areas. The same catchment area definition is used consistently in Chapter 5 and Chapter 6. In Chapter 5, a comparison study is presented, using data gathered in four catchment areas, one control area and two reference areas. Also in Chapter 5, multi-level analysis is presented on three catchment areas. In Chapter 6, the results of a questionnaire survey are presented for all the catchment areas and the control area.

I defined the catchment area guided by previous research, and specifically using the second approach (the analytical approach) discussed in the previous section (Weinberger, 2001, Guerra et al., 2012, Petheram et al., 2013, Xu and Zhang, 2016). This approach draws on the empirical evidence of the catchment area, where land use impacts associated with rail transit development were found (Weinberger, 2001, Xu and Zhang, 2016), rather than referring to walking distance to the station. It also depends on referring to findings from a similar context (Xu and Zhang, 2016), because, for the reasons explained above, the walking distance to the station that is appropriate in one context is not necessarily transferrable to another. This is especially true for the mountainous topography in central Chongqing. Furthermore, the roads through the old city are much narrower than the new city in the north, with
tight bends. The provision of public transport by bus is therefore insufficient in the old city, and there is always problematic traffic congestion in the old city centre. These unique geographical conditions make the real catchment areas in the old city larger in scale than those in the new city.

Considering all of these factors, a base scale of 800 m was adopted for catchment areas in this study. This is compatible with the study by Guerra et al. (2012), who used a 400 m catchment area to detect the change in employment and an 800 m catchment area for population. These distances are suggested for considering transit-oriented land use policy and collecting labour-intensive data, such as surveys. It is also compatible with the study by Xu and Zhang (2016) in Wuhan, which showed that the area of influence area extends to 700 m for LRT and 900–1000m for MRT. This research covers both population and employment impact analysis as well as adopting survey methods, and considering both LRT-type (Line 2) and MRT-type (Line 1, 3, 6) transit lines. Therefore, whilst an 800m radius was adopted in this research as the base scale for a catchment area, it was also subject to modifications (discussed below).

Two major factors affecting catchment area delineation were the availability of data (in terms of both location and categories) and the boundaries used for official municipal data collection. Raw, unprocessed data in Chongqing (in fact, for local areas in most Chinese cities) are quite difficult to obtain, and most often not accessible to the public. Data for catchment areas at the local level could only be acquired by relying on people working in the local authorities sourcing it, aggregating it and sending it to me. The data availability limited the number of catchment areas for analysis. An ideal comprehensive analysis of catchment areas in a whole region, or along a section of transit line, was therefore nearly impossible to carry out. As a result, only four catchment areas and one control area, in three sub-districts were defined for analysis. These catchment areas were adjusted to be compatible with the boundaries of the smallest unit of census data — a community.
— and each catchment area could contain several communities. For these reasons, the physical boundaries of catchment areas in this research were modified considerably from the base scale of 800 m radius. This ultimately resulted in different scales for each catchment area.

Five study areas were used for analysis as station catchment areas; four of which (Daping [DP], Jiazhoulu [JZL], Hongtudi [HTD] and Huahuiyuan [HHY]) surround new station nodes on the network, and one (Luneng [LN]) which is situated away from new transit station developments (Figure 3.7). These areas are based on the boundaries used by the local authorities to collect public demographic census data from Chongqing. As shown in Figure 3.7, JZL has an area of 2 km² — roughly the size of an 800 m radius circle. It was defined by merging several communities within 800 m from the JZL station. However, both HHY and HTD are much smaller. HHY is 1.5 km², while HTD is 0.6 km², and quite irregular in shape. These sizes were a result of both areas around the transit station being at the edge of their respective sub-districts. Data for the analysis were gained from the local officials of the sub-districts, and beyond the boundaries, data were not available. Finally, and in contrast, DP is much larger, at 3.24 km². It covers the whole sub-district, because data of subdivided spatial units were not available. To adjust for the influence of the different sizes of catchment area used, density statistics were calculated for use in the comparative study and multi-level modelling study.

It is worth noting that, conventionally, a comparison is carried out between a catchment area and a ‘control’ area. ‘Control areas’ are used to control for the effect of other factors that may have contributed to changes in the intervening period. A control area is defined as an area that was not affected by the rail transit stations. It has the similar size as the station catchment area, but does not contain a rail transit station. In previous studies, control areas were chosen to be near the catchment area, so that they had a generally similar level of development, and would therefore have broadly similar changes without the new transport facility. In the JLE study,
control areas were found to be impractical to identify, given the unique conditions found in several of the catchment areas.

Although a control area was also identified in this thesis, it proved to be difficult to find a suitable control area to isolate other influences. The control area identified in this study (Luneng [LN]) was at a quite different developmental stage from the catchment area, as it was a fast developing residential area. Even outside the catchment distance, it had experienced massive population increase. Therefore, ‘reference area(s)’ were instead identified for each catchment area (Lane et al., 2004).

Appropriate ‘reference areas’ were identified to compare to the catchment areas in this study. The idea of using a reference area was inspired by the Jubilee Line Extension Report (Lane et al., 2004). The reference area represents a larger area, but one that is likely to be subject to similar pressures to those that would have been experienced in the catchment areas. In this study, the boundaries of these reference areas corresponded to the lowest administrative unit in Chinese cities — the sub-district — which administers several communities and is under the jurisdiction of a district. Each reference area contained a number of catchment areas, and also included other adjacent areas outside the catchment radius. The performance of the indicators of change in those reference areas — such as population levels, employment rates and income levels — can be considered as an ‘average’ value of a larger area, expanding beyond the catchment areas.

The two reference areas used were in the rapidly-developing region on the north bank of the river: Longxi Sub-district (LXSD) and Longta Sub-district (LTSD), as shown in Figure 3.7. In LXSD and LTSD, a small proportion of the residents are relocated farmers, living in settlement communities. Buildings in these settlement communities are especially built for the relocated residents in Chinese cities. However, most of the residents are newly affluent, having moved from the old city
region or outside the main city area, in keeping with the urbanisation trend in China. These people tend to live in new, luxury communities.

The two catchment areas Jiazhoulu (JZL) and Huahuiyuan (HHY) are in LXSD. The catchment area Hongtudi (HTD) and the control area Luneng (LN) is in LTSD. The catchment area Daping is in its own district, Daping Sub-District (DPSD).

Both DP and JZL are fast developing areas and experiencing large-scale land development, with commercial centres and office buildings at the stations. HHY and HTD are both mature residential areas. Residential communities in HHY were mostly developed in the 1990s, while those in HTD were recently developed (within the last 10 years). JZL is located along the main transit corridor linking the south of the city to the airport in the north. Both HHY and HTD lie on the route of Line 6, which also runs north-south but off the main transport corridor.

Daping (DP) is in the old city region. It is also along the east-west corridor in the old city, but is less developed due to the economic environment and the restrictions of the topography. Many older residents reside in DP, in poor living conditions, either as redundant workers or as long-retired farmers. This is also a popular destination for migrants to the city. Recently this area has experienced massive urban regeneration with a ‘refilling’ trend towards the city centre. New investment has developed land into commercial centres, offices and expensive residential properties.

The control area, Luneng (LN), is located in the LTSD reference area, and is a large residential area. The land was restored years ago and has been developed gradually over the last 10 years. Though off the transit corridor, and without public transport assess within 500 m, it is a comparatively wealthy residential area.
Figure 3.7: Reference regions, station catchment areas and areas not affected by stations
3.7 Methods for exploring spatial variations of indirect impacts (research question 2)

3.7.1 Methodological review of existing literature and implications for this study

In previous transit impact studies, a ‘before’ and ‘after’ comparison of travel and economic activity in the affected areas has commonly been adopted (Hall and Hass-Klau, 1985, Lane et al., 2004). Some more sophisticated studies tried to infer the impact of a new transport facility by comparing changes in the area served by the transport facility with a ‘control area’ which was not expected to benefit from the facility (Cervero and Landis, 1993, Cervero and Landis, 1997, Du and Mulley, 2007, Pagliara and Papa, 2011). A similar comparison method was adopted for this study.

Previous literature has shown changes in population, employment, business activities (and more) in local areas around new rail transit developments, but there is still a question whether these developments have contributed to the wealth of the population in that area. This question relates to the distribution dimension of impact: whether local residents actually benefit from the value uplift provided by the transport investment. Average income level is generally regarded as a measure of standard of living of people in the local area, and it can be conveniently compared. It is necessary to explore whether and how those indicators of growth, such as population and employment, influence the average income level before and after rail transit opening.

Sometimes data gained in the real world have a hierarchical nature, meaning that
some variables are clustered within other variables. In this study, data were gained from different sub-districts. The specific context where data are gathered can introduce locational dependencies into the data. If a model is then built on the data, the non-independent observations make the coefficients of the prediction variables vary as a function of the location. Thus the relationship between variables is different in different locations. Therefore, simply pushing the survey data through a conventional multivariate regression package may result in inferential error, for units within the same cluster (in this case, the same location) are likely to be correlated (Jones, 1991).

As has been mentioned before, local models can be used as statistical methods to explore the nature of this spatial autocorrelation (Mennis and Jordan, 2005, Cardozo et al., 2012). Apart from GWR, there are other methods, such as spatial regression and multi-level modelling (Jones, 1991). Multi-level modelling, developed largely in the 1980s, builds on the concepts of the multiple regression model. However, it does not oversimplify the world by applying one linear equation to reality. It is instead defined by discrete hierarchies, which makes it possible to specify and estimate models at several different levels simultaneously (for example, at the level of the individual cases and the locations they belong to) (Mennis and Jordan, 2005). It allows different relationships in different places being modelled, and some element of contextuality to be incorporated into the model, albeit crudely (Jones, 1991). There has been many applications of multilevel models in geographic research, including exploring national variations in education (Raudenbush and Bryk, 1986), fertility (Entwisle et al., 1984), earnings in the engineering industry (Davies et al., 1988), immunization uptake (Jones et al., 1991), housing price (Jones, 1991), and, more recently, environmental impact (Schweitzer and Zhou, 2010).

Having said this, it has been argued that the hierarchies used in multilevel models tend to ignore the continuity of space, unlike GWR. Furthermore, the hierarchy nested in the multilevel model is arbitrarily structured, while the validity of the model
depends on the spatial hierarchy capturing the spatial process being modelled in reality (Mennis and Jordan, 2005). However, in most situations, data that lack geographic locational information, have a limited number of observations, or are not continuous in space, mean that GWR analysis cannot be carried out.

In this study, data are considered as attributes of different spatial units — station catchment, control, and reference areas. The number of cases is limited and the spatial units of the research areas are not continuous in space: both meaning that GWR analysis is not appropriate. However, multilevel modelling is still a choice superior to a conventional least-squares regression model, as it takes into account the locational dependency of the data.

### 3.7.2 Data acquisition

Data were obtained from two main data sources: census data\(^{20}\) and data from Chongqing Statistical Yearbooks (2006-2014)\(^{21}\). Census data were collected at four time points: 2007, 2009, 2011 and 2013, as shown in Table 3.2. This period spanned the expansion of the transit network in the city (Line 2 opened in 2004, Lines 1 and 3 opened in 2011, and Line 6 in 2012). The changes in the indicators of impact could therefore be explored longitudinally.

---

\(^{20}\) The census data was collected from multiple local government offices, while data was only available for selected years, and not publicly available.

<table>
<thead>
<tr>
<th>Descriptive statistical analysis – variables for comparison</th>
<th>2007</th>
<th>2009</th>
<th>2011</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rail transit station catchment areas</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Land development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land development pattern</td>
<td>NA</td>
<td>NA</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>• Population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential population size and density</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment amount and density</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Local employment rate</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Economic performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business accumulation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Social economic characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Age structure</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Household structure</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reference areas and control areas</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Land development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land development pattern</td>
<td>NA</td>
<td>NA</td>
<td>✓</td>
<td>NA</td>
</tr>
<tr>
<td>• Population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential population size and density</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment amount and density</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Local employment rate</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>• Economic performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business accumulation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>• Social economic characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Age structure</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Household structure</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 3.2: Variables of indirect impacts in comparison method

### 3.7.3 Analytical techniques (research question 2)

#### 3.7.3.1 Comparative study: defining research areas

In answering the second research question, the research framework was based on comparison (Figure 3.8). The aim of the comparison was twofold:

1. By comparing rail transit station affected areas and its reference areas or control areas, the other influential factors such as local economic environment and policies could be largely controlled. Therefore the impact of the mass rail transit
on development could be investigated largely in isolation. To validate the comparison, the reference and control areas were carefully chosen to have spatial proximity to the station catchment areas, and to ensure a similar surrounding economic and social context.

2. By comparing rail transit station affected areas in different part of the city, the influence of the existence of other factors which may affect the effect of transit investment — such as different local development policies — could be explored. Therefore the importance of other supportive initiatives could also be identified.

A comparison between the indicators of change in the catchment areas and those in the reference area or control area largely removed the effects of regional trends (e.g. in local economic environment, policies, property prices, or employment), and thus the impact of rail transit could be observed relatively independently. It is assumed that, if there is little impact from the rail transit, the indicators of change of the catchment areas should have similar performance as those of the reference area and control area. While if the catchment area exhibits significantly different results from the control/reference areas, it is likely that this resulted from (and can justifiably be attributed as an effect of) the transit system.
Comparison between rail station catchment areas and reference areas

Comparison between rail station catchment areas and control area

Comparison between different rail station catchment areas

Figure 3.8: Comparison between rail station catchment areas and reference area
Figure 3.9 is a schematic illustration of how these indicators may change over time. The solid represents the putative changes in these indicators in the rail catchment areas, while the dashed line represents those in the reference areas or catchment area. There are separate figures in Chapter 5 to show the changes in different indicators. The statistical analysis aims to test the difference between these two lines, for each of the comparison fields.

Figure 3.9: Statistical comparison of diverse fields

### 3.7.3.2 Multilevel regression model

Descriptive statistical analysis by comparison was then followed by multilevel modelling, to explore whether developments around new rail transit stations have contributed to the income change of the population in that area. Sometimes data gained in the real world are hierarchical in nature, meaning that some variables are clustered within other variables. The other variables introduce dependencies into the data, so that the residuals are correlated. When entities are sampled from similar contexts, there is very likely dependence within the data. Those variables which
introduce dependency into the data are known as the contextual variables. In this case, location is a contextual variable, because there were a number of different locations from which the data were gathered and compared, and it is reasonable to expect the impacts of the variables in the model to vary as a function of the variable of location. The correlation between residuals violates the assumption in some statistical models that residuals should be independent. To deal with this problem, multilevel models are specifically designed to model these relationships between residuals. By factoring the contextual variables into the analysis, multilevel models overcome the problem of non-independent observations.

The change in pattern of average income level over time was used as the dependent variable in the model, to explore the relationship between income level and a variety of other factors. A growth curve effect was introduced as an independent variable, to model the change in pattern over the course of time, during the period between the beginning of the construction and the opening of the new transit system. Population and employment indicators were included as predictor variables: reflecting the land use and economic environment in the local area. Population and employment density in the local area were used to adjust the size of the local areas for the sake of comparison. Thus, by using average income level, this model largely simplified the study of the mechanisms by which various factors impact on people’s standard of living.

A multiple linear regression model can be used to predict the dependent variable by introducing a linear combination of a series of independent variables. The regression model can normally be represented as:

\[ Y_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + b_3 X_{3i} + \epsilon_i \]  

(34)

When we use a regression, as shown by the function above, we assume that each regression parameter, \( b_k \), is fixed. In other words, we assume the model holds true.
across the entire sample and for every case of data in the sample we can predict a score using the same values of the slope and intercept. However, for the reason provided above, that there is a contextual variable, we assume that the regression parameters are not fixed, but can vary. This means that these parameters can be conceptualized as being random. When multilevel linear model is introduced, i can be regarded as representing the level 1 variables, and the contextual variable is called the level 2 variable. By introducing the multilevel linear model, the intercepts, slopes or both can be allowed to vary across locations.

Firstly, the model is allowed to include a random intercept by adding a component to the intercept which measures the variability in intercepts, \( u_{0j} \). The \( j \) parameters in Equation 35 reflect levels of the variable over which the intercept varies. In this case, they are the contexts of different locations — the level 2 variables. In this way, the intercept has changed from a fixed \( b_0 \) to a random \( b_{0j} \).

\[
Y_{ij} = b_{0j} + b_1 X_{1ij} + b_2 X_{2ij} + b_3 X_{3ij} + \varepsilon_{ij} \\
 b_{0j} = b_0 + u_{0j} \quad (35)
\]

Then the random slopes for effect of transit are included by adding a component to the slope of the overall model that measures the variability in slopes, \( u_{1j} \). This term estimates the slope of the overall model fitted to the data, \( b_1 \), and the variability of slopes in different contexts around that overall model, \( u_{1j} \). By replacing the fixed intercept \( b_0 \) and slope \( b_1 \) with their random counterparts, the overall model becomes:

\[
Y_{ij} = b_{0j} + b_{1j} X_{1ij} + b_2 X_{2ij} + b_3 X_{3ij} + \varepsilon_{ij} \\
 b_{0j} = b_0 + u_{0j} \\
 b_{1j} = b_1 + u_{1j} \quad (36)
\]

where \( i \) represents the level 1 variables while \( j \) relates to the level 2 contextual
variable. By adding a component to the intercept and slope terms, the multilevel model factors the contextual differences into the model. The parameters of the model include indicators of time, population and employment. The model thus explores whether the economic growth and opportunities created have contributed to the income increase of the whole population in that area.

### 3.8 Methods of exploring social equity of indirect impacts (research question 3)

#### 3.8.1 Methodological review of MANOVA and discriminant analysis for group comparison

To address the third research question, a residential survey (Appendix 2: Transport attitude survey) was carried out by the author, in order to examine people's perceptions and attitudes towards the impact of rail transit expansion on their lives, and on developmental changes at the neighbourhood level. The aim of the survey was to explore the existence of uneven spatial distributions of impact that varied according to people's social-economic characteristics. The questionnaire can be found in Appendix 2: Transport attitude survey.

*Multivariate analysis of variance* (MANOVA) and *discriminant analysis* are both methods that are capable of comparing groups. Theories behind these two methods and their differences are explained later in this thesis. MANOVA is widely used in psychology (Zimet et al., 1990, Haley et al., 1995, Carr and Jessup, 1997, Beaumont and Sofronoff, 2008), and discriminant analysis has had many applications in neural science (Baudat and Anouar, 2000), ecology (Harris and Trewella, 1988, Benediktsson et al., 2003) and psychology (Crask and Perreault Jr, 1977).
However, their use in urban planning studies is quite limited, which is surprising, given that they can be especially useful for comparing groups — ranging from population groups (Jim and Shan, 2013) (e.g. different socio-economic groups) to specific kinds of urban areas (Steiniger et al., 2008) or cities (Lane, 2008). Jim and Shan (2013) investigated visitors’ views on key variables relating to urban green spaces and the effect of socioeconomic status on perception of urban green spaces in Guangzhou, China. MANOVA was used, and significant differences in perception were found across most socioeconomic variables, including gender, age, marital status, education, and occupation. Lane (2008) assessed a variety of measures of travel and land-use that might promote or hinder rail transit construction, at the urban area level, by utilizing a two-group discriminant analysis, to distinguish cities that built rail from cities that did not. Discriminant analysis was performed on a set of cities that, since 1980, have considered rail transit construction projects, and it determined the significant variables that predicted group assignment.

As far as I am aware, the two methods have seldom been applied to evaluating the social equity dimension in the domain of urban planning, and even less frequently to the sub-field of transport investment. In this study, MANOVA and discriminant analysis are used to examine the differences between different population groups.

### 3.8.2 Sampling, questionnaire design and data

The sampling method adopted in this survey was analogous to a multistage clustering sampling method\(^2\) (De Vaus, 2013). A total of 1,300 surveys were sent

\(^2\) Multistage cluster sampling involves drawing several different samples. In this methods, initially a large city is divided into a number of districts. A sample of districts is selected using simple random sampling. Each selected district is divided into blocks. Then a random sample of households within each block is drawn.
out across all the catchment areas (DP, HHY, JZL, HTD) and the control area (LN) defined in Chapter 5. In total, 700 questionnaires were sent to the four station catchment areas, while 600 were sent to the control area. The non-affected area was deliberately over-sampled, relative to the proportion of its population to the whole surveying area (DP, HHY, JZ, HTD and LN). The over-sampling was designed to achieve a comparable number of responses from the transit unaffected area. The sample size of each community was otherwise proportional to the population, in both the station catchment areas and the control area. A random sample of buildings within each community was then selected with attention paid to not missing out either low-rise or high-rise buildings in each community. This was done to help maximise the chance of capturing the existing population variety and to avoid ending up with an unrepresentative sample. Households were then randomly selected from within each selected block and questionnaires were delivered by hand. As a response rate, 1,000 surveys were returned and 752 were deemed reliable after checking. Those with incomplete or obvious faulty information were rejected. In the final sample, 407 questionnaires were from residents in the control area (LN), and the remaining 355 were from the station catchment areas. Respondents were asked a series of questions relating to factors reflecting both the direct dimension of impact (travel convenience, including accessibility for the daily commute and weekend commute) and various indirect impact dimensions (e.g. the economic dimension impact indicators included property price, property rent and living costs).

In correspondence with the four dimensions of transport impact — travel convenience, economic impact, urban/physical environment and social environment — a framework (Figure 3.10) was designed in the questionnaire to explore peoples’ perception and attitudes in each of these areas. Within each dimension, several sub aspects were listed.

Travel convenience indicators included accessibility for both daily commute and
weekend commute. Economic impact indicators included property price and rent, and living costs. Indicators relating to physical environment included urban image and open spaces, pedestrian environment, noise, safety, commercial and service facilities. Social environment indicators included local employment opportunities, community population changes and related community harmony factors. Specifically, the community population change included the population accumulation effect promoted by the new transit system, along with migrant trends in Chinese large cities. There were thirteen aspects in total within the four dimensions.

In the questionnaire, respondents were asked a series of questions relating to each aspect, and each of the thirteen aspects were addressed twice in two different questions. They are exhibited below as the two facets on the left and right side of Figure 3.11. One facet aimed to explore their perception of transit effects on their neighbourhoods. The other one aimed to explore their perception of impacts on themselves, or the importance of these changes to themselves. Respondents were asked to provide the answer with a score on a 5-point scale from −2 to 2.
People could be categorized into groups according to their social attributes (as shown in Figure 3.12). Potentially vulnerable groups were identified as: low income groups, migrants, older people, and those who did not have access to private cars.

From an economic perspective, the impact of a scheme on an individual's wellbeing varies most according to income, which makes it a better variable to differentiate groups than other attributes. Taking into account the social situations in China, especially in Chinese large cities, income level is obviously a straightforward criterion influencing the amount of benefit that people receive as a result of policies and public investment, as well as their perceptions and attitudes towards society. Besides the essential advantage of income as a differentiating variable, the unique context in China makes income data much easier to collect than in other countries, because there is a cultural willingness to share it openly. Every year, people who work in the neighbourhood communities sample their residents in the region and visit their homes to collect annual data including income. People are categorized into groups according to their income level.
With regards to demographic make-up, the respondents to the survey were fairly representative of the wider population, hence some inference can be made about the wider significance of the results. For example, 50.1% of the survey respondents were women (compared to 49.4% in the census data for Chongqing, 2013) (see Table 3.3); 5.5% of the respondents were above 65 years old (Table 3.4) (11.9% in the census data); and migrants accounted for 9.4% (Table 3.5) (4.8% in the census data).

<table>
<thead>
<tr>
<th>Gender proportion (2013 Chongqing census data and 2014 Attitudinal survey data)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 Chongqing census data (Permanent residential population)</td>
<td>50.62%</td>
<td>49.38%</td>
</tr>
<tr>
<td>2014 Attitudinal survey data (Survey respondents)</td>
<td>49.90%</td>
<td>50.10%</td>
</tr>
</tbody>
</table>

Table 3.3: Gender proportion comparison: census data and survey data. Source: 2013 Chongqing census data and 2014 Attitudinal survey data

<table>
<thead>
<tr>
<th>Age proportion (2013 Chongqing census data and 2014 Attitudinal survey data)</th>
<th>Below14</th>
<th>15-64</th>
<th>Above65</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 Chongqing census data (Permanent residential population)</td>
<td>16.40%</td>
<td>71.70%</td>
<td>11.90%</td>
</tr>
<tr>
<td>2014 Attitudinal survey data (Survey respondents)</td>
<td>0</td>
<td>15-24</td>
<td>15-34</td>
</tr>
<tr>
<td></td>
<td>9.90%</td>
<td>15.90%</td>
<td>46.50%</td>
</tr>
</tbody>
</table>

Table 3.4: Age proportion comparison: census data and survey data. Source: 2013 Chongqing census data and 2014 Attitudinal survey data
### Migrant proportion (2013 Chongqing census data and 2014 Attitudinal survey data)

<table>
<thead>
<tr>
<th></th>
<th>From within greater Chongqing area</th>
<th>Outside Chongqing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013 Chongqing census data (Permanent residential population)</td>
<td>95.17%</td>
<td>4.83%</td>
</tr>
<tr>
<td>2014 Attitudinal survey data (Survey respondents)</td>
<td>Central area</td>
<td>Outside central area but within greater Chongqing area</td>
</tr>
<tr>
<td></td>
<td>59.70%</td>
<td>30.90%</td>
</tr>
</tbody>
</table>

Table 3.5: Migrant proportion comparison: census data and survey data. Source: 2013 Chongqing census data and 2014 Attitudinal survey data

A comparison of car ownership figures in the four rail transit catchment areas between this attitudinal survey sample and the Chongqing official citywide travel survey, 2014, indicates that the attitudinal survey is representative of car ownership.

### Household Car Ownership (2014 Citywide Travel Survey and Attitude survey)

<table>
<thead>
<tr>
<th></th>
<th>Cars owned in household</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2014 Citywide travel survey</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huahuiyuan (HHY), Jiazhoulu (JZL), Hongtudi (HHD)</td>
<td>53.50%</td>
<td>43.40%</td>
</tr>
<tr>
<td>Daping (DP)</td>
<td>75.30%</td>
<td>24.00%</td>
</tr>
<tr>
<td>Attitude survey data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huahuiyuan (HHY), Jiazhoulu (JZL), Hongtudi (HHD)</td>
<td>59.80%</td>
<td>32%</td>
</tr>
<tr>
<td>Daping (DP)</td>
<td>71.40%</td>
<td>24.20%</td>
</tr>
</tbody>
</table>

Table 3.6: Car ownership comparison: citywide travel survey data and survey result. Source: 2014 Chongqing travel survey data and 2014 transport attitude survey result

### 3.8.3 Analytical techniques (research question 3)

Multivariate analysis of variance (MANOVA) and discriminant analysis were utilized to assess whether an individual’s response to the opening of a new transit station was affected by their economic status. MANOVA was chosen because it is useful to examine whether the income groups differ according to a number of response

---

23 In the comparison in Table 3.6, data from LN the non-transit affected area is excluded. The comparison is of the four rail transit catchment areas between the two dataset sources.
variables, namely their attitudes towards the various factors mentioned above. However, MANOVA does not distinguish the cause of the difference found between any two groups. For example, a significant difference found in a MANOVA model result might come from the difference between Group 1 and Group 2, or Group 1 and Group 4, etc., but we don’t know where the difference exists. Therefore, MANOVA was utilised first, followed up by a discriminant analysis to differentiate the results in more detail, and identify more specifically what the difference between any two groups is.

The basic underlying principles of MANOVA and discriminant analysis in differentiating groups are the same: to calculate underlying linear combinations of the variables. But conceptually, they work in reverse ways. The method of MANOVA is to predict a set of outcome variables from a grouping variable — the income level in this case. It aims to investigate whether people’s responses to the opening of a new transit station are affected by their economic positions, and thus whether an individual’s income level is significant in predicting his/her perceptions towards the impact of the rail transit. Conversely, in discriminant analysis we predict a grouping variable from a set of variables. In this case it is useful to separate a set of income groups by using several predictor variables, namely the factors measuring the transit impact. Therefore, the different income groups are the independent variables in the MANOVA analysis, while the factors relating to the factors of transit impact (increase in house prices, cost of living, neighbourhood safety, etc.) are the dependant variables, and vice versa in discriminant analysis. The linear combinations of the variables in differentiating groups are identified as ‘linear variates’ in MANOVA, and are called ‘discriminant functions’ (Field, 2013). Hence, discriminant function \( i \) can be described in a linear format as:

\[
V_{ij} = b_0 + b_1F_{1j} + b_2F_{2j} + \cdots + b_nF_{nj}
\]  

(37)

24 In order to avoid confusion, this thesis will use the term ‘function’ to represent ‘variate’ in the following analysis.
where $V_i$ represents discriminant function $i$ on the left side of the equation, while $F_n$ represents the factors of transit impact (i.e. the dependent variable $n$) on the right side. $j$ is the index of a row in the data matrix and corresponds to the index of a person in the data set. Similar to the equation of the widely used multiple regression (see above), $b$-values in this equation are weights\(^{25}\), which represents the contribution of each dependent variable to the discriminant function.

In addition, in comparison to the more commonly used analysis of variance (ANOVA), MANOVA analysis is adopted for situations in which there are several dependent variables. It can avoid the errors that mount up when carrying out multiple tests, such as using separate ANOVAs on the same data, by counting in any combined effects among the dependent variables.

In MANOVA, Pillai’s trace is utilized to assess the overall fit of the model. This is similar to $R^2$ in a regression model — it is the sum of the proportion of explained variance on the discriminant functions, and explains how much effect the variations in income have on differentiating people's perceptions. Pillai’s trace is given by:

$$V = \sum_{i=1}^{s} \frac{\lambda_i}{1 + \lambda_i}$$  \hspace{1cm} (38)

\(^{25}\) In discriminant function analysis, the values of $b$ are obtained from the eigenvectors of the matrix $HE^{-1}$ calculated from the data set of the dependent variables of MANOVA. $H$ is the model sum of squares and cross-product matrix (the model SSCP matrix) of the data set, while $E$ is the residual sum of squares and cross-product matrix (the residual SSCP matrix) of the data set. Therefore $HE^{-1}$ represents the ratio of the systematic variance to the unsystematic variance in the model and can access the fitness of the model. The eigenvectors measure the dimensions of a data set. For more information of eigenvectors, suppose that $A$ is a square matrix of size $n$ and $\lambda$ is a scaler, there is a nontrivial solution $X$ of $AX = \lambda X$, such an $X$ is called an eigenvector of $A$ with eigenvalue $\lambda$. Reference: http://www.math.harvard.edu/archive/20_spring_05/handouts/ch05_notes.pdf
where \( \lambda \) represents the eigenvalue\(^{26} \) for each discriminant function and \( S \) represents the number of discriminant functions in the model\(^{27} \).

### 3.9 A statement on data quality and the resulting limitations of model-based analyses

Unprocessed data for local areas in Chinese cities are quite difficult to acquire. The smallest unit of publicly-available census data is generally at the city level. Besides, only limited categories of data are normally recorded in a census, and most are not accessible to the public. Therefore, for this study, data for a designated area at the local level could only be acquired by relying on people working in the local authorities to do aggregation for selected years. What’s more, there is generally a lack of harmonised statistics for these data. Data reported across different administrative regions often have different categorisation. For example, the indicators of change in employment and income were missing in the reference area LTSD, and the catchment area HTD and control area LN. The inherent limitations of the data, in terms of geographic scale, timing and categories from three main sources (citywide travel survey, census data from local government and primary attitude survey data gathered by the author) have naturally set limitations on the analysis methods and results. The limitations of data are explained below. The results affected by these limitations are presented in Section 4.6, 5.5, 6.6 in the analysis chapters, as well as in Section 8.4 in the conclusion chapter.

The categories of data gathered in the citywide travel survey dataset were limited and lacked indices of residents’ socio-economic status. For example, the income

---

26 Eigenvalues are the length of the eigenvectors to describe the dimensions of the matrix \( HE^{-1} \) (as explained in the previous footnote 25). Pillai’s trace is one of the ways to assess how large the eigenvalues are, compared to what we would expect if there were no effect in the differentiation of groups in the population.

27 The number of variates in MANOVA is the smaller of the number of dependent variables and the number of independent variable minus 1. In this study, the smaller is the number if independent variable, 4, minus 1, thus 3.
level statistics were not available from the survey, and there was unfortunately no real substitute for these important data. This affected the accuracy of model predictions in exploring the impact of influential variables (e.g. people’s socio-economic attributes, travel patterns and residential location) on their travel mode choice.

Meanwhile, for some categorical variables in the data, the classification rules were very rough and unclear, or there were simply not enough categories. For example, in the survey instructions for surveyors, the residential property type contained three categories — old property/public rental house, ordinary property and luxury property — and it was reliant on the surveyors themselves to identify property type, subjectively. However, what is the standard of an “old property”; how old is “old”; what is “luxury”? In the data collection process, the local surveyors were apt to interpret the guidelines according to their own views, as has been verified by conversations with some surveyors. The quality of data collected was therefore undoubtedly adversely affected by the subjective interpretations and biases of local surveyors. Furthermore, classifying residential properties into only three categories was absolutely not enough to capture the status of residential conditions in Chongqing. This kind of classification didn’t make the most of a rare opportunity to gather important data in an expensive citywide travel survey, which is only carried out once every few years.

As a result, the explanatory power of the model presented in Chapter is low; as is Moran’s I value. This is discussed further as critique of methodology in Chapter 8. The main issue is probably the lack of certain, critical predictive variables in the model, e.g. income. The quality of the socio-economic statistics entering the model from the survey data were also poor, especially the roughly classified categorical variables. The model described therefore doesn’t account well for the actual variations in people’s travel mode choice.
The lack of harmonised statistics and sufficient quantity of data has also affected the multilevel modelling in this study. A caveat needs to be made here. An important question in multilevel modelling is what constitutes a sufficient sample size for accurate estimation. A lot of research has been done into determining the influence of different sample sizes, at the group level, on the accuracy of estimates (i.e. regression coefficients and their standard errors) (Maas and Hox, 2005). It has been suggested by Maas and Hox (2005) that only a very small sample sizes (50 or less) leads to biased estimates of the standard errors of level 2 variables. In this study, the sample size at each level is quite small (roughly 3 at level 2 and 6 at level 1), limited by the availability of data. As presented above, the limited public accessibility to local data limited the number of catchment areas for analysis to only four. One catchment area was further excluded in the multi-level model, due to its lack of employment and income data (as data collected in different sub-districts were not necessarily consistent in terms of categories). Therefore, the results of the modelling might possibly be biased. The multilevel model used here can be considered as an exploration of the research question, although the limitation of the research method must be clearly highlighted.

The analysis of transit’s indirect impacts on population groups didn’t include an assessment of spatial variations. The initial intention was to introduce a location variable into the MANOVA and discriminant analysis models. Unfortunately, for some areas, the sample size was much smaller than the other areas. This was due to resource limitations of the author when carrying out the survey. The final dataset had very uneven distribution of samples across different locations, and therefore was not suitable for carrying out analysis of spatial variation. If the data included better locational information, the research could have been greatly improved by the analysis of social equity impact, with differentiation between locations, e.g. comparison of catchment areas vs. control areas and old city vs. new city.

The data quality has not only affected the modelling analysis, but also the definition.
of reference and control areas in the comparative study. Limited by available data, an idea control area was nearly impossible to define. Thus reference areas corresponding to administrative boundaries of census tracts were identified instead. However, the reference areas were also far from ideal, because other parts of the reference region were also influenced by rail transit. The control area and reference areas identified in the research therefore did not fully fulfil their roles in excluding other influential factors. This likely reduces the reliability of the analysis results. If more census data, appropriate for a longitudinal study, were publicly available, the comparison could be much better validated, by identifying more suitable control areas.

3.10 Qualitative analysis

It is argued that any statistical correlation between two variables may not necessarily represent a causal relationship, nor can it exclude other influential factors which might have actually contributed to the correlation (Flyvbjerg, 2006). Given this concern, a qualitative study was also carried out to interpret and infer causality, in order to supplement the quantitative analysis (Pluye et al., 2009, Denzin and Lincoln, 2011). Qualitative analysis is also able to explore other influential factors that qualitative methods may miss.

The qualitative study consisted of a series of interviews of different stakeholders involved in the process of rail transit investment, development and use. The first phase of the interviews was comparatively comprehensive, generally aimed at exploring how the different stakeholders perceived the impacts of the rail transit. Questions were asked about factors influencing their investment decisions, attitudes towards the importance of the transport on their investment decisions, and opinions on the impact of the rail transit impact in the short- and long-term. At this stage, seventeen persons from different backgrounds were interviewed, namely the
municipal government, the municipal government-owned Transit Corporation, investors and developers, local district governments and communities, planning professionals and local academics (Table 3.7). The questionnaire was designed to contain both common questions for all stakeholders, and also exclusive questions specifically for different kinds of sectors, and the full questionnaire is in the appendices (Appendix 3: Interview questions for stakeholders). It was aimed to explore the mind-set of different stakeholders, especially in their decision-making.

The second phase of the interviews specifically probed into the cooperation issues between different stakeholders with diverse intentions. At this stage, very intensive interviews were carried out with only seven persons in representative departments (Table 3.7). Questions were especially focused on the cooperation, competition or even conflicts among different stakeholders in the process, relating to their power and interests.

In parallel to the second phase of intensive interviews of different stakeholders, interviews were also carried out among residents in the research areas, including long-term residents and new migrants. It provided supportive evidence about the impact of the rail transit system, both its positive and negative aspects, and especially concern about the possible “winners” and “losers” from the development. The complete list of interviewees is in Appendix 4: Interviewee list.
<table>
<thead>
<tr>
<th>Interviews</th>
<th>The first round of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal government</td>
<td>3</td>
</tr>
<tr>
<td>Transit Corporation</td>
<td>1</td>
</tr>
<tr>
<td>Local district government</td>
<td>9</td>
</tr>
<tr>
<td>Investors &amp; Developers</td>
<td>2</td>
</tr>
<tr>
<td>Local planning professionals and academics</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The second round of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Municipal government</td>
</tr>
<tr>
<td>Transit Corporation</td>
</tr>
<tr>
<td>Local district government</td>
</tr>
<tr>
<td>Local planning professionals and academics</td>
</tr>
<tr>
<td>Communities</td>
</tr>
</tbody>
</table>

Table 3.7: Table of interviewees
Chapter 4. Direct travel impact of the transit system

4.1 Introduction

There are two fundamental concerns, within the literature, regarding transit investment and the availability of public (rail) transit systems; these being, a) whether they influence people’s transportation mode choice; and b) whether usage patterns are distributed evenly across space and among different socio-economic groups (Geurs et al., 2009, Lucas, 2012, Schwanen et al., 2015).

These questions can be disentangled at two levels. At the first level, we can ask what factors explain the variation in people’s choice as to whether or they use rail as their mode of transit? Many studies employ multivariate statistical analyses to explore the interrelationships among variables that may predict people’s public transport use (Messenger and Ewing, 1996, Kuby et al., 2004, Cervero, 2006, Cervero et al., 2010, Taylor et al., 2009, Souche, 2010, Pan et al., 2009, Pan et al., 2013). The conventional multivariate regression produces a global predictive model of these relationships. However, at the second level, we also need to acknowledge that the relationships among the independent and dependent variables vary over space. That is to say, statistical models that incorporate spatial data may exhibit spatial non-stationary, and this is a reflection of what is unique about individual places. To account for this, spatially-weighted statistical models need to be used, to account for the spatial variation in model parameter estimates (Fotheringham et al., 2003).

Local political and economic environments may produce a relationship between people’s travel mode choice and travel patterns and socio-economic variables that are unique to a particular location (Mennis and Jordan, 2005). When taking into
consideration the spatial non-stationary of a model, the research questions should also be explored further. Does the relationship between transit mode choice and other influential variables vary significantly over space? Then, how do we explain the spatial non-stationary in this context?

There has been previous research on the impact of socio-economic characteristics on people’s ‘travel mode shift’ in response to a newly built mass rail transit line or other rail transit network (Jones, 2015). In the study by Jones and colleagues, the critical factors influencing the travel mode shift were those relating to income, car ownership, education level, age, perceptions, and residential status (newcomers vs. established residents). Many of the factors actually related to people’s ability to access the benefits generated by the new transport provision. For instance, the overall effect of income on demand for rail services was quite strongly positive. It has been found that income growth can be expected to increase average trip length (Paulley et al., 2006). Besides, income has an influence on people’s choice of transit. The greater use of Metrolink in Manchester, UK, has been associated with persons in employment or full-time education, of non-manual social class, and having no (or restricted) car availability (Knowles, 1996, Senior, 2009). It is argued that most often people choose bus travel because of the cheaper fare, and that rail transport is the mode of choice for a relatively affluent population (Gwilliam, 2002, Gwilliam, 2003).

Similar results have also been demonstrated with the Jubilee Line extension (JLE) (Lane et al., 2004) in East London. In contrast to the established population, it is the newcomers who have benefited a lot from the JLE. It was found that, compared to the established residents, the newcomers in the JLE-impacted areas were more likely to be: younger, white, employed, highly qualified, earn much higher incomes, be car owners, make more use of the underground, and be less likely to use buses or walk. Results of both a JLE household panel survey and a ‘perception survey’ showed that, by utilizing the provision of the new line, the newcomers had made a significant shift in the pattern of destinations visited — travelling for work, shopping,
leisure or social activities. However, the established residents living in the area made relatively limited use of the JLE, and there was minimal evidence of any change to their travel patterns. There was also less change in employment locations of the established residents than had been expected (Butler, 2007, Gatersleben et al., 2007).

The objective of this chapter is to contribute to a more substantive understanding of why people choose rail transit as a mode of travel: studying factors that vary across space and population cohorts within the city; and exploring whether inequity issues arise from the socio-spatial distribution of benefit from a new transit development.

This chapter explores the research questions first at the level of the whole system, by employing a logistic regression model to explore which variables have an influence on transport choice. The effects of spatial heterogeneity are then assessed, by introducing a geographically weighted regression (GWR) model. This is utilised to reveal the spatial variation in parameter estimates of the global model, as a reflection of what is unique about individual places. Therefore, it helps to more deeply explain the causes of the variation. The findings presented extend beyond the literature mentioned above, which has focused on global models to explain the relationships, and may have lost valuable information due to local spatial variations.

4.2 Description of the statistics

The dataset used was taken from the official citywide household panel travel survey carried out in 2014, after three years’ operation of Line 1, 3 and 6 (0). The survey sampled households in the main city region (the region as defined in the Chapter 1, Introduction). Data of the central city impacted zones were first extracted from the wider dataset of the whole city region. In order to focus the analysis on commuters, data about the population below 18 years old were excluded. The final dataset,
consisting of data from 3,642 persons, was used for the statistical analysis.

The theory of binary logistic regression was explained in Chapter 3. Here we explore the use of this approach for this study. In summary, the model was used to explore the relationship between a combination of explanatory (independent) variables (on the right side of Equation 39), and the choice of rail transit use, or other measures of transport (on the left side of Equation 39), which was the dependent (response) variable.

\[
\text{Travel mode (all other travel modes, 0; rail transit user, 1)} \sim \text{Travel Distance} + \text{Distance to the nearest transit station} + \text{Age} + \text{Household car ownership (no car, 0; one car, 1; two or more cars, 2)} + \text{Property type (old property, 1; ordinary property, 2; luxury property, 3)} + \text{Gender (female, 0; male, 1)} + \text{Official residential permission (Hukou holder, 0; non-Hukou holder, 1)}
\]

(39)

Travel mode choice was the dependent variable in the model. It was coded by a dummy categorical variable, with rail transit as 1 and otherwise, 0. Independent variables included travel distance, geographic accessibility to a transit station, and other social economic variables such as age, gender, residential property type, car ownership and official residential permission status.

Travel distance, geographic accessibility and age were continuous variables. Travel distance was calculated as the distance between the person’s home and the destination of their outbound journey on an ordinary weekday, based on the road network in the city. As is mentioned above, the dataset used excluded those people below the age of 18; therefore the distance could be considered as the daily commuting distance. Geographic accessibility to a transit facility was calculated as the Euclidian distance from a resident’s home to the nearest rail transit station.
The others are categorical variables, including residential property type, car ownership and official residential permission status. Socio-economic characteristics are commonly used to identify population groups. In the 2014 citywide travel survey, actual income data is unavailable. However, resident's residential property type was recorded in the survey. The residential properties were coded as three types: Type 1, poor condition properties/old properties/public rental properties; Type 2, ordinary properties; and Type 3, luxury properties, including upscale new residential buildings, gated communities and town houses. The dwellers of the first property type are generally low-income individuals. Car ownership was categorized into three groups, according to the number of cars owned by the household: 0, no car; 1, one car; and 2, two or more cars. Official residential status, or Hukou is a unique policy in China, which is explained in Chapter 2. In this study, people were categorized as local Hukou holders or non-Hukou holders.

A descriptive table of the whole dataset is presented below in Table 4.1.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variables: Numerical variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Mode</td>
<td>Travel Distance (km)</td>
</tr>
<tr>
<td>Frequency</td>
<td>Min</td>
</tr>
<tr>
<td>0_Other modes</td>
<td>3214</td>
</tr>
<tr>
<td>1_Rail transit mode</td>
<td>428</td>
</tr>
<tr>
<td>Sum</td>
<td>3642</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent variables: Categorical variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property Type</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>1_Old property</td>
</tr>
<tr>
<td>2_Old property</td>
</tr>
<tr>
<td>3_Luxury property</td>
</tr>
</tbody>
</table>

Table 4.1: Description of variables for model, for all users
The original information from the survey was stored in a ‘spatial point dataset’ format. In the dataset, some points shared the same geographic location, because the sampling of the survey included households living in the same building. Therefore, points representing the households in the same building overlapped each other spatially. In order to effectively present the information of the overlapped points in the model, a grid was cast spatially on the study region.

In some previous studies (Liu et al., 2012, Liu et al., 2015) on travel pattern and city structure in Shanghai, the study area of the whole city region was partitioned into a grid of 1×1 km cells. It was suggested by those authors that this grid size is detailed enough to depict the urban structure of the whole city. However, for this study, smaller grid sizes, based on degrees of latitude/longitude (°), were considered for partitioning the study area, namely: 0.01°×0.01°, 0.005°×0.005°, 0.002°×0.002°, and 0.001°×0.001°. After considering the great variety of mixed land use and different building conditions in Chongqing’s central city, as well as considering the presentation of the results, a grid size of 0.002°×0.002° was chosen for use in this study.

At Chongqing’s latitude of 29.56° and longitude of 106.55°, 1°×1° corresponds to a rectangular area of sides 110,845 m (North-South) and 969,06m (East-West). Thus the spatial unit of 0.002°×0.002° corresponds to a grid unit of approximately 220 m (N-S) × 194 m (E-W). This spatial scale of grid unit in the central city usually contains relatively uniform land use and residents with similar socio-economic characteristics. Attributes of variables of the points within the same grid unit were therefore aggregated. An average score of each variable of points within each grid unit was thus generated and presented as follows.

---

28 A spatial point dataset includes information that represents a set of points, which are defined in a geographic coordinate system.
It is important for the reader to note that, in the whole chapter, the grid system is only used for presenting the variable attributes and model results, rather than for the calculation of the model. In essence, the grid has no demographic considerations and thus might be subject to issues related to the ‘modifiable areal unit problem’ (Openshaw and Taylor, 1979) and ‘ecological fallacy’ (King, 2013). Therefore, aggregation of point data is only meaningful if the underlying phenomenon with the spatial unit is homogeneous across space. In this case, this potential problem can be eliminated because of the small spatial scale. However, all the statistical models presented in this chapter, including logistic regression, spatial autocorrelation, and GWR, were still carried out on the raw dataset rather than on the one after aggregation in the spatial grid system. This is because the dependent variable of the model is binary, so aggregation of this variable has the risk of affecting the structure of the categorical variables and measures of association, such as regression coefficients and estimated regression parameters. But by building the model using the raw data, containing all the data points, the variety of information carried by the dataset is not sacrificed.

4.2.1.1 Travel mode choice

Figure 4.1 shows the spatial distribution of the dependent variable — choice of rail transit as mode of travel. As shown, there is a high level of rail transit as the mode of choice concentrated in the old city region (which is located on the Yuzhong peninsula). This result is summarised in Table 4.2, which confirms that there is higher usage of rail transit as daily travel mode in the old city region (16.49%) than in the new city region (6.38%).

Looking in more detail at the spatial distribution (Figure 4.1), three main locations in the old city region show a concentration of preference for rail transit. One focus is seen at the old city centre (dashed circle in Figure 4.1), where there is a typical commercial centre completed with modern office buildings, standing side-by-side
with old communities, with people living in dilapidated residential buildings. A second focus is seen at the neck of the Yuzhong Peninsula, where there are two stations in close proximity: Liziba on Line 2 and Eling on Line 1, located either side of the mountain ridge which runs along the Yuzhong Peninsula. The third focus is seen at the regeneration area of Daping and Shiyoulu, where there are several brand new commercial complexes, including offices and residential properties, standing alongside dilapidated residential buildings of the early established communities.

In contrast, in the new city region, only one area shows a comparatively high degree of transit usage, around Dalongshan and Ranjiaba — a newly developed area with residential and office properties.
Figure 4.1: Descriptive analysis: travel mode choice. Higher saturation (of purple colour) and larger radius of a data-point indicate a larger proportion of people in that grid who chose rail transit as their mode of travel. The value on the colour-bar represents the average score in each grid, between 0 and 1 (arbitrary units). 1 means all the people in the grid choose transit, 0 means no-one choose transit.
### Travel mode

<table>
<thead>
<tr>
<th>Travel mode</th>
<th>Other modes</th>
<th>Rail transit</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Old city region</strong></td>
<td>(sample size)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1615</td>
<td>319</td>
<td>1934</td>
</tr>
<tr>
<td></td>
<td><strong>83.51%</strong></td>
<td><strong>16.49%</strong></td>
<td><strong>100.00%</strong></td>
</tr>
<tr>
<td><strong>New city region</strong></td>
<td>(sample size)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1599</td>
<td>109</td>
<td>1708</td>
</tr>
<tr>
<td></td>
<td><strong>93.62%</strong></td>
<td><strong>6.38%</strong></td>
<td><strong>100.00%</strong></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>3214</td>
<td>428</td>
<td>3642</td>
</tr>
</tbody>
</table>

Table 4.2: Percentage of people’s commuting travel mode grouped by region. Source: Citywide household panel travel survey 2014

### 4.2.1.2 Travel distance

The data regarding the pattern of travel distance are presented spatially in Figure 4.2. As stated above, this is the commuting distance of people above 18 years old.

**The travel distance in the new city region (to the north of the river) is generally much longer than in the old city region (to the south of the river).** In the new city region, the longer distance trips are concentrated in three locations. One focus is seen at the new city centre (solid circle in Figure 4.2), around the commercial centre of Guanyinqiao and the transport node, Hongqihegou. The second focus is seen at the north of the new city region, Zhengjiayuanzi, a newly developed residential area. The third focus is seen at the northwest of the new city region, expanding from Dalongshan station to the riverside to the southwest: an upscale residential area. A fourth focus is also seen in the southeast of the new city region, near the newly-built Chongqing Theatre, just opposite to the old city centre. Currently, that area is included in the newly-planned financial district of Chongqing, at the junction of the two rivers. It has a convenient link to the city centre via newly-built bridges across the river. At the time when the citywide official survey was conducted, the second phase of Line 6 had not yet been completed. This was planned to extend from the station Wulidian to the south of the city, bypassing the Yuzhong Peninsula. With the first phase of the line ending at Wulidian, the area was left with a limited link to the transit network.
In the old city region, there is no obvious concentrated pattern of longer travel distance, except some relatively longer-distance trips concentrating at some nodes. These nodes are either the commercial centres or public transport hubs. For example, longer journeys are concentrated at the old city centre, the transport hubs of Niujiaotuo and Lianglukou, and the regeneration area of Daping — areas that are all provided with convenient rail transit links.
Figure 4.2: Descriptive analysis: travel distance. Higher saturation (of blue colour) and larger size of data-points indicates a longer travel distance. Travel distance values on the colour-bar are in units, metres.
In order to explore the spatial pattern of travel distance in more detail, travel distance was split into four categories: 0–5 km, 5–10 km, 10–20 km, and above 20 km. Table 4.3 provides a comparison of percentages of travel distance in each of these categories, divided between the old city region and the new city region. The old city region is found to have a higher proportion of travel distances below 10 km, and a lower proportion of travel distances above 10 km than the new city region. That is to say, the old city has a higher percentage of shorter distance travel.

The last two columns of Table 4.3 show the mean travel distance of the whole sample and the rail transit users, respectively. In the old city region, trips by rail transit are longer on average (mean 8.72 km) than the average of all travel modes (mean 5.54 km). In the new city region, there is a greater difference: mean 10.44 km on rail transit; 6.56 km by all travel modes. In summary, travel distance by transit is longer than the average, both in the old city and in the new city region.

<table>
<thead>
<tr>
<th>Travel distance categories</th>
<th>0-5km</th>
<th>5-10km</th>
<th>10-20km</th>
<th>above 20km</th>
<th>Sum</th>
<th>Average travel distance (all data)</th>
<th>Average travel distance (rail transit)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Old city region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sample size)</td>
<td>1133</td>
<td>540</td>
<td>195</td>
<td>66</td>
<td>1934</td>
<td>5.54km</td>
<td>8.72km</td>
</tr>
<tr>
<td>Percentage</td>
<td>58.58%</td>
<td>27.92%</td>
<td>10.08%</td>
<td>3.41%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>New city region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(sample size)</td>
<td>929</td>
<td>448</td>
<td>237</td>
<td>94</td>
<td>1708</td>
<td>6.56km</td>
<td>10.44km</td>
</tr>
<tr>
<td>Percentage</td>
<td>54.39%</td>
<td>26.23%</td>
<td>13.88%</td>
<td>5.50%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>2062</td>
<td>988</td>
<td>432</td>
<td>160</td>
<td>3642</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3: Left: Percentage of travel distance categories grouped by region. Right: Average travel distance for users of all travel modes and for the rail transit users, grouped by region. Source: Citywide household panel travel survey 2014

A cross-tabulation of travel distance and travel modes in the city, by old and new city regions is shown in Table 4.4. Within both the old city and the new city, the longer the distance people travel, the higher the percentage of transit use there is. For example, the percentage of transit use in the old city is 8.3%, 26.3%, 31.3%
and 33.3% for the travel distances of 0–5 km, 5–10 km, 10–20 km and above 20 km, respectively. The largest increase in rail transit mode is between the categories of 0–5 km and 5–10 km (in the old city region), with the percent increasing from 8.3% to 26.3%. A similar pattern is seen for the data from the new city. As already shown in Table 4.2, rail transit users represent a much larger proportion of the population in the old city than they do in the new city region in all four travel distance categories. For example, 26.3% of people in the old city region who travelled 5–10 km chose rail transit as their travel mode, compared to only 8.48% of people who travelled in the same category of distance in the new city region. However, whilst the data in Table 4.4 suggest that rail transit may have greater impact in the old city than the new city region (and may be facilitating people’s longer trips), the GWR method was also then used to explore this spatial distribution in more detail.

<table>
<thead>
<tr>
<th>Travel mode</th>
<th>Travel distance categories</th>
<th>Rail transit</th>
<th>Other travel modes</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old city region</td>
<td>0-5km</td>
<td>94</td>
<td>1039</td>
<td>1133</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.30%</td>
<td>91.70%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>5-10km</td>
<td>142</td>
<td>398</td>
<td>540</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.30%</td>
<td>73.70%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>10-20km</td>
<td>61</td>
<td>134</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.28%</td>
<td>68.72%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>above 20km</td>
<td>22</td>
<td>44</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33.33%</td>
<td>66.67%</td>
<td>100.00%</td>
</tr>
<tr>
<td>New city region</td>
<td>0-5km</td>
<td>31</td>
<td>898</td>
<td>929</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.34%</td>
<td>96.66%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>5-10km</td>
<td>38</td>
<td>410</td>
<td>448</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.48%</td>
<td>91.52%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>10-20km</td>
<td>26</td>
<td>211</td>
<td>237</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.97%</td>
<td>89.03%</td>
<td>100.00%</td>
</tr>
<tr>
<td></td>
<td>above 20km</td>
<td>14</td>
<td>80</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14.89%</td>
<td>85.11%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>428</td>
<td>3214</td>
<td>3642</td>
</tr>
</tbody>
</table>

Table 4.4: Percentage of transit use in different travel distance categories grouped by region. Source: Citywide household panel travel survey 2014
4.2.1.3 Car ownership

The data regarding the spatial distribution of car ownership are shown in Figure 4.3. There is a higher degree of car ownership in the new city region than in the old city region. In Figure 4.3, brown points represent household ownership of one car, while yellow points represent two (or more) cars, and the remaining small grey points represent no car. As shown, two-car ownership is concentrated in the north and the northeast of the new city region, where there are most newly developed residential communities. An area in the southwest part of the new city region also has a concentration of households owning two or more cars. Here there are newly-built upscale residential properties, developed at the bank of the river, mixed with some early, established communities with worse residential condition.

In comparison, in the old city, only one location has a concentration of households owning more than two cars — in Chaotianmen, at the very core of the old city, at the junction of the two rivers. In contrast, the area of the old city centre (dashed circle in Figure 4.3) still has very low car ownership. This may be because the function of the old city centre was originally mostly governmental, financial and commercial. In recent years, there are still very few regeneration projects of residential properties in this area. People residing there are mostly established residents living in poor-condition residential properties. In the regeneration area around Daping and Shiyoulu, there is a more obvious concentration of car ownership. The regeneration projects have resulted in several new upscale residential properties, attracting residents who are more likely to be car owners. However, in the area just within the station catchment area of the Daping station, there is still a low level of car ownership, where there are lots of dilapidated residential communities.
Figure 4.3: Descriptive analysis: car ownership. The saturation (of yellow colour) and size of data-points show the categorical levels of car ownership. The larger yellow points indicate two or more cars; the smaller darker yellow points indicate one car; and the smallest dark grey points indicate no cars.
As shown in Table 4.5, the percentage of rail transit use was much lower for people with one car or more (6.12%) than for people with no cars (14.25%).

<table>
<thead>
<tr>
<th>Household car ownership</th>
<th>Rail transit</th>
<th>Other modes</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No car</td>
<td>359</td>
<td>2160</td>
<td>2519</td>
</tr>
<tr>
<td></td>
<td>14.25%</td>
<td>85.75%</td>
<td>100.00%</td>
</tr>
<tr>
<td>One car</td>
<td>63</td>
<td>962</td>
<td>1025</td>
</tr>
<tr>
<td></td>
<td>6.15%</td>
<td>93.85%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Two/more than two cars</td>
<td>6</td>
<td>92</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>6.12%</td>
<td>93.88%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Sum</td>
<td>428</td>
<td>3214</td>
<td>3642</td>
</tr>
</tbody>
</table>

Table 4.5: Percentage of transit use grouped by household car ownership. Source: Citywide household panel travel survey 2014

4.2.1.4 Property type

The spatial pattern of property type found in the study is displayed in Figure 4.4 (as discussed, this was used as a substitute for income level). As can be seen from Figure 4.4, there is a higher percentage of ordinary and luxury properties in the new city region. These are mostly located in the north part of the new city, where the area has been newly developed, corresponding with a northward trend in development in the city. There is only one area of the old city that has a concentration of luxury properties; like the longer travel distance and two car ownerships, this was at the junction of the two rivers in the old city, associated with a few regeneration projects with luxury buildings.

It is also important to note the concentration of Type 1 (lowest value) properties. These are concentrated in some parts of the new city region (bigger, solid circle in Figure 4.4) — around the transport hub of Hongqihegou, just next to the new commercial centre Guanyinqiao — and also at locations along the south river bank, where there were once industrial plants before they were moved away by the
government. In the old city region, the old properties are concentrated in some inland areas of the Yuzhong Peninsula; for example, in the area between Daxigou and two transport hubs of Lianglukou and Niujiaotuo, which is surrounded by mountain topography (in the dashed circle), and around the Daping station (in the smaller solid circle).
Figure 4.4: Descriptive analysis: property type. Larger, blue points represent luxury properties; smaller, light-purple points represent ordinary properties; the smallest dark purple points represent old properties.
A multi-level contingency table is presented in Table 4.6 to show the percentage of rail transit use, grouped according to residential property type. For those people living in old properties/public rental properties, the percentage of rail transit as their mode is 13.63%. While for people living in ordinary properties, the percentage decreases slightly to 11.41%. However, for people living in luxury properties, the level of transit mode is only 4.76%. In summary, a higher standard of residential property is associated with a lower percentage of rail transit as the chosen mode of travel for people’s daily commute.

<table>
<thead>
<tr>
<th>Property type</th>
<th>Rail transit</th>
<th>Other travel modes</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old/public rental property</td>
<td>110</td>
<td>697</td>
<td>807</td>
</tr>
<tr>
<td>13.63%</td>
<td>86.37%</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Ordinary property</td>
<td>314</td>
<td>2437</td>
<td>2751</td>
</tr>
<tr>
<td>11.41%</td>
<td>88.59%</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Luxury property</td>
<td>4</td>
<td>80</td>
<td>84</td>
</tr>
<tr>
<td>4.76%</td>
<td>95.24%</td>
<td>100.00%</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>428</td>
<td>3214</td>
<td>3642</td>
</tr>
</tbody>
</table>

Table 4.6: Percentage of transit use grouped by different property types. Source: Citywide household panel travel survey 2014

4.2.1.5 Non-Hukou holders

Another sensitive issue in Chongqing is Hukou, which is the official residential permission system in Chinese cities. In other Chinese large cities, such as Beijing, it can be used as a critical variable to assess the distribution of social security benefits to rural migrants. However, the situation is Chongqing is quite different in two aspects. Firstly, Chongqing, as a large inland city, is the experimental city for an urban-rural integration policy. Rural residents are thus encouraged to move to the urban area to work. They can therefore easily change their rural Hukou to urban Hukou (much more easily than other large cities in China), with the governmental aim of a higher urbanisation level. Secondly, in the past 20 years there has been a dramatic migration trend into the new city region. Residents have moved there from
all other parts of the main city region, and from other nearby towns and rural areas in
the wider municipality. Therefore, people who don't have local Hukou at their
residential location can be both rich residents having just moved to the wealthier
region or those poorer rural migrants. Because a citizen's Hukou is registered at the
local area when he/she was born, there is no need for the rich residents who moved
from within the city change their Hukou location. However, there is a set of policy
requirements for those poorer rural migrants to get an urban Hukou and normally the
requirements are difficult to meet.

From my analysis, it is evident that in the new city region, there are several
locations of concentration of non-Hukou holders (see Figure 4.5). For instance,
there are concentrations in more wealthy communities, especially around the new
city centre of Guanyinqiao and Hongqihegou (bigger solid circle in Figure 4.5) in the
north of the new city region, and along the southwest bank of the new city region.
These non-Hukou holders are likely to be those who can afford a more expensive
new property in the region. In the old city region, there are denser concentrations of
non-Hukou holders at the old city centre (dashed circle in Figure 4.5) and around
the redevelopment region of Daping (smaller solid circle). These non-Hukou holders
in the old city region could be both property owners and rural migrants. However, for
those moving into the less developed old communities, they are more likely to be
rural migrants.
Figure 4.5: Descriptive analysis: Non-Hukou status. The saturation (of pink colour) and size of points indicate the categories of non-Hukou status. The larger pink points represent non-Hukou holders, and the smaller grey points represent Hukou holders.
4.3 Results of global logistical regression model

Following the analysis of the patterns of spatial distribution of the variables, binary logistic regression was next carried out. Regarding car ownership, there were only 98 people in the category of ‘owning two cars or more’, which was much smaller than the number in the other two categories (2519 owning no car and 1025 owning one car). If the number within each category is very different, it will add to the error term in the model. Therefore, in the model calculation, the categories of owning one car and two cars were combined into one group, namely ‘car owners’. For the same reason, the property type categories of ‘ordinary property’ and ‘luxury property’ were also combined into one category, namely ‘ordinary and luxury property’. Therefore, the model shown in Equation 39 was modified as:

\[
\text{Travel mode (all other travel modes, 0; rail transit user, 1)} \sim \\
\text{Travel Distance + Distance to the nearest transit station + Age} \\
+ \text{Household car ownership (no car, 0; car owner, 1)} \\
+ \text{Property type (old property, 0; ordinary and luxury property, 1)} \\
+ \text{Gender (female, 0; male, 1)} \\
+ \text{Official residential permission (Hukou holder, 0; non-Hukou holder, 1)}
\]  

(40)

The binary logistic regression model was carried out using the \textit{R} statistical package (\textit{R} Foundation for Statistical Computing, General Public Licence). The goodness of fit of the binary logistical regression model in Equation 40 was thus calculated using the Hosmer and Lemeshow goodness of fit (GOF) test, in which:

\[
\chi^2 = 29.663 \\
df = 8 \\
\text{AIC} = 2241
\]

This gave a \( P \)-value = 0.0002424 (thus \( p < .000 \)) which demonstrated that this
model was a good fit for the data. The AIC value here was used for later model comparison.

The coefficient values of each variable in this model are shown in consecutive rows in Table 4.7. The first row is the constant in the model. Coefficients in the second to fourth row are similar to those of a linear regression model. The last four rows are the coefficients of the categorical variables.

Each row shows the comparison of this category of the variable to the default level. For example, the default level of car ownership is the category of ‘no car’. So the row ‘car ownership’ shows the change in the probability of the outcome compared to ‘no car ownership’. Similarly, the default level of gender is ‘female’; of property is ‘old property’, and of Hukou is ‘local Hukou holder’.

The Wald z-statistic (as explained in Equation 8) is shown in the fourth column of Table 4.7. It indicates whether the coefficient for a predictor is significantly different from zero and the $p$-value associated with this z-statistic is shown in the fifth column. If it is significant ($p < .05$) then we can assume that the predictor is making a significant contribution to the prediction of the outcome. In this model, travel distance, distance to the nearest station, age, and car ownership are found to be significant predictors of whether a person chooses rail transit. (As shown in Table 4.7, these variables all have $p$-values of $p < .000$.) However, property type, gender and official residential permission (Hukou) are found to be not significant in predicting whether someone chooses rail transit as their main travel mode.
In order to eliminate the effect of the non-significant variables on the model effectiveness, a second model was therefore run with only the significant variables: travel distance, distance to nearest transit station, age and car ownership.

Travel mode (all other travel modes, 0; rail transit user, 1) $\sim$

Travel Distance + Distance to the nearest transit station + Age + Household car ownership (no car, 0; car owner, 1)

(41)

The goodness of fit of the binary logistical regression model in Equation 41 was also calculated using the Hosmer and Lemeshow goodness of fit (GOF) test in R software.

$$\chi^2 = 37.809$$

$$\text{df} = 8$$

$$\text{AIC} = 2236$$

This gave a $p$-value < .000, which indicated that this model was a good fit of the data. The difference of AIC between the two models was $2241 - 2236 = 5$. In model selection, a difference of AIC of more than 4 is positive evidence that the model with
the lower AIC is better. Thus the model presented in Equation 41 was a better fit of the data and was used for later analysis.

The values of the coefficients of this modified model are shown in Table 4.8. As expected, in this modified model, travel distance, distance to the nearest station, age, and car ownership (own one car) are all significant predictors of whether a person chooses rail transit ($p < .000$).

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Wald z-statistic</th>
<th>Sig.</th>
<th>exp(B)</th>
<th>95% confidence intervals for Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Constant</td>
<td>0.316</td>
<td>0.219</td>
<td>1.442</td>
<td>0.149</td>
<td>1.372</td>
<td>0.894</td>
</tr>
<tr>
<td>Commuting travel distance</td>
<td>0.082</td>
<td>0.007</td>
<td>10.990</td>
<td>0.000</td>
<td>1.085</td>
<td>1.069</td>
</tr>
<tr>
<td>Distance to the nearest transit station</td>
<td>-0.002</td>
<td>0.000</td>
<td>-10.319</td>
<td>0.000</td>
<td>0.998</td>
<td>0.998</td>
</tr>
<tr>
<td>Age</td>
<td>-0.039</td>
<td>0.005</td>
<td>-8.049</td>
<td>0.000</td>
<td>0.962</td>
<td>0.953</td>
</tr>
<tr>
<td>Car owner</td>
<td>-1.098</td>
<td>0.146</td>
<td>-7.540</td>
<td>0.000</td>
<td>0.334</td>
<td>0.249</td>
</tr>
</tbody>
</table>

Table 4.8: Coefficients of the binary logistical regression model with significant variables

The second column, ‘B’, in Table 4.8 shows the estimates of the coefficients of the predictor variables in the logistic model, which are analogous to the values of the ‘b’ coefficients in a linear model. Here the value of B represents the change of logit of the outcome variable associated with a one-unit change in a predictor variable. The logit of the outcome is the natural logarithm of the odds of the outcome $Y$ occurring in Equation 12.

The sixth column, $\exp(B)$, in Table 4.8 is the exponential of $B$ for the predictor, and is equal to the odds ratio. The calculation of the odds ratio is discussed in Equation 13. Here, for example, take the $B$-value for travel distance, and take the exponential, $e^{0.082} = 1.085$. If the value of odds ratio is greater than 1, it indicates that as the predictor increases, the odds of the outcome increase; conversely, a value less than 1 indicates that as the predictor increases, the odds of the outcome occurring decrease.
The last two columns show the 95% confidence intervals for the odds ratio $\exp(B)$. For a predictor to be significant, the important thing is that the interval doesn't contain 1, as this is the value at which the direction of the effect changes. For the interpretation to be reliable, the confidence interval of $\exp(B)$ should not cross 1 (i.e. both values should be greater than 1, or both less than 1).

In this model, the travel distance data indicate that for every one kilometre increase in travel distance, the odds of choosing transit increased 1.085 times (the odds ratio was 1.085). In other words, for every one kilometre increase in people's travel distance, an individual's probability of choosing rail transit divided by the probability of not choosing transit increased 1.085 times. This suggests that in the global model, the rail transit system brings convenience to people's long-distance commuting journeys. However, even though there is a significant relationship between travel distance and the travel mode choice of transit, the causality can be explained in two directions. One, that if people travel longer distance, they are more willing to choose rail transit rather than other modes, such as buses or private cars; and two, that by utilizing the newly built rail transit systems, people expand their travel distance and thus change their travel destinations.

In contrast, for every one metre increase in the Euclidian distance from home to the nearest transit station, the odds of choosing rail transit change by a factor of 0.998 (the odds ratio is 0.998). In other words, the further an individual lives away from the rail transit station, the less likely they are to choose rail transit as their travel mode. Whilst the value seems small, the unit of distance is also small. Thus, if the person lives 100 m away, the odds ratio of them choosing transit decrease to 0.819, and for 200 m, the ratio was 0.670. So with still relatively small distances, we see a large effect of distance on travel mode choice.

With regard to the variable ‘age’, for every one year increase in age, the odds of
choosing transit change by a factor of 0.962 (the odds ratio is 0.962). Similarly, this doesn’t seem like a large decrease in odds with one unit change in age. However, with a 10-year increase in age, the factor would be raised to the power of 10, giving 0.679. This then reveals a considerable decrease in the odds of choosing rail transit. Therefore, in general, the older the person is, the less likely they are to choose rail transit. There is therefore a possibility that the rail transit system does not have an equal distribution across age groups.

Looking at the categorical variables, car ownership does have a significant effect on people’s choice of rail transit as their travel mode. The odds ratio of choosing rail transit is 0.334 for car-owners compared to those with no access to a car. In other words, in general, car owners are much less likely to choose rail transit as their commuting mode.

In summary, the results of the two binary logistic models show only four variables (among the original seven) that are significant in predicting people’s choice of rail transit as their travel mode. These are: travel distance, distance to transit stations, age and car ownership. When travel distance increases, the probability of choosing transit decreases. In contrast, when distance to a transit station and age increase, the probability of choosing transit decreases. If the resident is a car owner, they are less likely to choose transit.

The non-significance of ‘property type’ probably results from multicollinearity between the two variables of car ownership and property type. At the current stage

---

29 In statistics, multicollinearity is a phenomenon in which two or more predictor variables in a multiple regression model are highly correlated, meaning that one can be linearly predicted from the others with a substantial degree of accuracy. In this situation the coefficient estimates of the multiple regression may change erratically in response to small changes in the model or the data. A multiple regression model with correlated predictors can indicate how well the entire bundle of predictors predicts the outcome variable, but it may not give valid results about any individual predictor, referring to. In this case, there is multicollinearity between the variables of car ownership and property type in the model, which affects calculation of the predictor of the two variables FARRAR, D. E. & GLAUBER, R. R. 1967. Multicollinearity in regression analysis: the problem revisited. The Review of Economic and Statistics, 92-107.
of development in Chinese society, car ownership is still an effective indicator of the income level of a household, as is property type. Therefore using the two variables in the same model may have caused a multicollinearity problem. The insignificant variable of ‘property type’ was excluded in the new model. However, the dichotomy of car ownership is probably also too rough a division of population groups. Chapter 6 explores transit impact on population groups using a more detailed differentiation. Gender and Hukou were also not found to be significant factors. This likely means that, in general, gender has no significant effect on the probability of choosing rail transit; neither does the difference between newcomers to the area (without Hukou) and the established residents (with Hukou).

4.4 Examining spatial autocorrelation

As was introduced in Chapter 3, some of the unexplained variance of the global binary logistic model probably results from assuming the relationships in the model expression to be constant over space. In other words, the model assumed a stationary process over space, while in fact it might be non-stationarity. If such variations in relationship exist over space, the above model would be a misspecification of reality (Fotheringham et al., 2003).

A traditional method to investigate the spatial non-stationarity of a global model is to map the residuals of the model on a map in space, and this was performed for the residuals of the logistical regression used above, as plotted in Figure 4.6. On visual inspection, the distribution is seen to be non-random, with large positive residuals concentrated in some areas of the old city. However, without looking at statistical significance there is no basis for knowing if the observed pattern has spatial autocorrelation. Therefore, a spatial autocorrelation test was used to examine whether it existed in the model, as explained in Chapter 3.
Figure 4.6: Residual map of the binomial logistical model
Spatial autocorrelation is measured by a number of statistics, having slightly different formulations. Moran’s I statistic was used in this study, as discussed in Chapter 3. Moran’s test was carried out in this study using two kinds of neighbourhood criterion. One method was to use distance-based neighbour sets by K-nearest neighbours. In this method, neighbours of unit \( x_i \) are defined by user-defined parameter \( K \). \( x_j \) is a neighbour of \( x_i \). The method has an advantage of dealing with point datasets, which is appropriate for the dataset in this research. The K-nearest neighbours spatial weight matrix was adopted to define the spatial connectivity to each point. For every level of \( K \), each point was connected to the same number (\( K \)) of neighbours. For example, when \( K \) was defined as 4, the calculated neighbourhood set is shown below (Figure 4.7).

![Figure 4.7: Distance based K-nearest neighbours, when K = 4](image)

Once a definition of connectivity had been made, the neighbour list created above was translated into weights, which formed the elements \( w_{ij} \) of a spatial weighting
matrix $W$. A weighting matrix can be either binary or row-standard. In this case, a binary weighting matrix was chosen. Using this allows those observations with many neighbours to be up-weighted compared to those with few neighbours.

Once the spatial weighting matrix had been created, statistical tests of spatial autocorrelation were run by Moran’s test. In order to compare spatial autocorrelation with different levels of nearest neighbours, the value of $K$ was varied experimentally between 1 and 10. The result of the K-nearest neighbour test is shown in Table 4.9. The first column of the table shows the value of $K$ used for each iteration, and the second column shows the estimate of Moran’s $I$ statistic. The results are found to be significant, but the estimated values of Moran’s $I$ are low, which means the spatial autocorrelation is barely detectable. It can be seen that the values of Moran’s $I$ decrease as the $K$ value increases and that when $K$ is greater than 5, the estimated value of $I$ is less than 0.1, indicating that the spatial autocorrelation is very low.

<table>
<thead>
<tr>
<th>$K$</th>
<th>Estimate</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.180</td>
<td>7.24E-17</td>
</tr>
<tr>
<td>2</td>
<td>0.146</td>
<td>4.91E-22</td>
</tr>
<tr>
<td>3</td>
<td>0.114</td>
<td>4.23E-20</td>
</tr>
<tr>
<td>4</td>
<td>0.106</td>
<td>9.79E-23</td>
</tr>
<tr>
<td>5</td>
<td>0.095</td>
<td>6.69E-23</td>
</tr>
<tr>
<td>6</td>
<td>0.092</td>
<td>2.09E-25</td>
</tr>
<tr>
<td>7</td>
<td>0.087</td>
<td>2.50E-26</td>
</tr>
<tr>
<td>8</td>
<td>0.083</td>
<td>2.65E-27</td>
</tr>
<tr>
<td>9</td>
<td>0.081</td>
<td>7.99E-29</td>
</tr>
<tr>
<td>10</td>
<td>0.076</td>
<td>1.85E-28</td>
</tr>
</tbody>
</table>

Table 4.9: Moran’s $I$ statistics of residuals of binomial logistical regression for all the users

The other method used was to create contiguity-based neighbours as the neighbourhood criterion. As has been explained before, in the spatial point data set, some of the points had overlapped spatial locations. If polygon areas were created with the rule that each polygon contains one point, it would be inevitable that some polygons were overlapped by others. Thus in order to create polygon areas with a
unique spatial location, the residuals of the points were aggregated in accordance with the grid system of 0.002°×0.002°, used to present the variable attributes in the previous section. As has been explained before, aggregation of point data is only meaningful if the underlying phenomenon is assumed to be homogeneous across space. It is assumed the sample points within the same grid unit share similar residual patterns. The residual value is aggregated within each grid.

In this method, Queen’s rule was used in constructing the neighbourhood sets. According to this rule, areas sharing either boundaries or vertices are defined as neighbours, as shown in Figure 4.8. Using this contiguity-based neighbourhood list, binary spatial weights were also adopted and a spatial weighting matrix was created. Moran’s I was then calculated, giving a value of Moran’s $I = 0.12 \ (p < .000)$. This corresponds to a K-nearest neighbour test with a $K$ value of around 2 or 3.

![Figure 4.8: Contiguity based neighbours with Queen's rule](image-url)
In both neighbourhood criteria, the calculated value of Moran’s I is low. This means that spatial autocorrelation does exist in the data, but is barely detectable. However, GWR was still used as a method to reveal the spatial variations (although they may be small) in relationships behind the global model.

4.5 Geographic weighted regression analysis

In the previous section, the spatial non-stationarity, reflected in the error terms in Figure 4.6, was calculated by Moran’s I statistic. The associated p-values indicated that these results were significant, but the low estimates of Moran’s I value (as low as 0.12) suggested that the spatial autocorrelation was barely detectable. However, it is still possible that some of the unexplained variance of the residuals in the global model resulted from applying a global model to a spatially non-stationary process. The problem of global parameter estimates is that the global values are nothing more than spatial averages, that can hide a great deal of information about the process being studied. In order to model this non-stationarity process better, a GWR was utilized to provide a solution to the error terms in the global model. This allowed detailed spatial variations in relationships to be examined, and enabled the spatial heterogeneity in parameter estimates to be accounted for (Fotheringham et al., 2003). The theory of GWR was explained in detail in Methodology Chapter 3.

In this study, a general geographically weighted regression (GGWR) model was carried out in R software. GGWR can be used to deal with spatial variations in a logistic regression model. Dependent and independent variables are the same as in Equation 41. The results of distributions of coefficients in the GGWR model are explained below.
4.5.1 The coefficient of ‘travel distance’

The spatial distribution of the coefficient of ‘travel distance’ in predicting travel model choice of rail transit in GWR was next studied (Figure 4.9). In the global model, the coefficient is found to be significantly positive, which means that the longer the distance an individual travels, the more likely they are to choose rail transit as their daily travel mode.

In the GWR model, there is a contrast between the east part and west part of the old city area (the whole peninsula shown in Figure 4.9). The contribution of travel distance to the choice of rail transit as mode of travel is most significant in the old city centre and its adjacent area (dashed circle with grid units of brightest yellow colour). In contrast, it has the smallest contribution in the regeneration area, Daping, in the old city (grid units of dark red colour). With reference to Figure 4.1 to Figure 4.5, both of these two areas have quite similar patterns: a high level of preference for rail transit, with a low level of travel distance, low level of car ownership, a concentration of old properties, and a high level of non-Hukou holders. As shown in Figure 4.9, both areas have very good access to rail transit, given the location of the transit lines. The question, therefore, is why one unit change in travel distance has a much greater influence on people’s choice of rail transit in the old city centre than in Daping, which is just west to the old city centre? How and why does this locational difference occur?
Figure 4.9: Coefficient (B in Table 4.8) of the independent variable *travel distance* in predicting choice of rail transit as mode of travel. The coefficient represents the change of logit of the outcome variable (travel mode choice) associated with a 1 km change in travel distance. Bright yellow indicates a higher (more positive) value of coefficient than dark red.
For the relationship between use of rail transit and distance of commute: in the redevelopment area of Daping, the distance of commute has less of an influence on the probability of using transit than it does in the old city centre. Taking into consideration the undergoing mass redevelopment in Daping, a number of wealthy people moved into the newly built communities in that area. At the same time, a lot of rural migrant workers came into that area due to the cheap rent in the remaining dilapidated residential buildings there. Furthermore, there are particularly convenient bus services in that area compared to other parts of the old city (since it’s a transport node). For the new higher income residents, they may have the privilege of car ownership. For the majority of established residents and migrant workers, who earn lower incomes, they may rather choose buses, with cheaper ticket fares, if they travelled longer distances. Therefore, the range of other travel mode choices for both the wealthier people and the less well-off groups may explain why longer travel trips in Daping don’t have such an influence on the probability of using rail transit as in the old city.

In the north of the prosperous new city region (in an area similar to Daping), which is recently developed with new luxury communities, the coefficient is also much lower than that of the old city centre, as shown by a concentration of red colour grid units (solid black circle in Figure 4.9). In that area, travelling a longer distance therefore has less influence on residents’ choice of rail transit as their travel mode. As shown in Figure 4.1 to Figure 4.5, there is a lower level of transit use, longer travel distances, higher levels of car ownership, higher levels of more valuable property than in the old city, and more wealthy migrants (not holding local Hukou) moving from other parts of the city or from outside the city. The lower coefficient is partly due to there being only sparse transit provision in some areas. But even around the transit stations in that area, the coefficient is still found to be quite low. A possible explanation is that the north part of the new city region has a concentration of established residents and newcomers, who are more likely to have access to private cars, which makes longer distance trips have less impact on choice of transit mode.
than in the old city centre. Therefore in the new city region, travelling longer
distance doesn’t persuade residents to make the switch to rail transit as it does
in the old city centre.

4.5.2 The coefficient of ‘distance to the nearest rail transit station’

The coefficient of the independent variable ‘distance from individual’s home to the
nearest rail transit station’ in predicting travel model choice of rail transit was next
studied (Figure 4.10). In the global binary logistic regression model, the coefficient
for this variable is found to be negative, which means that the longer the distance
from an individual’s home to the nearest transit station, the less likely they would be
to choose rail transit as their daily mode of travel. This corresponds with the
expected result, but I additionally find that the effect of the variable on the outcome
varies spatially across the city.

Locations with more negative values of the ‘distance to station’ coefficient form a
belt running from the northeast of the new city region to the west of the old city
region, Daping (Figure 4.10). The lowest negative value of this variable emerges at
the east side of the new city region (dashed black circle). This area has been newly
regenerated with some high-level residential properties and is partly within the area
of the planned financial district of the city. This means that if people live further from
the rail transit station, it is less likely that they would take the rail transit for their daily
commuting trip. As was shown in Figure 4.4, there is a mix of high-level properties
and some old communities in this area.

The most negative coefficient value that appears in Figure 4.10 can likely be
explained by the limited accessibility to the transit station in that area. And for most
parts of the belt, the lower negative value is likely because of the mountain
topography. For example, a lower negative value is seen in the areas near the transit station, Huaxinjie, on the south bank of the new city region (solid circle) and a small part of the area on the north bank of the old city region, because of the steep mountain topography by both riverbanks. A unit increase in the distance to the nearest station makes it less likely for the residents to go to the rail transit station.
Figure 4.10: Coefficient of the independent variable *distance to nearest transit station* in predicting rail transit as choice of mode of travel. Presented as per Figure 4.9, but for 1 metre change in distance to nearest transit station. Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values.
However, a surprising result is seen in Daping. Here, there is a dense transit network, but living further from the transit station still has a relatively large effect on reducing people’s choice of rail transit (darker yellow colour in Figure 4.10). In contrast, in the old city centre, which has a similarly dense transit network (and other socio-economic variables) as in Daping, the value of coefficient is next to zero: thus the influence of distance from the station can be neglected. This difference in the impact of the variable between the two areas may be explained by the sufficiency of bus services in Daping; so if people live further away from the transit station in Daping, they have plenty of other choices and do not necessarily depend on rail transit. In contrast, in the old city centre, the bus service is limited in distribution and slow in speed, because of the curving and narrow road network there. And getting access to bus service is also quite inconvenient, because of the mountain topography. Even if residents live further away from the transit station, it doesn’t reduce the probability of them choosing rail transit as much as other parts of the city, despite of the inconvenience of getting to the station.

Apart from the old city centre, the vast west area of the new city region also has a concentration of coefficient values near zero. Distance to the nearest station is minimally influential on people’s mode choice of transit there. Referring to the pattern of travel mode choice in Figure 4.1, the west of the new city region has much lower percentage of transit users than the old city centre, and most people don’t depend on transit as their travel mode. For this reason, distance from home to the nearest station still doesn’t have much influence in their mode choice.

Therefore, the distribution pattern of this coefficient illustrates the importance providing mass public transit to the old city centre. Considering the low level of road transport capacity and insufficient provision of bus services, due to the mountain topography, and the lower level of car ownership of the residents, the role of rail transit is even more vital to facilitate people’s travel in this area than
any other parts of the city.

4.5.3 The coefficient of ‘age’

The coefficient of the independent variable ‘age’ in predicting travel mode choice of rail transit was next studied (Figure 4.11). In the global model of binary logistic regression, the coefficient is found to be significantly negative, indicating that the older an individual is, the less likely they will be to choose rail transit as their daily travel mode. A highly negative coefficient in certain areas may indicate an exclusion of the older generation from equally receiving the benefit of rail investment. As shown in Figure 4.11, this variable’s contribution to the choice of rail transit as mode of transport is the most negative at the south bank of the new city region. Also evident from the map below is that this region has a very limited access to rail transit stations. Consulting the descriptive analysis in Figure 4.1, Figure 4.3 and Figure 4.4, we see that this area has a very low preference for rail transit, a mixture of newly built properties and old properties, and also a high level of car ownership.
Figure 4.11: Coefficient of the independent variable age in predicting choice of rail transit as mode of travel. Presented as per Figure 4.9, but for a 1 year change in age. Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values.
In the areas described above, with a concentration of highly negative coefficients, there is a particular spot that merits further discussion, indicated by the solid circle in Figure 4.11. This is the area around the Huaxinjie transit station, which is assumed to enjoy convenient access to the transit system. However, it still exhibits a quite negative coefficient pattern. This was once the location of several ship factories, and there are still a lot of old residential communities in this area (as shown in Figure 4.4) and accumulation of low-income established residents. Referring to the descriptive analysis of travel distance in Figure 4.2, the average travel distance is quite low there, making it unique within the new city region. This indicates a limited spatial scale of travel for the established residents living there. This result from the ‘age coefficient’ analysis therefore suggests that the older residents living there are probably not receiving equal benefit from rail transit provision.

In contrast, the northeast part of the new city region (dashed circle in Figure 4.11) — which lies around transport node Hongqihegou, and contains part of the new city centre around Guanyinqiao, and some newly developed areas in the north — has a coefficient pattern close to zero. This area contains commercial centres, government buildings and luxury property communities. It also has a density of rail transit network coverage that is comparatively high for the new city region. In this area there is almost no difference of transit use with age. The older people here have almost the same transit usage as the younger people.

Interestingly, despite an even higher density of rail transit network, the whole old city region (the peninsula) still has a comparatively low level of the age coefficient. This suggests that in the old city, older people are more likely to be excluded from transit use than in the northeast part of the new city region. This could again be ascribed to the mountain topography in the old city region, which may make it more difficult for older people to access the station. However, it is more likely due to the socio-economic conditions of the older residents in the old city. The older people are
generally poorer in the old city than those in the new city region, and they may find the ticket price unaffordable.

4.5.4 The coefficient of ‘car ownership’

Finally, the coefficient value of the independent variable ‘household car ownership’ in predicting travel mode choice of rail transit was studied (Figure 4.12). In the global model of binary logistic regression, the coefficient is found to be significantly negative, which indicates that if an individual owns a car in their household, they are less likely to choose rail transit as their daily travel mode. As shown in Figure 4.12, locations of less negative coefficient form a belt of bright yellow colour running from the northwest of the new city region to the neck of the Yuzhong peninsular, at Liziba and Eling. This may indicate that the influence of car ownership on people’s travel choice of transit is not as modifiable as other areas in the central city region.
Figure 4.12: Coefficient of the independent variable *car ownership* in predicting choice of rail transit as mode of travel. Presented as per Figure 4.9, but for a one unit change in the categorical variable ‘car ownership’. Values are negative, with bright yellow indicating a value closer to zero, and dark red indicating the most negative values.
Of particular note, is that this variable’s contribution to the choice of rail transit is the most negative in the old city centre (dashed circle in Figure 4.12). This suggests that car ownership plays a more influential role in differentiating a person’s choice of travel mode in the old city centre, than in other areas, and makes the person less likely to choose rail transit as their daily mode of travel.

The reason for this finding is likely to be that in the old city centre there is quite an inconvenient public transport service because of the mountain topography. People often have to walk a long distance either up or down in order to get to the nearest bus station, and this is even more of a problem when getting to a rail transit station. Although driving a car is also quite inconvenient up and down the steep slopes in the old city centre, people still have a strong desire to possess their own cars. Once they own a car, they may not bother to walk a long way to the station. By comparison, in the whole new city region the topography is quite flat, and here the results indicate that owning a car is not as decisive in people’s choice of transit as in the old city centre. This is despite a high level of car ownership in the new city area (as shown in Figure 4.3). It is in the old city that owning a car makes it the least likely for those car users to switch to rail transit use.

### 4.6 Discussion

It is important to mention that income level statistics were not gathered in the survey, and there is unfortunately no real substitute for these important data for making accurate model predictions of income’s effect on people’s travel mode choice. In this study, property type information was used as a surrogate, but unfortunately, it is only a very approximate substitute for income level, and has a problem of multicollinearity with the variable ‘car ownership’. Therefore the property type variable was found to be not significant in the original model and was ruled out in the final model. Though the categorical variable of car ownership can be used as a
surrogate for income level, it has only two categories, namely ‘non car owner’ and ‘car owner’ and is only a roughly analogous variable to household income. This deficiency of income-level information in the travel survey dataset make it difficult to assess the relationship between choice of travel mode and income (an important criterion of people’s socio-economic status).

Because of this issue, a transport impact attitude survey was carried out by the author. This aims to fill in the gap in the previous analysis, and to provide a more holistic understanding of rail transit’s social impact, especially the social equity in the distribution of benefit from transport investment among different population groups. The findings of this survey are discussed in Chapter 6.

### 4.7 Conclusion

As indicated in study of the Jubilee Line Extension (JLE) in London, it is generally the newcomers who have benefited from the travel convenience that the JLE has provided, and base their work and life in the city centre by taking the JLE. In contrast, the established residents have only enjoyed limited benefits from the new metro investment. There is no sign that they have expanded their travel patterns for work, entertainment, or activities in response to this metro line (Lane et al., 2004). However, the result of the analysis in Chongqing demonstrates that the rail transit system plays a more important role in facilitating the travels of established residents in the areas that haven’t experienced dynamic trends of regeneration. It is in these areas that poor, established residents, rural migrants and those without a car are likely to be confined to their local area if there is insufficient supply of public transport. The situation is exacerbated by the interaction with their socio-economic conditions, which potentially results in expanding social segregation.
The preliminary descriptive analysis shows the spatial distribution of transit mode choice, travel distance and other socio-economic variables. Contingency tables were also presented to show separate analysis of the relationships between the choice of rail transit as a mode of travel and the various influential factors.

A higher level of preference for rail transit is exhibited in the old city region than in the new city region. When the trips are split into categories of 0–5 km, 5–10 km, 10–20 km and above 20 km, the old city has a greater percentage of trips within the distance of 10 km. Across all the four categories, the descriptive statistics show that the further people travel, the higher the proportion of trips taken by rail transit.

The new city region also has a higher level of car ownership than the old city. A contingency table shows that the percentage of rail transit use for car owners is much lower than those who don’t have car access. A higher percentage of ordinary and luxury properties are also concentrated in the new city region. Descriptive analysis by contingency table suggests that the higher the value of residential property people live in, the lower the percentage of transit use people will have. The preliminary descriptive analysis reveals some discrepancies in transit use among people, with differences in their travel patterns, spatial locations and socio-economic characteristics.

The contributions of these variables to travel mode choice in combination are tested in the global multiple regression model. In this binary logistic model, travel distance, distance to the nearest transit station, age, and car ownership are significant in predicting their choice of rail as a mode of travel. However, the weakness of the global model is that it overlooks the spatial variations of the various predictors across the geography of the city. GWR analysis was therefore used here, to take into consideration these spatial variations.

The result of the GWR model indicates that travelling a longer commuting distance
has more of an influence on people choosing rail transit in the old city centre of Chongqing (than other parts of the city). It is probably safe to make the inference that rail transit is the most effective in facilitating longer travel distance in the old city centre. Compared to other parts of the city, in the old city centre there is generally a very inconvenient public transport service, due to the steep mountain topography. Few redevelopments are happening in the older, more traditional areas. There are a number of communities where a high level of established residents and rural migrants (with relatively low incomes) are concentrated, without access to private cars and also with limited access to other public transport facilities. Thus the rail transit provision in that area does promote the distribution of transport benefits to the relatively deprived population there. Rail transit investment is also effective in addressing the insufficient public transport provision in the old city centre, as people living away from stations are likely to depend on rail transit for their daily commute. These results emphasise the importance of providing rapid rail transit systems, especially in the more deprived, old city areas.

The result also reveals a potential tendency towards the exclusion of some groups of people. Some areas have the potential to exclude the older generation. These areas include the less-developed bank area in the south of the new city region and the whole old city region. Car owners in the old city centre are also the least likely to choose rail transit as their travel mode. This, to some extent, reveals the polarisation between the car owners and people with no access to cars in the old city centre. All of these call for concern, as they are potential factors that may exclude a certain group of the population from the equal benefit distribution of public transport investment.
Chapter 5. Exploring geographic variations in demographic, economic and physical outcomes of rapid rail transit developments

5.1 Introduction

As well as travel convenience improvement, new rail transit systems can potentially also lead to economic, land use and social changes. It is these secondary benefits that are frequently put forward as urban economic incentives for transport investment (Hall and Hass-Klau, 1985, Banister, 1995, Llewelyn-Davies et al., 2004, Vickerman, 2008). It is debated whether the indirect impacts of the rail transit system vary between locations, e.g. between different parts of cities and between different sections of the rail transit lines. To explain these discrepancies, a number of studies (Hall and Hass-Klau, 1985, Banister and Berechman, 2003, Banister and Thurstain-Goodwin, 2011) have shown that transport investment is an important, but not sufficient condition for development of the built environment. In fact, rail transit development can be seen as a constraining factor on urban development if the appropriate infrastructure is not selected. Without sufficient transport provision, development can be hindered. But transport investment alone can’t bring about development: it requires other complementary resources to also be present. It is agreed that the necessary conditions are: strong local economies, supportive planning policies, investments, and the availability of attractive development sites (Hall and Hass-Klau, 1985, Banister and Berechman, 2003, Banister and Thurstain-Goodwin, 2011).

Planning’s role is growth-oriented in China, and is a significant factor in attracting investment. This is in contrast to the often common perception in Western countries that planning’s role is to constrain economic growth, and often involves restrictive
measures (Wu et al., 2015, Wu, 2015). The future plan of an area is highly valued by private developers, as it is an important method by which the government can assure investors of market stability. Development strategies implemented along with transport investment can provide opportunities for some locations to take advantage of the investment and drive its economic development. Meanwhile, the conventional motivation — that infrastructure investment should be in those locations where the greatest return is expected — has to be balanced against those projects which have the potential to bring regional development, reductions in levels of isolation and alleviation of poverty (Gwilliam, 2002, Banister and Berechman, 2003). It is useful to explore the impact of transport investment along with the influence of these factors, which are typically less researched in recent years in the Western literature.

The first aim of this chapter focuses on understanding the multiple indirect impacts of a metro investment, beyond the direct impact on transport accessibility. The impact of the transit systems is assessed by identifying indicators of change, including increases in local population, changes in employment rates or increasing income levels, and changes in business activity. This analysis is performed using census data from the time period 2004–2013.

Even with significant changes in indicators of development in the local areas, there are still emerging issues concerning the distribution dimension of the benefit generated in the transit development process. The second aim of this chapter is to explore whether the economic growth and opportunities generated, have contributed to the wealth of the whole population in that area. As discussed in Chapter 3, a multilevel regression model is used here to model the change pattern of people’s average income against time, and its interrelationship with other indicators of growth. The influence of the specific locational condition was included as a contextual variable in this multilevel model, which was designed to deal with the variation in model results resulting from the specific context of this study.
5.2 Research areas and data

As is discussed previously, there are difficulties in isolating the impact of transport on urban development from the supporting or associated innovations which are introduced in parallel (Hall and Hass-Klau, 1985) — including the economic environment, policies and investments, and other wider influences, such as land availability (Banister and Berechman, 2003). In order to observe the impact of transport largely independently, the approach in this chapter is to conduct a comparative study across geographic locations. Changes across time in transit station catchment areas are compared to those in reference and control areas. The terms ‘station catchment area’, ‘reference area’ and ‘control area’ are defined in Chapter 3.

Data reflecting various indicators of change — including increases local population levels, changes in employment rates or increasing income levels, and changes in business activities — have been previously collected by the local authorities of these three sub-districts at four time points: in 2007, 2009, 2011 and 2013. This is a period that spans the expansion of the transit network in the city (Line 2 opened in 2004, Lines 1 and 3 opened in 2011, and Line 6 in 2012).
<table>
<thead>
<tr>
<th>Area</th>
<th>Year</th>
<th>Population</th>
<th>Employment</th>
<th>Average annual income (Yuan/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DP (Daping)</strong></td>
<td>2008</td>
<td>58,495</td>
<td>70,500</td>
<td>19,200</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>58,783</td>
<td>73,000</td>
<td>20,400</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td>74,416</td>
<td>75,500</td>
<td>21,450</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>76,227</td>
<td>77,000</td>
<td>22,800</td>
</tr>
<tr>
<td></td>
<td>2012</td>
<td>77,128</td>
<td>81,020</td>
<td>24,200</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>77,809</td>
<td>85,250</td>
<td>26,500</td>
</tr>
<tr>
<td><strong>JZL (Jiazhoulu)</strong></td>
<td>2007</td>
<td>43,600</td>
<td>23,000</td>
<td>19,010</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>43,600</td>
<td>24,500</td>
<td>23,000</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>43,600</td>
<td>24,900</td>
<td>27,830</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>53,600</td>
<td>27,600</td>
<td>33,674</td>
</tr>
<tr>
<td><strong>HHY (Huahuiyuan)</strong></td>
<td>2007</td>
<td>31,200</td>
<td>13,500</td>
<td>16,850</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>31,200</td>
<td>13,800</td>
<td>20,388</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>31,200</td>
<td>13,800</td>
<td>24,669</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>33,500</td>
<td>14,100</td>
<td>29,849</td>
</tr>
<tr>
<td><strong>HTD (Hongtudi)</strong></td>
<td>2007</td>
<td>10,306</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>10,805</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>11,003</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>11,422</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>LN (Luneng)</strong></td>
<td>2007</td>
<td>3,114</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>14,891</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>17,791</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>22,243</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Reference region LXSD</strong></td>
<td>2007</td>
<td>130,000</td>
<td>65,000</td>
<td>17,865</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>140,000</td>
<td>70,000</td>
<td>21,616</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>150,000</td>
<td>68,000</td>
<td>25,446</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>170,000</td>
<td>72,000</td>
<td>29,372</td>
</tr>
<tr>
<td><strong>Reference region LTSD</strong></td>
<td>2007</td>
<td>74,222</td>
<td>27,316</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2009</td>
<td>82,651</td>
<td>28,029</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2011</td>
<td>94,122</td>
<td>30,150</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>2013</td>
<td>111,542</td>
<td>37,290</td>
<td>NA</td>
</tr>
</tbody>
</table>

Table 5.1: Summary of reference regions and case study areas. Source: Chongqing census data, 2007-2013
5.3 The secondary impacts of rail transit across different locations

5.3.1 Land development

This section explores how rail transit systems have had effects on the land development in the city. It is necessary to make clear some preconditions of the analysis. The status of the rail transit planning studied needs to be understood in context of the urban planning system in China. Furthermore, it is important to explore how transit investment is combined with other initiatives, such as supportive policies, to exert impacts on development. Only in this way, can the incremental and leveraging effects of the transit system be seen.

Given this aim, a number of comparisons need to be conducted, by carefully selecting appropriate control and reference areas. It is important to note though, that even if a correlation between transit investment and land use development is identified, the existence of a causal relationship between the two and the direction of causality is not proven. Also requiring study is how land use planning can conversely influence transit planning, to explore the possible benefits of the integration of land-use and transport planning in the future.

5.3.1.1 The impact on land development at the city scale

Figure 5.1 shows the land use pattern in March 2011, several months before the rail transit system opened. It shows the pattern of land being released to sell (in red) and land under construction (in purple). As can be seen, the lands that were under construction were distributed all across the city at that time, expanding from the very central city region to the main city region.
The land use pattern exhibited in Figure 5.1 can be seen as the combined result of the investment intentions and availability of land. Investment intentions are influenced and driven by the local development vision, which is shaped by the planning strategies of the city. As a part of the planning strategy, transit provision is often considered as a locational advantage by developers. With the government as the only legitimate land provider in China (Wu, 2015), investment choice is largely limited by land availability, which is controlled by the plan of the government to release the land for development. Therefore, any relationship that is found between rail transit and land development should be analysed whilst keeping this background context in mind.

Several research steps need to be taken in order to explore the relationship between transit investment and land development. Firstly, if correlation is found between the two variables, one needs to explore whether there is any causal relationship between the two variables. Secondly, one needs to investigate the direction of any causal relationship. Thirdly, even if a causal relationship with a defined direction is demonstrated, one needs to explore what other influential factors are involved in the process, and what contribution other influential factors make to the relationship.
Figure 5.1: Land development in the whole city region
It is important at this stage to explain the mechanisms of urban planning in China in more detail. As is discussed in Chapter 2, urban development strategies set by urban planning bodies play an important role in facilitating growth, and aim to increase the local GDP. Among these strategies, land development is considered by the local government as an efficient and vital resource that can be used to generate revenue, by attracting investment from the manufacturing and property development sectors. To facilitate this, the government convert the land by providing infrastructure and other public amenities. Because growth-oriented planning in China plays a crucial role in ensuring the market stability, the future plan of an area is highly valued by the private developers in making their decisions; even more so than other incentives from local governments, such as financial incentives, grants, and tax reductions. The manufacturing and high tech industries are examples of sectors that are particularly attracted by the market stability assured by the future strategic planning (Wu et al., 2015). By this rationale, at the city level, transport planning often plays a crucial role in the urban development strategies of the city, with the aim of shaping the city and promoting economic development. While at the local level, transport is also a part of the infrastructure system provided by the government, as part of the locational advantages to attract investment.

The pattern of land development (including land being sold and under construction) and transit development in Chongqing (by 2011) show a spatial correlation, as can be clearly seen in Figure 5.1. This is especially true at the urban periphery and in the suburbs, where land development exhibits an obvious tendency to concentrate around transit stations and along the routes of railway lines.

The patterns of land for sale and under construction together give an indication of the development strategies of the government. Land under construction (or sold but awaiting construction) better reflects the level of investment attracted to the areas.

It can be seen that there are more lands released for sale in the northern part of the
city than in the southern part (Figure 5.1). This reflects prioritisation of the northern region by urban development strategies. Transport infrastructure is also planned as part of these strategies. Large patches of land for sale are located in the outer ring of the city, outside a 10 km radius from the central city region. All of them have a close spatial proximity to the suburban metro stations. Some of this land for sale is also advertised as having the future benefit of a complete rail transit system, which is due to be completed by 2020 with six other lines added to the system.

In some circumstances, at the city scale, rail transit is planned in response to the existing land development pattern. For already developed areas, the mass rail transit system aims to improve accessibility and increase transport capacity. For example, the first stage of Line 3 runs from the south of the city, along the northeast developed corridor (which was shaped in the 2000s) to the airport in the north of the city. In this case, the land development already happened before the transit development, and transit investment was required to meet the increasing demand for transport, rather than being built with the aim of stimulating the development.

In other cases, the rapid transit system is planned as a part of a spatial strategy to promote the development of some areas. For instance, in the second stage of Line 3, the northern part was extended further north of the airport, to an area that is planned as an airport enterprise zone. There are large patches of land being sold or under construction (dashed circle C1 in Figure 5.1), concentrated around the northern end of the line. Similarly, another three large patches of land (dashed circles C2, C3, C4) are to be sold or under construction along the northern extension of Line 6. In some areas that had previously suffered from insufficient accessibility, the new transit system ‘opened the bottleneck’ and stimulated further development, with increased land value. Three further areas warrant discussion: one at the southern end of Line 3 (dashed circle C5), in the newly-developed residential area; one at the southeast end of Line 6 (dashed circle C6) on the vacant land beneath the Nanshan Mountain; and one at the end of Line 1 (dashed circle C7), in the newly-developed University
City to the west. In these locations, transport provision was integrated into the government’s urban development strategies, to promote development in these areas.

In the above two situations, there is little evidence that the land development is promoted solely by the transport development, but rather by the larger urban development package initiated by the government, of which transit provision is a part. In order to examine the impact of rail transit investment on land development, it is necessary to look into whether transit provision alone can be a significant attractive factor to investment into local areas. Therefore, the following study explores specific cases at the local scale.

5.3.1.2 Integrated transport and land development at the local scale

At the local scale, there are questions over: how transit provision attracts investment; to what extent, at what scale and for what type of land use; and how transport development and land use development can be integrated. Integration includes both the integration of different transport modes, but also the integration between the transport system and the pattern of social and economic activity that it serves (Curtis and James, 2004). The latter brings together land-use planning, transport planning and urban design, to consider the geographic context, spatial land use patterns, the form of the physical environment, and the economic and social drivers (e.g. retail shopping and employment) (Curtis and James, 2004). The analysis below deals with these aspects by focusing on case studies of land development around transit stations. Contextual variations are considered and potential economic and social effects are explored.

In the inner part of the city, there is often very limited availability of land around the rail transit stations. Due to the aims of refilling and intensifying built up areas, land
for sale in the inner city (red colour, Figure 5.2) is concentrated on five relatively small areas.

Four of these pieces of land are in the newly-developed region to the north (whereas one is in the old city region). They do not always have spatial proximity to the mass transit stations, and a considerable land clearance fee is required due to the built-up nature of the area. One patch of land (dashed circle D1 in Figure 5.2) is at the north periphery of the central city, around a transit station of Line 6. One is a high-standard residential area (dashed circle D2) near the office park of Ranjiaba, in the west of the northern new city region. One is along the river (dashed circle D3), in a developing residential area in the southwest of the northern region. Finally, there is an area called Jiangbeizui (dashed circle D4) at the junction of the two rivers and an area on the opposite bank of the river, where a future financial centre of the city is planned, with a new bridge linking the areas to the old centre of the city.

One of these pieces of land is in the old city, in a redeveloping area (solid circle D5) sited in a former dilapidated residential area, quite near Daping. The land was sold for expensive residential and commercial development. Though the area of land for redevelopment can’t be compared with the previous four in terms of size, the land price is very high — often even higher than the examples to the north.
The Transit Corporation of Chongqing is a government-owned transit agency that is responsible for the construction and operation of the mass transit system. There are a small number of case-examples of successful collaboration between the government and the private sector. A common factor in the success of these cases is the role played by the government in a number of areas, namely: land preparation for demolition; resettlement; relaxation and adjustment of urban planning regulations; coordination of land-use planning and transport planning; and giving priorities to key projects in land release proceedings.

In these cases, private investment was attracted in the form of a private-public collaboration with the transport corporation. In the preliminary stages, several development corporations bid for the collaboration. The transport corporation then selects the best project and decides on one corporation to collaborate with. They bid together in a ‘land bidding process’, the detail of which is explained further in Chapter 7. After bidding for the land, the partnership gains a legal right to use the
state-owned land (e.g. above a transit station) and they sign a contract to develop the project in collaboration. Throughout the development process, the two organisations share responsibilities and revenues.

A very important case study is undoubtedly the Liziba building (Figure 5.4), which is above a Line 2 transit station (station area S1 in Figure 5.2). It’s the result of successful coordination of planning interventions, as well as good structural design. As early as 1997, during the preparation stage of Line 2, the land around the station site of Liziba had already been sold to a local developer, but construction had not yet begun. It had been decided that the land should be acquired for development in integration with the construction of the transit station. Several rounds of negotiation were coordinated by the government, between the local developer and the potential joint developers (the transit corporation and a Taiwanese property development corporation).

![Figure 5.3: The building to the right with the train line passing through is Liziba Building at Rail transit station Line 2. Source: http://news.skykiwi.com/world/dl/sh/2014-08-01/183539.shtml](http://news.skykiwi.com/world/dl/sh/2014-08-01/183539.shtml)

As a result, the land acquisition and construction expenses were shared by the joint
developers. The Taiwanese property development corporation was responsible for the investment required for the construction of the building complex — both the station and the building complex above (Figure 5.4). The transit corporation acted as the land-resource provider. When Line 2 was being built, the sites above the stations were allocated by the government to the transit corporation, who reserved the right to a share in the revenues from property sale. In this way, this collaboration between the two corporations addressed the budgetary requirements for land acquisition and construction. The revenue gained from the property sale by the transit corporation was used for further transit construction, service operation and land development.

Figure 5.4: The train passed through the Liziba Building. Source: http://chuansong.me/n/413798443078

A second important case study is the Qingguishangcheng property development, above a rail transit station of Line 2 (station area S2 in Figure 5.2). The land release was realised via the government prioritising the direct assignment of the land to the transit corporation. The transit corporation was then required to pay the land-release
fee to the government afterwards. In this kind of land sale, the transit corporation has the advantage of being able to develop the land at low cost.

The land index of the whole building complex can be divided into two categories. The floors for station construction (floors –7 to –5) and for a control centre (floors 3 to 6) were allocated to the transit corporation for civil facilities. The floors for commercial parking (floors –4 to 2) and residential property (floors 8 to 29) were sold to the transit corporation with a promise of future payment. Construction began in 2007, three years after the opening of Line 2. The development of the property became a great success, with 86% of the properties sold within two hours of sales opening. Unlike the previous case, the transit corporation in this case played the dual role of transport project constructor and property developer. This avoided some coordination work and made operations more efficient. However, the construction of this building also led to the destruction of some old residential buildings nearby (Figure 5.6), which caused severe social problems, as discussed later in Chapter 7.
Figure 5.5: Entrance to the rail transit Line 1 and 2, through the ground floor of the building. The ground outside the building is occupied by the vendors.

Figure 5.6: Residential buildings next to the Qingguishangcheng property development
A third important case study is the Xinganxian Building (Figure 5.7) above Lianglukou station at the junction of Line 1 and Line 2 (station area S3 in Figure 5.2). The Chongqing city government has paid a lot of attention to the project, as it was a pilot of a scheme to make optimal development use of land above a station site. Throughout the process, it was offered a series of favourable policies by the government, including: land preparation by the government; financial support for land demolition and resettlement; adjustment of urban planning regulation indices for the project; and priorities in land-release procedures — all of which contributed to the implementation of the project.

During the land preparation and demolition process, the mayor of Chongqing himself endorsed the removal of local government offices from the site. To make sure of the efficient removal, the necessary policies of compensation and allocation in the demolition process were secured. Meanwhile (in line with the aim of economic efficiency of land development and the intensive land-use principle), the government relaxed the regulation of the land-use index on that site. The plot ratio was guaranteed to rise to maximise the potential revenue of the project. The process also involved negotiation of land-use disputes and revenue ownership, and concessions in various areas, such as physical planning requirements and building function requirements.

Again, the transit corporation and a property developer collaborated in the development. With sufficient financial support from the government, a successful bid was made by the partnership with no competitors in the bidding process. Because of the high cost of land demolition and resettlement, most developers pulled out of the bidding. A commercial complex was built, with mixed commercial and residential development above ground, and a commercial centre leading to the metro station below ground.
In all of the above cases, the constructions are above the station area. Via a legitimate process in China, the land above the station could be assigned, by direct assignment, to the transit corporation by the government with fewer obstacles. The government could also provide priorities to the transit corporation to allow them to win in the bidding process. Therefore all the above cases could be initiated by the transit corporation, either as sole developer, or in a development partnership.

In the next part of this section, I examine case studies where rail transit investment has attracted private developers to develop the nearby area, and also explore the possibility that land development conversely influences transit planning in the development process.
In the area of Shiyoulu, the local government has schemes to clear a large area of land (station area S4 in Figure 5.2) of existing old residential properties and factories, and redevelop the land by selling it to developers (see Figure 5.8). This patch of land was once a state-owned military enterprise. The government moved the industry to the suburbs and cleared the land for redevelopment. The site had the advantage of the imminent opening of a rail transit station. A single developer brought the land, and the first phase of construction consisted of 170,000 m². The first construction began in 2011 and opened at the end of 2012. It is a huge commercial complex with mixed-use functions, including retail, office, hotel and residential property. The built-up area is 1,000,000 m² in total, with a 600,000 m² commercial area (including the 170,000 m² mentioned above). The second phase contained 150,000 m² and opened at the end of 2014. However, when the tube station was constructed, there was no pre-consideration of integration with the nearby facilities, and thus no reserved passageway. Only when the land development was being decided, the mass of passengers brought to the areas by the tube was taken into consideration. There was great demand to directly link the tube station and the commercial complex under-ground. After negotiations between the developer, local government and the Rail Transit Corporation, a direct passageway was built afterwards, on the condition that the land developer paid money to the Rail Transit Corporation.
In this case, the land redevelopment in the old city area was realised through the promotion of redevelopment strategies by the local government. Mass public transport provision is one of the primary attractions for developers, among other locational advantages. However, the development could not have been realised without the land preparation and acquisition process assisted by the local government. This involved considerable cost of demolition and compensation, resident relocation and removal of old industry. Figure 5.9 and Figure 5.10 shows the communities near the development site. Part of the surveys and interviews were carried out in these communities, and are explained in Chapter 6 and Chapter 7.
Figure 5.9: Communities nearby. The established residents sit outside their residential buildings in an ordinary afternoon.

Figure 5.10: Communities nearby. Shops along the streets after a rain shower.
Another important case study is the commercial complex development at the Jiazhoulu rail transit station along Line 3 (station area S5 in Figure 5.2), in the new city region. In this case, land development had an influence on the rail transit planning. Jiazhoulu is an area of luxury residential communities, with a population who have a lot of purchasing power. Also in the area are government agencies that have moved there within the last ten years, from the old centre of the city. The area has therefore formed a new political and commercial centre.

In the early 1990s, at the beginning of the development of the real estate market in China, the Jiazhoulu area was farmland. A local development company bought 30.5 hectares of land from the local government and restored it. By the time the construction began in 2013, the land had been vacant for more than 10 years. But in those 10 years the land property market in China has gone through drastic growth, and the land price has increased tenfold.

Construction on the site began in 2013 and will be finished in 2017. The land development was divided into four stages, with a total construction area of 2,400,000 m$^2$. It includes commercial centres, five-star hotels, high-grade offices and luxury properties, which together form a cultural, relaxation and leisure centre (see Figure 5.11). It also tends to attract financial institutions. When Line 3 construction began in 2007, an underground link to the site was reserved, and currently Line 5 is being planned. The design of the line has been adjusted over several rounds. Now a transit node will form, with the intersection of Line 5 and Line 3 at the site. Therefore, in this case, it is not so much how the rail transit influenced the land development, but how the land development has reshaped the transit network. This site has influenced the location of Jiazhoulu station on Line 3, and now the future route and station location of Line 5 are also being influenced.
The above case studies have illustrated how transit development interacts with land development, either by rail transit provision influencing land development investment or *vice versa*. However, for the interaction to take place, there are other necessary conditions. For example, in the case of Lizibadasha, the development was realised with the aid of the government to coordinate the collaboration and land acquisition. In Qingguishangcheng, the direct land assignment to the transit corporation by the government was a necessary pre-condition. In Xinganxiandasha, the role of the government in nearby land acquisition and preparation was critical. And in the Shidaitianjie case (aside from the necessary supportive political measures), the general redevelopment strategies and the positive local economic environment helped make the development happen.

Conversely, it has been demonstrated that in some areas, even with transit provision, there is no spatial concentration of land development in response to the transit development. For example, in the southern part of the city, there is little sign of development attracted by the line, because this region is not the focus of the general development strategies of the city, and thus there are less favourable local
economic conditions to attract investment.

In general, the relationship between transit development and land use development is manifested at two scales in Chongqing. Firstly, at the city scale, transit planning is part of the spatial and economic development strategies of the city. These strategies are promoted by the government for the development of larger-scale projects in certain areas in the city; for example, allocation of land for industry and high-tech research and development (R&D). Transit is either provided (where insufficient) to meet the travel demand in the built-up corridors or can lead to urban expansion. Secondly, at the local scale, there are some successful cases in which land development and rail transit development interact with each other. Land development is attracted by the local positive economic environment and supportive policies, and transport planning is a small part to consider in the decision making of the developers. Finally, transit development can also be influenced by sufficiently large-scale land development.

5.3.2 Population change

5.3.2.1 Population density

Population change is studied in terms of density, age structure and household size. Both reference sub-districts show a similar rate of increase in population density, with a slightly faster rate of increase evident after the opening of Metro Lines 1-3 in 2011 (Figure 5.12). As shown in Table 5.2, from 2007–2011 (before metro opening) in LXSD the annual growth rate was 3.9%, while in 2011–2013 (after opening) it was 6.7%. In the other reference region, LTSD, the respective rates were 6.7% (before opening) and 9.3% (after opening)30.

---

30 The slope of the increase in the two reference areas are quite similar, whether compared in Figure 5.13 or calculated in Table 5.2. However, because the density level in LTSD is much lower than that in LXSD, which makes the denominator much smaller, the growth rate is higher than that of the latter one.
In the old city region, the population in the catchment area, DP, increased dramatically, by 15,633 (4,825/km$^2$), between 2009 and 2010 due to a new residential property development, and this was from a low baseline population. However, it increased more slowly afterwards, and there is little discernible change seen after the opening of Line 1. From 2007–2011 the annual growth rate was 7.6%, which actually dropped to only a 1.0% annual growth rate after the opening of Line 1.

For JZL and HHY, from 2007–2011, the population patterns are remarkably stable over the four years. This may be because the residential zones are at absolute capacity, with very little inward or outward migration. Therefore the statistics gathered at the community level didn’t detect the, presumably, negligible changes. Not surprisingly, for the developing area JZL, there is a strong increase seen immediately after the opening of the closest transit, Line 3. Indeed, there was an 11.5% annual growth rate in 2011–2013, compared to 6.7% for its reference region LXSD. For the mature station catchment areas, such as HHY and HTD, in the new city region, a slightly faster increase is experienced after opening, although the growth rates are still lower than their corresponding reference regions. HHY had only a 3.7% annual growth rate in 2011–2013, compared to 6.7% for its reference region, LXSD.

In comparison, the population density in the non-affected area also exhibits quite a strong increase due to residential property development. The control area, Luneng (LN), is a newly-developed residential area. The land was sold by the city government to a single developer, Luneng Group Co Ltd, which belongs to a large state-owned enterprise. The land was divided into 13 areas for development. The first residential property project started pre-selling in around 2007. Since then, the population in the area has increased quickly, with the land being developed and sold gradually.
Figure 5.12: Population density in research areas: comparison of different locations. Source: Chongqing census data, 2007-2013

<table>
<thead>
<tr>
<th>Research Area</th>
<th>Population density (person/km²)</th>
<th>Periods before and after the transit lines opened</th>
<th>Total growth rate 2007-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affected station catchment- DP</td>
<td>18,054</td>
<td>23,527</td>
<td>24,015</td>
</tr>
<tr>
<td>Affected station catchment- JZL</td>
<td>21,692</td>
<td>21,692</td>
<td>26,667</td>
</tr>
<tr>
<td>Affected station catchment- HHY</td>
<td>20,800</td>
<td>20,800</td>
<td>22,333</td>
</tr>
<tr>
<td>Reference region- LXSD</td>
<td>23,214</td>
<td>26,786</td>
<td>30,357</td>
</tr>
<tr>
<td>Affected station catchment- HTD</td>
<td>17,177</td>
<td>18,338</td>
<td>19,037</td>
</tr>
<tr>
<td>Non transit affected catchment- LN</td>
<td>3,244</td>
<td>18,532</td>
<td>23,170</td>
</tr>
<tr>
<td>Reference region- LTSD</td>
<td>11,246</td>
<td>14,261</td>
<td>16,900</td>
</tr>
</tbody>
</table>

Table 5.2: Population density in research areas: comparison of different locations. Source: Chongqing census data, 2007-2013
Hence, in maturely developed areas, the effect of transit on population density is not so obvious over a short period of time. But in an area with a strong rate of development (either in the new city region or in the redeveloping old city) the population accumulation trend is quite marked. Here the transit investment seems to strongly support the existing trend for development. In this way, the rail transit system dynamically facilitates the relative transformation of different areas in the city, and plays a role in balancing regional development. But, critically, it is the development strategy that leads to the transit ‘impact’ — hence there is a need for a package of transit and development if the most is to be made of the transit investment.

### 5.3.2.2 Demographics: age structure

A comparison of age structure and household size was carried out between a station catchment area, HTD, the control area LN and their reference area, LTSD, as well as at the average city level. The study areas were confined to the LTSD area because of the limit of data availability in other areas.

As is shown in Figure 5.12, from 2007–2013, the difference in population density between HTD and its reference region, LTSD, is reduced by the faster population increase rate in the reference region. The rapid population increase in the control area LN is also impressive, with large residential properties being developed in the area during these years.

From 2007–2013, the percentage of population under 16 years old in the reference area LTSD decreased over the whole period (Figure 5.13). Between 2007 and 2011, the percentage of population above 60 decreased (Figure 5.14) while the percentage of population between 16 and 60 years old increased (Figure 5.15). Between 2011 and 2013, the trend inverted again, with the percentage of population above 60 increasing and the percentage of population between 16 and 60 decreasing. When compared with Chongqing’s average trend, the decline in
percentage of the youngest population corresponded very closely to the whole city’s pattern. Although there was a slight increase in the 16–60 year-old population between 2007 and 2011, which was probably due to the population concentration effect resulting from development, the whole LTSD region still developed towards a generally older society.

Zooming in on the station catchment area HTD, we see a slight increase in the percentage of population below 16 years old from 2007–2009, much earlier than the opening of the transit station. A corresponding increase also happened in the percentage of population above 60 in the same period. This change was most probably because a residential property was completed at that time and people moved in. Then, after 2009, it remained stable. The station catchment area doesn’t follow the reference area’s pattern. Indeed, an opposite pattern is seen between these two. The age structure in the station catchment area didn’t fluctuate in correspondence with the trend towards an older society in the reference region (and the whole city). Compared to the reference area, (LTSD) until 2013, the station catchment area (HTD) ended with a higher percentage of population between 16 and 60, a lower percentage above 60, and an almost identical percentage of the youngest population, below 16.

As for LN (the control area), from 2007–2011 there was a similar trend, with a continuously increasing percentage of population below 16 years old and a continuously decreasing percentage of population between 16 and 60 years old. The percentage of people above 60 increased from 2007–2009 but remained stable after that. The age structure remained stable after 2011. Compared to the station catchment area (HTD), both the youngest and oldest population in LN increased faster and ended with a higher population percentage. However, the percentage of middle-age residents was higher in HTD. In comparison with the reference area, the change in age structure in HTD was also contradictory to the regional average level, ending with a higher percentage of population below 16.
and between 16 and 60, and a lower percentage of older residents, above 60.

Figure 5.13: Percentage of people below 16 years old. Source: Chongqing census data, 2007-2013

Figure 5.14: Percentage of people above 60 years old. Source: Chongqing census data, 2007-2013
5.3.2.3 Demographics: household size

Household size in the region is grouped into three categories: ‘single-person household’, ‘two-to-three-person household’ (most probably a couple with a child) and ‘multi-person household’ (more than four persons). In the reference region, LTSD (and more generally in China), single person households tend to be much younger and more highly educated than to two-to-three person and multi-person households. Multi-person households, however, tend to be more stable in household structure than single-person and two-to-three person households. The ‘one-child policy’ in China, which was introduced in 1979, has limited most families to have no more than one child, in order to prevent unsustainable population growth. Only in October 2015 was this switched to a two-child policy, in the aim of coping with the population’s rapid ageing. Nevertheless, in the past 35 years, the one-child policy has been strictly implemented, especially in cities, and was only seldom broken in some rural parts of the city, by desperate farmers who wanted to have more children.
(especially sons). In the current period it can still be estimated with reasonable confidence that urban households with more than four persons consist of at least three generations.

The proportions of each household size category in HTD, LN and LTSD are shown in the three figures below (Figure 5.16, Figure 5.17 & Figure 5.18). In the whole reference region, there’s a clear difference in pattern before and after the opening of the metro. From 2007–2011 in LTSD, the percentage of multi-person households kept increasing (with the other two categories decreasing). This is likely to be due to that many families had their older generation coming to live with them. But after 2011, two-to-three person households increased while the other two categories decreased. This trend may continue after 2013. In general, after the transit opening, with the population increasing faster, the household size structure in LTSD featured more small-sized households (likely to be families moving in), in comparison to before the rail transit opening, when there were more multi-person households.

However, this pattern in the reference area was not obvious in the rail station catchment area or the control area. From 2007–2009 in HTD, a very slight increase in single-person households and decrease of multi-person households can be seen, with the two-or-three person households remaining unchanged. From 2009–2013 there's almost no change at all in household structure.

In LN, there was also a slight increase in single person household from 2007–2009. From 2007–2011, multi-person households continued to increase and two-to-three person households continued to decrease rapidly. But after 2011, there was almost no change at all. In comparison to the reference area, the proportion of single-person households clearly increased in the other two areas.

When comparing the station catchment area (HTD) and the control area (LN), there
are two particular aspects of note. Firstly, there’s a slightly contradictory trend in household size between HTD and LN. The percentage of multi-person households kept increasing in LN while there was an opposite trend in HTD. Secondly, from 2007–2013, the percentage of different-size households in HTD and LN was becoming more similar. In LN, at the beginning of 2007, the percentage of both single-person and multi-person households was lower than the rail catchment area (HTD) and the reference region (LTSD). However, across these years, with newcomers moving in, and more families having babies, it is likely that the old generation moved to live with their adult children to take care of their grandchildren. LN had an increasing proportion of multi-person households throughout the whole period.

Figure 5.16: Single-person household percentage for each area. Source: Chongqing census data, 2007-2013
Figure 5.17: Two-to-three person household percentage. Source: Chongqing census data, 2007-2013

Figure 5.18: Multi-person household percentage. Source: Chongqing census data, 2007-2013
Generally speaking, there is a slightly contradictory trend between the station catchment areas in LTSD and the overall LTSD reference area. Before 2011, the positive economic environment might have resulted in a slightly rising percentage of population between 16 and 60 in the reference area, and declining percentage of older people. However, when the development went into the next stage, after 2011, the most prosperous sub-district in the city—LTSD, was likely affected by the overall aging trend in society. Throughout the period 2007–2013, the percentage of people above 60 years old in the rail catchment area (HTD) and the control area (LN) is lower than the average level in the reference region (LTSD). LTSD also has a constant decline of single-person households throughout the period. The reference region developed towards being an older society, with a more stable household structure. The percentage of young population below 16 years old is the highest in LN, with a strong increasing trend until 2011. There is also an obvious trend in LN towards a larger household structure, with an increase of multi-person households. As a fast-developing residential site, the changes in LN were to be expected. There was actually little dynamic change in the rail catchment area HTD from 2009–2013. However, HTD still had the lowest level of older residents and the highest level of population between 16 and 60, compared to LN and LTSD, which actually exhibited a more active demographic pattern. However, in comparison to the regional trend exhibited in LTSD, the higher percentage of working-age population in the rail transit catchment (HTD) is still evident.

5.3.3 Employment change

In the old city region (in catchment areas such as DP) there was a clear increase in employment associated with metro opening (Figure 5.19), with a 3.1% annual growth rate before 2011 and 5.4% after (Table 5.3). This might suggest that business and economic development in the old city are promoted by the regeneration trend in the area. On the other hand, as expected, in the developing region in station catchment areas, such as JZL, the employment increased faster
after the opening of the transit system. The employment growth rate is much steeper than before, and the increase rate is much higher than the reference region. JZL had a 2.1% annual growth rate in employment prior to metro opening and 5.4% post-opening. For comparison, the reference region LXSD had 1.2% before and 2.9% after (Table 5.3). In terms of employment change, DP was comparable to its equivalent area, JZL, in the north region. Its growth has been as robust as JZL. In contrast, a station catchment area such as HHY, which is maturely developed and away from the main transport corridor, does not seem to see as much employment and population increase following the opening of a new transit station.

Figure 5.19: Employment density in research areas: comparison of different locations. Source: Chongqing census data 2007-2013
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DP</td>
<td>21,759</td>
<td>23,765</td>
<td>26,312</td>
<td>20.9% (2008-2013)</td>
</tr>
<tr>
<td>JZL</td>
<td>11,443</td>
<td>12,388</td>
<td>13,731</td>
<td>19.99%</td>
</tr>
<tr>
<td>HHY</td>
<td>9,000</td>
<td>9,200</td>
<td>9,400</td>
<td>4.44%</td>
</tr>
<tr>
<td>LXSD</td>
<td>11,607</td>
<td>12,143</td>
<td>12,857</td>
<td>10.77%</td>
</tr>
<tr>
<td>LTSD</td>
<td>4,139</td>
<td>4,568</td>
<td>5,650</td>
<td>36.51%</td>
</tr>
</tbody>
</table>

Table 5.3: Employment density in research areas: comparison of different locations. Source: Chongqing census data 2007-2013

Studying the employment/population balance ratio, Figure 5.20 illustrates the distinct differentiation in the city between the old city and new city. With the ratio over 1, DP is more of an employment area. There was a sudden drop in 2010, most likely due to the opening of a new residential property. However, the ratio grew again in 2011, with a stable population but more rapidly increasing employment. This reflects a more active economy in the station catchment area, supported by the transit system. In comparison, the ratio in other areas in the new city appears to remain stable, with only an occasional increase or even decrease. For example, though there is a distinct increase both in population and employment in JZL, the employment/population balance decreases after the opening of two lines in 2011. This is also the case in the reference area LXSD.
To better understand the high employment/resident ratio in Daping, compared to other areas in the old city, it is necessary to delve into a little more detailed analysis. Figure 5.21 shows the change in the number of residents who work locally in DP. The number employed locally reduces over time, with a particularly steep fall just after the opening year of 2011. We can recall that the population in DP only slightly increased in 2009 and has remained stable afterwards. However, the locally-employed population decreased by 3,778 persons from 2008–2013. Therefore, at least 3,778 residents who once worked here are either unemployed, or (more likely) have changed their working place to outside the area.

Figure 5.20: Employment/residential population balance: comparison of different locations.
Source: Chongqing census data 2007-2013
There are potentially many factors involved, but it is probable that the improved rail transit has expanded the employment catchment of the local residents; hence many have chosen to work elsewhere. Although there has been plenty of employment created in the local area, this has not provided many job opportunities suitable for the local residents. The new jobs are mostly taken up by people residing outside the area. These are key issues for researchers examining the developmental impacts of transit investment. There are important questions concerning who benefits from the employment increase associated with a new transit system and whether much of the new employment is taken up by the established population.

### 5.3.4 Business activities

In order to explore economic development in more detail, the change in number of registered firms in LXSD was explored, including the two catchment areas, JZL and DP (Figure 5.22). The number of ‘self-employed entrepreneurs’ was also
investigated (Figure 5.23), as another index for evaluating the economic activities in the area. A ‘self-employed entrepreneur’ is a very small trading unit, representing people who have their own business.

On the y-axis in Figure 5.22, the increase in number of firms registered is expressed as a figure per 10,000 population. For the reference region (LXSD), after a slight dip in 2009, a discernible increase is seen from 2011, and the increase amount is much greater after 2011. In 2007, the additional number of firms registered in both JZL and HHY is below the reference region level. However, there is a leap in firm registrations JZL in 2009, much higher than the level in the reference region. In 2011, the level drops back to below the reference region. Nevertheless, both JZL and LXSD exhibit a steeper increase after 2011. In contrast, in HHY (a mainly residential area) the increase amount is always below the reference region level. Before 2011, it followed the trend of the reference region, with similar pattern of change. However, a slight increase in 2011 was not sustained.

![Graph showing annual increased numbers of firms registered (per 10,000 population) in Longxi Sub-district. Source: Chongqing census data, 2007-2013]

Generally, after 2011 there was a rise in increased number of firms registered in the
reference region and the station catchment area JZL. Especially for JZL, an area with dynamic economic performance, there was an increase two years before the transit opened, which made its increase amount in that year much higher than the reference region. However, for HHY, an area with a much less dynamic economic environment, the annual increase amount isn’t so distinctive.

The pattern of seen in the increase in self-employed entrepreneurs (SEE) is quite different from the pattern of registered firms (Figure 5.23). Both JZL and HHY have a higher increase in SEE than the reference region. However, the pattern in the reference region is similar to that seen with registered firms: a constant increase from 2009–2013, with a mild dip. The increase in SEE in JZL is higher than the reference region. There was also a sudden leap in JZL in 2011: a similar peak to that seen with firm registrations, but with a lag of two years. The increase in SEE then dropped suddenly to a lower level than 2007. The annual increase in SEE in HHY was higher than the reference region. However, it exhibited a constant decrease throughout the period 2007–2013.

Figure 5.23: Annual increase in number of self-employed entrepreneurs in Longxi Sub-district. Source: Chongqing census data, 2007-2013
In general, there are three aspects worth noting. Firstly, the increase in firm registrations in the station catchment area took place in advance of the opening time. However, self-employed entrepreneurs increased mainly adjacent to the opening time. This may be because self-employed entrepreneurs are more sensitive of the transit effect than larger firms. Secondly, the effect on both firms and self-employed entrepreneurs in the station catchment area JZL only happened for a short and transient period. In comparison, the population and employment increases were sustained for much longer periods. Thirdly, again, the effect of rapid rail transit only seems to favour certain kinds of area, such as fast-developing areas like JZL. However, in areas without such a dynamic economic environment, such as HHY, rail transit does not seem to have such an effect on business and enterprise.

5.3.5 Income change

Residents in the three station catchment areas earn higher incomes compared to the average level of urban households of Chongqing (Figure 5.24). The income level in JZL and HHY is higher than in the reference region, LXSD, and the old city.

![Per Capital Annual Disposable Income](image)

Figure 5.24: Income level: comparison of different locations. Source: Chongqing census data 2007-2013
### Per capital annual disposable income (yuan/year)

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2011</th>
<th>2013</th>
<th>Periods before and after the transit lines opened</th>
<th>Total growth rate 2007-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Annual growth rate 2007-2011</td>
<td>Annual growth rate 2011-2013</td>
</tr>
<tr>
<td>Affected station catchment - JZL</td>
<td>19,010</td>
<td>27,830</td>
<td>33,674</td>
<td>11.60%</td>
<td>10.50%</td>
</tr>
<tr>
<td>Affected station catchment - HHY</td>
<td>16,850</td>
<td>24,669</td>
<td>29,849</td>
<td>11.60%</td>
<td>10.50%</td>
</tr>
<tr>
<td>Reference region - LXSD</td>
<td>17,865</td>
<td>25,446</td>
<td>29,372</td>
<td>10.61%</td>
<td>7.71%</td>
</tr>
<tr>
<td>Chongqing urban resident average level</td>
<td>12,590</td>
<td>20,250</td>
<td>25,216</td>
<td>15.21%</td>
<td>12.26%</td>
</tr>
</tbody>
</table>

Table 5.4: Income level: comparison of different locations. Source: Chongqing census data 2007-2013

JZL has a higher income growth rate than its reference region, with 11.6% annual growth rate before opening and 10.5% after opening, compared to 10.6% and 7.7% in the reference region (Table 5.4). In spite of its lower rate of population and employment growth, HHY also has an obviously higher rate of income increase than its reference region. Its average income level is below the reference region in 2007 but then surpasses it in 2013. This can be explained as an income increase for the established residents and/or a higher income level for the newcomers to the area. However, in JZL, HHY and the reference region, LXSD, the annual growth rates slightly slowed down in the post-opening period. As to the whole city level, the annual growth rate also slowed down from 15.2% before opening to 12.3% after opening. In comparison to the areas in the northern region, DP didn’t exhibit such an impressive growth rate in incomes. Its annual growth rate in the before-opening period is only 6.3% (compared to 11.6% in JZL and DP). In the after-opening period, its annual income growth rate increased to 8.1%.

In summary, spatial impacts associated with transit investment develop over decades, but the analysis considered in this paper has considered impacts over the
time period 2007–13. Transit appears to have a differential impact across locations, in terms of population change, employment increase, and local employment. An important result is that the most significant difference is not between areas of the old city and new city, but between the areas with a strong developing trend and the maturely developed areas. For example, the affected station catchment area of DP exhibits a strong change (especially in employment increase), comparable to that of a fast-developing area (JZL) in the new region. But the affected station catchments of HHD and HHY do not exhibit much change. The income level change of DP is not as significant as other areas. What makes DP more exceptional is the employment/residential ratio. It is obvious that fewer local residents work in the local area. This indicates that the increased employment opportunities are not taken up by the established residents of the area. Local residents are perhaps not equipped with the necessary skills to gain the new employment associated with the rail transit system. This raises a critical question of benefit distribution associated with transit investment.

5.4 Exploring the relationship between average income level and other indicators of development

Following the issues of distribution discussed above, this study aims to explore whether the economic growth and opportunities created have contributed to the wealth of the whole population in that area. The average income level is a convenient surrogate of standard of living of people in a local area and can be easily compared. Income was therefore chosen as the outcome variable for a model-based analysis, covering the period spanning before and after the opening of the rail transit. The model was built with predictor variables including population density and employment density. A growth curve effect was also introduced to model the changing pattern over the course of time. Three transit-impacted areas were used for this analysis (restricted by data availability). These were DP in the old
city, and JZL and HHY in the new city.

As is explained in the methodology chapter, when entities are sampled from similar contexts, it is very likely that there is a hierarchical structure in the data. The specific context where data are gathered introduce locational dependency into the data. If a model is built on the data, the non-independent observations make the coefficients of the prediction variables vary as a function of the location. This makes the residuals of the model correlated, and thus breaks the assumption, of linear regression models, that the residuals should be independent. Therefore, here, a multilevel model was used to overcome this problem by factoring the contextual differences into the analysis.

In a multiple linear regression model, the coefficients of variables are fixed across the entire sample. For every case of data in the sample, a score is predicted using the same values of slope and intercept. However, for hierarchical-structured data, the slope and intercept of a multiple regression model can no longer be fixed. These coefficients can vary across locations. In doing this, the model is allowed to include random intercept and random slope, by adding a component to the intercept and slope terms. Meanwhile, when data are gathered over time, the change over time is nested within the cases of observations. In this study, the cases at different locations used in the model were the indicators of population, employment and income at different time points. So the time indicator was included in the model as a variable.

Therefore, the conventional multiple regression model shown in Equation 42 was expanded to Equation 43. The variable i is the ‘level 1’ variable, which represents the observations in the same location, and j is called the level 2 variable, which represents the contextual variable. Random components of $u_{0j}$ and $u_{1j}$ were added to the intercept and the slope terms.
The model was built up gradually. A linear trend of the time variable to model the change over time was first applied in the model. The local economic environment was taken into account by adding the employment density and population density. First, the basic model was built as below:

\[ Y_i = b_0 + b_1 X_{1i} + b_2 X_{2i} + b_3 X_{3i} + \epsilon_i \]  
\[ Y_{ij} = b_{0j} + b_{1j} X_{1ij} + b_{2j} X_{2ij} + b_{3j} X_{3ij} + \epsilon_{ij} \]

\[ b_{0j} = b_0 + u_{0j} \]
\[ b_{1j} = b_1 + u_{1j} \]

The modelling was carried out in the SPSS statistics package (version 21, IBM Corporation, NY, US). The contextual variable ‘location’ was specified as such in the software. The results of this model are shown in Table 5.5. The linear trend of change with time significantly predicts income change, with \( F(1, 3.02)=48.765, p=0.006 \). The impact of employment density also significantly predicts income change, \( F(1, 15.725)=28.18, p=.000, b = 0.21 \) (b is the ‘Estimate’ in Table 5.6). This means that when employment density increases, income also tends to increase. However, the impact of population density is not significant.

<table>
<thead>
<tr>
<th>Source</th>
<th>Numerator df</th>
<th>Denominator df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepts</td>
<td>1</td>
<td>15.694</td>
<td>316.22</td>
<td>.000</td>
</tr>
<tr>
<td>Population density</td>
<td>1</td>
<td>15.512</td>
<td>3.99</td>
<td>.064</td>
</tr>
<tr>
<td>Employment density</td>
<td>1</td>
<td>15.725</td>
<td>28.18</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>3.020</td>
<td>48.76</td>
<td>.006</td>
</tr>
</tbody>
</table>

Table 5.5: Tests of fixed effects: a linear trend of growth
### Estimates of Fixed Effects

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Std.Error</th>
<th>df</th>
<th>t</th>
<th>Sig.</th>
<th>95% Confidence interval</th>
<th>45% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepts</td>
<td>13433.19</td>
<td>755.41</td>
<td>15.694</td>
<td>17.78</td>
<td>.000</td>
<td>11829.24 - 15037.14</td>
<td></td>
</tr>
<tr>
<td>Population density</td>
<td>-0.03</td>
<td>0.01</td>
<td>15.512</td>
<td>-2.00</td>
<td>.064</td>
<td>-0.06 - 0.00</td>
<td></td>
</tr>
<tr>
<td>Employment density</td>
<td>0.21</td>
<td>0.04</td>
<td>15.725</td>
<td>5.31</td>
<td>.000</td>
<td>0.13 - 0.30</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>1975.69</td>
<td>282.92</td>
<td>3.020</td>
<td>6.98</td>
<td>.006</td>
<td>1078.71 - 2872.67</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.6: Coefficient estimate: a linear trend of growth

Studying Figure 5.24, it appears that a quadratic trend (a second-order polynomial) may better describe the relationship between income level and time. Therefore, a quadratic trend was added to the model. Meanwhile, the random coefficients of the intercept and slope were also included. The function was thus revised as:

\[
Income_{ij} = b_{0j} + b_{1j} \text{Time}_{ij} + b_{2j} (\text{Time} \times \text{Time})_{ij} \\
+ b_{3j} \text{Employment density}_{ij} + b_{4} \text{Population density}_{ij} + \epsilon_{ij} \tag{45}
\]

\[
b_{0j} = b_{0} + u_{0j}
\]

\[
b_{1j} = b_{1} + u_{1j}
\]

### Type III Tests of Fixed Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Numerator df</th>
<th>Denominator df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepts</td>
<td>1</td>
<td>6.557</td>
<td>2761.06</td>
<td>.000</td>
</tr>
<tr>
<td>Population density</td>
<td>1</td>
<td>14.821</td>
<td>21.02</td>
<td>.000</td>
</tr>
<tr>
<td>Employment density</td>
<td>1</td>
<td>14.828</td>
<td>303.47</td>
<td>.000</td>
</tr>
<tr>
<td>Time</td>
<td>1</td>
<td>0.520</td>
<td>17.06</td>
<td>.304</td>
</tr>
<tr>
<td>Time*Time</td>
<td>1</td>
<td>14.800</td>
<td>120.67</td>
<td>.000</td>
</tr>
</tbody>
</table>

Table 5.7: Tests of fixed effects: a quadratic trend of growth
### Table 5.8: Coefficient estimate: a quadratic trend of growth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Std.Error</th>
<th>df</th>
<th>t</th>
<th>Sig.</th>
<th>95% Confidence interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercepts</td>
<td>14365.93</td>
<td>273.40</td>
<td>6.557</td>
<td>52.55</td>
<td>0.000</td>
<td>13710.49</td>
<td>15021.37</td>
<td></td>
</tr>
<tr>
<td>Population density</td>
<td>-0.02</td>
<td>0.00</td>
<td>14.821</td>
<td>-4.58</td>
<td>0.000</td>
<td>-0.03</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td>Employment density</td>
<td>0.20</td>
<td>0.01</td>
<td>14.828</td>
<td>17.42</td>
<td>0.000</td>
<td>0.17</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>1242.79</td>
<td>300.90</td>
<td>0.520</td>
<td>4.13</td>
<td>0.304</td>
<td>-39016.18</td>
<td>41501.76</td>
<td></td>
</tr>
<tr>
<td>Time*Time</td>
<td>103.98</td>
<td>9.47</td>
<td>14.800</td>
<td>10.99</td>
<td>0.000</td>
<td>-39016.18</td>
<td>41501.76</td>
<td></td>
</tr>
</tbody>
</table>

To compare how the quadratic trend improved the model, the $-2\text{LL}$ of the new model was compared to the value when only the linear polynomial was included.

$$\chi^2_{\text{change}} = 273.90 - 239.38 = 34.52$$

$$df_{\text{change}} = 9 - 8 = 1$$ (46)

The critical values for the chi-square statistic for $df_{\text{change}}=1$ are 3.84 (p<.05) and 6.63 (p<.01). Therefore this change is highly significant. The model should, therefore, contain a quadratic term for best performance. In Table 5.7, the linear trend, with $F(1, 0.52)=17.06$, p=.30, is not significant, but the quadratic trend, with $F(1, 14.8)=120.67$, p<.001, is highly significant. Therefore the trend in the data from 2007–2013 can be best described as a second order polynomial. With the quadratic trend added to the model, the effects of other variables also change. As shown in Table 5.8, employment density still significantly predicted the income change, with $F(1, 14.8)=303$, p<.000, b=0.20 (b is ‘Estimate’ in Table 5.8). This therefore means that employment density growth has a positive impact on the average income level in the areas. Finally (and unlike previously) population density also significantly predicted the income change. $F(1, 14.8)=21.02$, p<.000, b=−0.02 (Table 5.8). This means that when the population density increases, the income level slightly decreases.
The statistical analysis aims to explore the change in pattern of income level in the rail station catchment areas, and how it is impacted by other variables. After the locational influence is accounted for by the model, in the period from 2007 (when rail construction began) to 2013, the income level increased with a quadratic trend against time. Income level can be significantly predicted by population density and employment density change (but with opposite polarities of coefficient). This means that in general, across the three study areas, employment opportunities have a positive relationship with the average income level (i.e. when local employment increases, the local average income level also increases). However, it should be remembered that in DP (the old city), the number of locally-employed residents still dropped. It is also important to note that the dependent variable of the model is just a regional average and does not reveal the discrepancy of groups with different ranges of income. The jobs created in the local areas may be provided for people living in other parts of the city, and some established residents may find jobs elsewhere. However, there are still some population cohorts, with a lower income, who don’t benefit from the increased job opportunities. This is explored further in Chapter 6.

Finally, the population density has a negative relationship with the income level. This might be because, as population increases around a transit station, the number of rural migrants, or low-income residents, near the station may increase. Though no causal relationship can be inferred merely from the regression model results, it is probable that the quadratic trend in income level changes corresponds to an economic upswing trend in the local area. The economic upswing trend is closely related to the local planning strategies, of which transit development is a part.
5.5 Discussion

There are still some inevitable limitations with the methodological approach used, which should be acknowledged explicitly here. Because of the difficulty in finding a suitable control area, reference areas corresponding to administrative boundaries were identified instead. If more data were publicly available, the comparison could be validated much better, by identifying more suitable control areas. In this way, other influential factors, such as economic environment, policies and investments and other wider influences, could be better isolated and the effect of rail transit could be observed more independently. Therefore complexities inherent in the mechanism by which rail transit takes its effect could be better unravelled.

Importantly, even if there is an apparent difference in the growth rate of the indicators of change after the opening of the transit, there is not necessarily a correlation between the discerned changes and rail transit's impact. Nor does the difference between the catchment areas and the reference areas necessarily indicate an impact from the transit system. The difference might, in fact, result from other influential factors, such as the economic environment, policies, investment and land availability. To figure out the impact of the transit system, one needs to have greater insight into the context and effect of social impacts on people’s lives. Only then can the actual impact (beyond the obvious changes) be clearly understood. To address some of these limitations, a primary qualitative survey was carried out by the author, aiming to better assess the variations of the impact on people’s lives. The results of this are presented in the next Chapter.
5.6 Conclusion

Using comparative methods, the results found in this chapter confirm previous findings that transit investment has disparate impacts across different locations. In this study, I have shown how it has a powerful, but relatively varied, effect on different locations along the lines. It therefore has an influence, to some extent, on balancing the regional development discrepancy, especially for the less developed areas and for the revival of the old city.

Aside from the expected short-term effect on land development, increases in population and employment were also witnessed in this study in Chongqing, particularly in the long term. However, it seems that transit only has a major influence on development when it is supported by other conditions. This research demonstrates the synergistic effects of combining spatial urban development strategies and associated planning interventions with rail transit investment. It emphasises the importance of developing a ‘package’ of policy measures that will lead to desirable impacts on the neighbourhood and city.

Though model-based analysis indicates a positive relationship between employment and people’s average income level across three local areas, statistical analysis of local employment in one area (DP) suggests that increased employment opportunities might not benefit the local residents. There are therefore some cohorts — most likely the low-income residents — who may not benefit from the development associated with the rail transit investment.

This chapter presents evidence to demonstrate (in line with trends in the transportation and urban development literature) that new transport can reinforce the established trend, but conversely can also powerfully transform the relative positions of different centres along the railway lines (Hall, 1995b). Regional differences have therefore been narrowed in some areas, especially between the
new prosperous city centre (JZL) and the old city redevelopment area (DP) — particularly in areas such as land development and employment change.

It has also been previously argued that impact from transport will favour the locations which can take direct advantage of it (Hall and Hass-Klau, 1985). The term “taking direct advantage” has been interpreted in different contexts, in which sometimes preconditions are required. For example, as mentioned before, economic externalities, investment factors, and political factors are often necessary conditions (Cervero, 1998, Banister and Berechman, 2003, Banister and Thurstain-Goodwin, 2011). In many cases, the old city centre is often considered an area that finds it difficult to benefit from the regeneration effects of the rail transit systems. Economic externalities in the underdeveloped old city centre region are not optimistic, and the area thus lacks attractiveness to investors. It’s also unlikely that favourable policies are implemented in these areas. Furthermore, lacking the available land to attract new developers, these central city areas are often deteriorated, even if provided with new public transport facilities (Hall and Hass-Klau, 1985).

However, in this case, rail transit played a role in facilitating developments in less developed areas — dynamically transforming the relative status of the multiple centres of the city, and balancing the development in the new city and old city. With the impact of the rail transit, massive changes happened in the old city, in the areas with a strong redevelopment trend. With employment growth, for example, changes in the old city areas can be compared to prosperous areas, like JZL, in the new city region. These changes are much greater than in the more mature areas, such as HTD and HHY (in the new city), which haven’t exhibited such big changes in land development, population increase, employment increase and economic activities.

It is argued in previous literature that land use change and property markets often
exhibit the impacts of transport investment in a short term, while population change, employment increase and firm accumulation are more likely manifested in the middle to long term. The impacts of transit at the local level are primarily changes in land use and the property market (Banister and Thurston-Goodwin, 2011). However, in this research, I demonstrate that some population and employment increase effects are also witnessed on a short time scale at the local level, e.g. in JZL and DP. These changes likely happened as a result of large-scale land development projects in these areas. After the transit station opened, it seems there was a trend for more younger people and two-to-three person households to move into the station-affected areas of the new city, creating a shift towards younger age structure and smaller household size.

This result underlines the important synergistic effect of high-level policies and planning interventions (especially urban development strategies), in combination with rail transit development, in order to achieve the best result. It is the package of measures that is important. The emphasis should therefore be on identifying the synergistic measures that will lead to the desired impacts on the neighbourhood and city. For example, DP in 2011 was the only area in the old central city to have the highest land development activity, comparable to areas in the new developing region. This is probably because the local government had implemented redevelopment schemes in this area. There were heavy subsidy inputs for land clearance and resettlement, to reserve land and sell it to developers.

As demonstrated in American cities, by being part of a larger, heavily-subsidised development plan, with changes in planning policies, rail transit systems can launch a wave of renewal (Banister and Berechman, 2003). In dilapidated areas that lack good economic externalities, a rail transit system can facilitate development, given appropriate planning policies for regeneration, such as land use development. With new offices and residential properties built, employment and population can increase subsequently. Moreover, supportive policies alone are not enough to
make areas effectively take advantage of the transport provision. Effective integration of land development and public transport planning is critical to facilitate the effect. This important topic is discussed in Chapter 7.

The model-based analysis across DP, JZL and HHY shows that the average income level increased with a quadratic trend from 2007 (the beginning of the construction of rail transit) to 2013, two years after the transit opened. The employment density in these areas had a positive relationship with the average income level in the local area. This may suggest that increased employment opportunities (reflecting economic development in the area) have a positive influence on the overall wealth of the local population.

However, despite a similar employment increase rate in DP and JZL, the changes were heterogeneous in their patterns; indeed the patterns have divergent impact on residential population there. In the old city, there seems to be a gentrification effect. Statistics show that fewer local residents work in the local area. This indicates that the increased employment opportunities are probably not taken up by the established residents of the area, but rather by newcomers. The reason for this may be that the increased employment opportunities are generally either in offices or in shops and restaurants, and there is a mismatch between the specific skills required for these jobs and those of the local residents. The established residents in the old city likely don’t have the capabilities to take up the office jobs, and they are also reluctant to serve in restaurants or shops. In the old city, there is a trend for rural migrants to move into these areas, concentrated particularly around the transit station areas, for the convenience of the public transport provision. While in the new city, the newcomers are comparatively highly-educated and thus able to take up the opportunities. These factors therefore have disparate impacts across different spatial contexts and the result can potentially be social inequity. This is discussed in the next chapter.
Chapter 6. Exploring Equity Dimensions of Rail Transit Impact

6.1 Introduction

Understanding the spatial variation in the demographic and socio-economic impacts of transit investment can be challenging, as many of the impacts are indirect and are likely to be lagged by some time period. As is explored in Chapter 5, these impacts might include increases in local population levels, changes in employment rates or increasing income levels.

One way of conceiving of this spatial variation is to view it through the lens of spatial inequity. Let us assume that the guiding motivation of planners of large infrastructural developments is to improve the lives of citizens and reduce socio-economic or residential inequalities. This may be achieved through increasing access to residential and employment opportunities in a city by improving the speed or quality of the transport connections between the two. In this scenario, as Hay (1995) noted, such “policies and programmes should be judged on the extent to which they serve to eliminate, or at least reduce (rather than increase or create), such inequities”.

The conceptual understandings of equity in this context can be quite diverse, with Hay (1995) developing a typology covering eight concepts, including: procedural fairness (the process of transit infrastructure development is fair, and there is a correct application of the rules); formal equality (the likely benefits, or burdens, are enjoyed, or suffered, by like persons); and substantive equity (there is equality of outcomes, viewed in terms of net aggregates of benefits and burdens). Feitelson (2002) has called for environmental equity studies in transport, comparing the attributes of the users of the new systems to those affected. Yet even now, there is
little clear evidence on what substantive impacts are likely to arise, on what scale, in which locations, and on whom.

There is an emerging body of evidence in the Western industrialised context (Hall and Hass-Klaau, 1985, Banister, 1995, Llewelyn-Davies et al., 2004, Vickerman, 2008), examining transport and wider economic impacts, suggesting that rail transit systems tend to benefit certain locations over others, and that the developmental and regenerative effects of rail transit also occur differentially across population groups (Feitelson, 2002, Geurs et al., 2009, Jones and Lucas, 2012). In particular, Jones (2015) found that the impacts of investment on the Jubilee Line Extension (JLE) in London tended to favour the wealthy newcomers to the area — who use the new Underground services, access new employment and other activities, and gain from the property uplift — and not the lower-income established residents. There is some emerging evidence on relationships between urban structure and travel from the Chinese context (Shen, 1997, Cervero and Day, 2008, Wang and Chai, 2009, Wang et al., 2011, Pan et al., 2009, Pan et al., 2013, Zhao, 2010). However there is less work, to my knowledge, studying transit investment and economic and social impacts in China.

The aim of this chapter is to understand whether the new transit developments in Chongqing have been for the benefit of all citizens, by examining the ways in which individuals occupying different socio-economic positions in the city perceive the impacts of new transit developments differently. These perceptions are recorded via an opinion survey (Appendix 2: Transport attitude survey) conducted by the author, and MANOVA and discriminant analysis are used to explore variations in these perceptions.

Based on the findings of previous work in this area (Gatersleben et al., 2007, Jones, 2015), it is expected that the higher socio-economic groups might look more favourably on the rail transit developments. In contrast, those in lower income
groups might look less favourably on these developments, as the benefits for them are quite limited and new developments may bring about adverse impacts on their lives, such as the increasing rent and property prices.

### 6.2 Definition of income groups

Though a range of economic impacts can be revealed in the analysis of aggregate secondary data (as in Chapter 5), the social impacts of transit investment still can’t be assessed because of the limited available data (across location, time and category variables). Therefore, the analysis in Chapter 5 is followed here by a residential survey, carried out by the author in 2014, examining people’s perceptions and attitudes towards rail transit’s effects on the developmental changes at the neighbourhood level, and also the impacts on their lives. The attitudinal survey undertaken by the author helps to explain and add further understanding to the quantitative analysis in the previous chapter.

The survey method and data was introduced in detail in Chapter 3. Its aim was to explore the aspects of disproportionate spatial distribution according to people’s social-economic characteristics and travel behaviours. A total of 1,300 surveys were sent out to the catchment areas and control areas, with around 30-40 surveys sent to each community. 1,000 surveys were returned and 752 were deemed reliable after checking. Those with incomplete or obvious faulty information were rejected.

Within the survey, respondents were categorized into groups according to their income level. According to the Chinese Household Finance Survey, which covers 2,585 cities and 8,000 households in China, the average household annual income level is ¥52,087 RMB (Chinese Yuan Renminbi) (circa. £5,200 GBP\(^{31}\)), accounting for both urban and rural households. The average level for the urban household is

\[1 \text{ Chinese yuan} = £0.10 \text{ GBP (05 November 2015)}\]
¥71,546 (c. £7,200). McKinsey (2013) report on the significant rising middle class in China, especially the upper middle class, with a striking differentiation from their mass middle-class counterparts. The upper middle class has a household annual income between ¥106,000 (c. £10,600) and ¥229,000 (c. £22,900). This provides a reference for the classification used in the income groups. Taking into account the specific economic situation and the residents’ income and consumption level in Chongqing, the respondents of the survey were divided into four groups (Table 6.1), namely: ‘lowest income group’ (group 1), ‘mid-low income group’ (group 2), ‘mid-high income group’ (group 3) and ‘highest income group’ (group 4).

<table>
<thead>
<tr>
<th>Group number</th>
<th>Group income level</th>
<th>Annual household income (RMB_yuan/year)</th>
<th>Sample amount</th>
<th>Sample percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group1</td>
<td>Lowest income group</td>
<td>Below 50,000</td>
<td>289</td>
<td>38.90%</td>
</tr>
<tr>
<td>Group2</td>
<td>Mid low income group</td>
<td>50,000-100,000</td>
<td>182</td>
<td>24.50%</td>
</tr>
<tr>
<td>Group3</td>
<td>Mid high income group</td>
<td>100,000-200,000</td>
<td>166</td>
<td>22.30%</td>
</tr>
<tr>
<td>Group4</td>
<td>Highest income group</td>
<td>Above 200,000</td>
<td>106</td>
<td>14.30%</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td></td>
<td>743</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 6.1: Income group definition

Table 6.2 gives a cross-tabulation of the distribution of the income groups across the three reference regions from the attitudinal survey (performed in 2014). It should be noted that the non-station catchment area LN was deliberately over-sampled in order to present a comparable dataset (401 cases) with the station catchment areas (342 cases each). DP (in the old city region), has the highest proportion in the low income group (below ¥50,000), at 72.9%, compared to the other catchment areas in the new city region: JZL 46.8%, HHY 55.6% and HTD 60.7%.

---

32 http://www.mckinsey.com/insights/consumer_and_retail/mapping_chinas_middle_class
### Locations and household annual income level (yuan/year)

<table>
<thead>
<tr>
<th></th>
<th>household Income groups (yuan/year)</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 50,000</td>
<td>50,000 -100,000</td>
</tr>
<tr>
<td><strong>Station catchment areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daping (DP) Old city region</td>
<td>Amount: 70</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>72.9%</td>
</tr>
<tr>
<td>Huahuiyuan (HHY) New city region</td>
<td>Amount: 40</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>55.6%</td>
</tr>
<tr>
<td>Hongtudi (HTD) New city region</td>
<td>Amount: 68</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>60.7%</td>
</tr>
<tr>
<td>Jiazhoulu (JZL) New city region</td>
<td>Amount: 29</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>46.8%</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>Amount: 207</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>60.5%</td>
</tr>
<tr>
<td><strong>Non-station affected area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luneng (LN) New city region</td>
<td>Amount: 82</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Percentage in the research area:</td>
<td>20.4%</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td>Amount: 289</td>
<td>182</td>
</tr>
<tr>
<td></td>
<td>Percentage in total%</td>
<td>38.9%</td>
</tr>
</tbody>
</table>

Table 6.2: Spatial distribution of household annual income level from 2014 attitudinal survey. Source: Primary survey data (Lixun Liu)

Around the station catchment areas in the old city, the population predominantly has a low income. Often low-income rural migrants concentrate there: likely attracted by the public transport convenience and also the lower rent and living costs in the old city. In the new city, this concentration effect of low-income people around station catchment areas is not so obvious.

### 6.3 Exploring social equity issues revealed spatially in the survey

As shown in the descriptive statistical analysis in Chapter 5, in maturely developed areas (such as HHY and HTD), the effect of transit on population accumulation is not so obvious on a short time-scale. But in an area with more rapid development (for
example in the new city region, JZL, or in the redeveloping old city, DP, the population consolidation trend is quite marked, and transit investment seems to support the existing trend for development. However, population density in the non-affected area also exhibits quite a strong positive trend, due to residential property development. With the rapid urbanisation trend in China, many farmers have left their farmland and moved to the city, becoming migrant workers. The transit station catchment areas are usually an attractive destination for such migrants, because of the convenience of public transport. Integrating the rural migrants into the local communities has become a critical issue, and maintaining community harmony is especially important.

The effect of rail transit on community harmony was therefore a key question in the survey. Both the importance of this factor and the perceived impact of rail transit were explored. Residents both in DP (in the old city) and HHY (a mature developed residential area in new city) report a less positive perception of the effect of transit effect on community harmony than the other areas studied (grey bars, Figure 6.1). However, residents in DP attach a higher importance to community harmony (black bars, Figure 6.1). In fast-developing areas, like JZL, residents tend to present a more positive perception of the transit effect on their community, as well as attaching a high level of importance to community harmony. Unsurprisingly, in the control area LN, which is not affected by the rail transit station, the perceived transit effect is the lowest among the areas studied.

In summary, for the mature residential areas, such as HHY and DP, the respondents’ evaluation of the perceived transit effect on community harmony is relatively negative compared to newly developed areas, such as JZL and HTD. Although there was not actually much population change in the local area in HHY, the survey suggests that residents are more sensitive to community harmony changes associated with rail transit. In DP, in the old city, where there was actually a significant population increase, community harmony is indicated by the residents to
be more important than other areas, with a score as high as in JZL.

As presented in Chapter 5, in the rail transit station catchment area DP (in the old city region), there is an obvious increase in employment after transit opening. In station catchment area JZL (in the developing region), the employment increase slope is much steeper than before transit opening, and the increased rate is much higher than in the reference region. However, in station catchment area HHY (a maturely developed area, off the main transport corridor) there is no clear increase in either employment or population. Additionally, in DP, despite local employment increasing, the number of residents who work in the local area has declined steadily.

Figure 6.1: Perceived transit effect on community harmony and importance of community harmony to individuals: comparison of different locations. The perceived effect ranges from -2 to 2, while the importance to individuals is from 0 to 2. Source: Primary survey data (Lixun Liu)
It is probable, therefore, that the increased job opportunities in DP are mostly taken by people commuting in from outside the area. The question arises, therefore: if the new transit system has promoted an employment increase, what proportion of this benefit has actually been distributed to local residents?

The survey raises a similar issue. There is a disparity between the perceived effects of transit on increasing employment (grey bars, Figure 6.2) and the importance of local employment to residents (black bars, Figure 6.2), across both mature and developing areas, and across both the old and new city. Generally, residents in the areas DP, HHY, and HTD attach relatively higher importance to local employment than the areas ZL and LN. HHY exhibits the largest disparity, with the highest importance attached to local employment and lowest perceived effect of transit on local employment. Despite there actually being a fast increase in employment in DP, the residents attach a relatively high level of importance to local employment, compared with other areas, which suggests that the increased jobs may not be benefiting the local people. Of course, this may be because they are not equipped with the necessary capabilities to take the jobs generated by the development in the local area.

Compared to other station catchment areas, residents in the newly-developing area JZL attach the lowest level of importance to local jobs, and this area enjoys the most positive perception of transit's influence on employment increase, which is consistent with the truly rapid development there. Meanwhile, residents in the well-off residential area LN attach the lowest importance of the five areas to local employment increases, and their perceived transit effect is also the lowest. The low importance of local employment for residents in fast developing areas such as JZL and LN may indicate that the local residents are not as restricted to the local area for employment as residents in other areas might be. They are more likely to possess private cars and have a higher level of access to other employment opportunities.
Next, respondents were asked about their perception of the effect of transit on property prices in their area (black bars, Figure 6.3), and the individual impact that rising property prices may have had on them (grey bars, Figure 6.3). Residents in DP tend to be the most aware of property price rises, as indicated by their high perception of transit effects on property prices. Perhaps because of their economic status, they are the most adversely affected by price rises, as indicated by the very negative individual impact of property price rises.
Figure 6.3: Perceived transit effect on property price rising and the impact on individuals: comparison of different locations. Source: Primary survey data (Lixun Liu)

The above analysis raises concerns about benefit distribution from transit investment. In order to further explore the gap between desired outcomes and possibly less favourable social equity, it is necessary to look deeper into the data to ascertain the social composition of people in the local areas, and what their socio-economic characteristic might be. To address this aim, the primary survey explores the attributes of the local residents, their behaviours, perceptions and attitudes.
6.4 Exploring changes in travel mode share among different income groups

Previous research on the Jubilee Line Extension (JLE) suggested that there was only limited change in travel mode to the Jubilee Line by former car users (Lane et al., 2004). Though the Metrolink in Great Manchester demonstrated an attractiveness to former car users as great as that to former bus users, the socio-economic characteristics of those attracted to the Metrolink are not well researched (Knowles, 1996, Senior, 2009). Therefore, what is still poorly understood is what groups are excluded from the opportunities provided by new rapid transit investment. The attracted new users are presumably the winners from the transport provision, while the groups that do not use the transport provision (or even suffer from adverse impact) are the losers. This study attempts to explore this issue more deeply, by studying people’s transit use frequency and changes in their travel mode, using a primary survey with a more careful subdivision of the population’s socio-economic characteristics.

As has been mentioned, in the Chongqing official travel survey data (2014), the residents’ income information is not publicly accessible. Yet income is an important criterion for assessing people’s socio-economic conditions and also for exploring transit’s social impact. The survey carried out by the author therefore collected information about respondents’ income levels. People were also asked about their travel mode choice before and after the opening of transit. The aim of collecting these data is to compare people’s change in travel mode against their socio-economic characteristics; for example, their travel mode before and after the rail transit opened. These data can be used in supplement to the citywide travel survey. It is important to mention that, because the survey only sampled residents within the five research areas — four of which are around the transit stations — the transit mode share is much higher than the dataset extracted from the official
transport survey.

Improved accessibility is the direct impact of transport investment, and with this in mind, Table 6.3 provides a contingency table showing people's income groups and their current travel mode share of commuting trips. People were divided into four categories according to their income level. The mode share includes three categories: ‘rail transit’, ‘bus or walk’, and ‘private automobile, (including car, taxi or company special bus)’.

As shown in Table 6.3, there is a noticeably higher percentage of rail transit use in the mid-low (57.5%) and especially mid-high income group (59%). The middle-income groups appear to make great use of rail transit, and presumably benefit most from the direct impact of new rail transit systems. The lowest income group also has a comparatively high percentage of transit use (47.7%) and the highest share of bus or walk (41.5%) among all the groups. However the highest income group has only a share of 39.4% of rail transit use, and a particularly high share (49%) of private transport. This clearly suggests that the lower income groups use public transport most for their daily commuting trips — both rail transit and bus. They also derive large benefit from the increased travel convenience that results from rail transit investment (as opposed to investment in other transport, such as buses). The question remains whether this high usage of transit actually means they benefit more from the transit system in developmental terms.
### Current travel mode of residents in the survey

<table>
<thead>
<tr>
<th>Household Income categories (yuan/year)</th>
<th>Travel mode</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rail Transit</td>
<td>Bus or Walk</td>
</tr>
<tr>
<td>Group 1: Lowest income group below ¥50,000</td>
<td>137</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>47.7%</td>
<td>41.5%</td>
</tr>
<tr>
<td>Group 2: Mid - low income group ¥50,000-100,000</td>
<td>104</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>57.5%</td>
<td>22.7%</td>
</tr>
<tr>
<td>Group 3: Mid - high income group ¥100,000-200,000</td>
<td>98</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>59.0%</td>
<td>13.9%</td>
</tr>
<tr>
<td>Group 4: Highest income group above ¥200,000</td>
<td>41</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>39.4%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Sum</td>
<td>380</td>
<td>195</td>
</tr>
<tr>
<td></td>
<td>51.5%</td>
<td>26.4%</td>
</tr>
</tbody>
</table>

Table 6.3: Household income groups and current travel mode share. Source: Residents’ perception survey in rail transit station catchment areas 2014 by the author

In order to explore the impact of the rail transit system on people’s travel mode after the opening of rail transit system, and how changes in travel mode differ between groups who previously used different travel modes, the whole sample is divided into two groups according to their travel mode choice prior to the opening of the new rail transit. The two groups are: i) previous private automobile users (including private car, taxi and special company bus), shown in Table 6.4; and ii) previous public transport users (including bus or walking), shown in Table 6.5. The two contingency tables show the current travel mode share of these two groups.

For the private automobile users who chose to switch to rail transit use, the most significant change is seen in the mid-high income group (Table 6.4). Of the mid-high income group who were previously private automobile users, 55.7% changed their travel mode to use rail transit. There is also a comparatively high proportion of change in the low-income group (50.8%), and from the mid-low income group (49.1%). However, the highest income group of previous private mode users are the least likely to change to rail transit use, with only 40.7% switching to rail transit. A
higher proportion (57%) of this group remains in their previous private travel mode.

<table>
<thead>
<tr>
<th>Household Income categories (yuan/year)</th>
<th>Travel mode</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rail transit</td>
<td>Bus or Walk</td>
</tr>
<tr>
<td>Group 1: Lowest income group below ¥50,000</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>50.8%</td>
<td>16.9%</td>
</tr>
<tr>
<td>Group 2: Mid - low income group ¥50,000-100,000</td>
<td>28</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>49.1%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Group 3: Mid - high income group ¥100,000-200,000</td>
<td>54</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>55.7%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Group 4: Highest income group above ¥200,000</td>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>40.7%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Sum</td>
<td>147</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>49.2%</td>
<td>5.0%</td>
</tr>
</tbody>
</table>

Table 6.4: Current travel mode share of previous private automobile users (car, taxi or company special bus) divided by different categories of household income. Source: Residents’ perception survey in rail transit station catchment areas 2014 by the author

One the other hand, looking at the transit’s effect on change in mode share of previous bus users/walkers (Table 6.5), the largest change from public transport users to rail transit is still in the mid high income group (63.8% change to rail). Similarly, the mid-low income group of previous bus users/walkers also exhibits quite a high level of change to rail (61.3%). The lowest income group of previous bus users/walkers is less likely to change to transit: only 46.9% of them shift to transit use and 47.8% of them continue using their previous travel mode. Finally, the highest income group is again the least likely to change from their previous travel mode (only 33.3% change to rail transit).
From the two separate contingency tables above, we can see that the mid-high income group are generally the most willing to change to rail transit use. The mid-low income group are also fairly likely to change from their previous travel modes to transit. The lowest income group of previous private automobile users is also likely to change from private mode to transit use. This indicates that rail transit provision may provide increased convenience to this group. However, the lowest income group of previous bus/walkers are, comparatively speaking, not willing to change to transit use. Finally, the highest income group is the most reluctant to change from either of their previous modes to rail transit use.

The result of the analysis above suggests that the mid-income groups (especially mid-high income group) gain most in terms of transport benefits from rail transit. However, a specific group of people, the previous bus/walkers in the lowest income group, don’t benefit as much from the new transit.
6.5 Differential impact by income group

6.5.1 The perceived rail transit effects on an individual’s local neighbourhood

In order to examine differences between population sub-groups, such as the income groups described in Table 6.1, multivariate analysis of variance (MANOVA) and discriminant analysis are utilised. The theory of these methods was already introduced in Chapter 3. Here we will use these methods to assess whether an individual’s response to the opening of a new transit station is affected by their economic position. Our data allow us to separate out, not only how an individual perceives the transit impact on their local neighbourhood, but also how they perceive the impact upon their own lives. Measurement of the ‘transit impact’ could relate directly to factors asked about in the questionnaire — such as the price of property, the cost of living, neighbourhood safety, etc. — but also to any of these factors in combination. In the MANOVA analysis, the perceptions of transit impact relating to ‘property rent’ and ‘weekend travel convenience’ in the questionnaire were removed due to multi-collinearity affecting the reliability of the model. The remaining factors can be seen in Table 6.9.

Table 6.6 shows the main results from this model. The table is divided into two rows, and test statistics are quoted for the intercept of the model and for the grouping variable ‘income’. The intercept in the first row represents the parameter $b_0$ in Equation 37. The second row is of interest because it tells whether or not income level has an effect on differentiating people’s attitudes. In MANOVA, Pillai’s trace is utilized to assess the overall fit of the model; for example, Pillai’s Trace of ‘Income groups’ in Table 6.6 is $V = 0.107$. In the fourth column, the value of Pillai’s Trace is transformed into a $F$-ratio. The $F$-ratio is a measure of the ratio of the variation explained by the model divided by the variation explained by the unsystematic
Thus it assesses the overall fit of the model to the data (in this case, $F = 2.335$). The last column indicates the significance of the multivariate tests by calculating a $p$-value from the $F$-ratios, by referring to a $F$-distribution. For this data, the $p$-value of the $F$-ratio is below the criterion of 0.001 ($p = 0.000$ and it is therefore highly significant). It can be concluded that there is a significant effect of income level on differentiating people’s perceptions of how rail transit has affected their local neighbourhoods. But considering the Pillai’s trace value of $V = 0.107$, it is still a small effect. This is equivalent to saying that around 10% of the variance in perception is accounted for by the variance in income levels. It suggests that there are many other factors that could influence their perceptions.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>$F$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.860</td>
<td>387.236</td>
<td>0.000</td>
</tr>
<tr>
<td>Income groups</td>
<td>0.107</td>
<td>2.335</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 6.6: Multivariate tests of perceived transit effects on the local neighbourhood

However, as is explained above, this analysis does not tell us which groups differed from which. To determine the nature of the effect, discriminant analysis is adopted. The output of discriminant analysis on the income group data reveals three discriminant functions. In Table 6.7, the second column shows the eigenvalue of each discriminant function. In the third column, these eigenvalues are converted into the percentage of variance of the matrix $\text{HE}^{-1}$ (refer to Section 3.8.3) of the dependent variables that this function can account for. Canonical correlation is also shown in the last column (which can also be squared to give an effect size, like an $R^2$, of the model). When the values of the last column are squared and added up, the result is equal to the value of Pillai’s trace of income groups (Table 6.6, $V = 0.107$). Table 6.7 shows that the first discriminant function explains around 60.7% of the variance of the matrix $\text{HE}^{-1}$ (canonical $R^2 = 0.064$), whereas the second explains 25.1% of the variance (canonical $R^2 = 0.028$).
Table 6.8 shows the significance tests for the discriminant functions. Wilk’s Lambda$^{33}$ is calculated in the second column. It represents the ratio of error variance to total variance of the model of the functions. This value is transformed into a Chi-square value (third column), from which significance of the model is calculated as a $p$-value (fourth column). The first row shows that these three discriminant functions in combination significantly differentiated the income groups, $p = 0.000$. After removing the first function (second row), function 2 and function 3 do not significantly differentiate the groups, $p = 0.062$, and after removing the first and second functions (last row) function 3 reveals no significance, $p = 0.27$.

### Table 6.7: Eigenvalues of discriminant functions of differentiating income groups

<table>
<thead>
<tr>
<th>Function</th>
<th>Eigenvalue</th>
<th>% of Variance</th>
<th>Cumulative%</th>
<th>Canonical Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.068*</td>
<td>60.7</td>
<td>60.7</td>
<td>0.253</td>
</tr>
<tr>
<td>2</td>
<td>0.028*</td>
<td>25.1</td>
<td>85.8</td>
<td>0.166</td>
</tr>
<tr>
<td>3</td>
<td>0.016*</td>
<td>14.2</td>
<td>100</td>
<td>0.126</td>
</tr>
</tbody>
</table>

Table 6.8: Significance of discriminant functions on differentiating income groups

<table>
<thead>
<tr>
<th>Test of Function(s)</th>
<th>Wilks' Lambda</th>
<th>Chi-square</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 through 3</td>
<td>0.896</td>
<td>76.523</td>
<td>0.000</td>
</tr>
<tr>
<td>2 through 3</td>
<td>0.957</td>
<td>30.477</td>
<td>0.062</td>
</tr>
<tr>
<td>3</td>
<td>0.984</td>
<td>11.089</td>
<td>0.270</td>
</tr>
</tbody>
</table>

Table 6.9 reveals the correlations between the dependent variables and the discriminant functions 1, 2 and 3. The values in Table 6.9 are called the ‘standardised canonical variate correlation coefficient’ of each dependent variable, and represent the relative contribution of each dependent variable to group

$^{33}$ Wilk’s lambda is: $\Lambda = \prod_{i=1}^{s} \frac{1}{1+\lambda_i}$. $\lambda$ represents the eigenvalues of each of the discriminant functions and $s$ represents the number of functions. For the meaning of eigenvalues please refer to Section 3.8.3 Large eigenvalues lead to small values of Wilk’s lambda, and statistical significance is found when Wilk’s lambda is small. FIELD, A. 2013. *Discovering statistics using IBM SPSS statistics*, London: SAGE.
separation. They are the standardised versions of the values of $b$ in Equation 37 and vary between 1 and $-1$. Remembering that these functions are used to differentiate groups, as shown in Table 6.9, some dependent variables have high correlations while others have low ones. Theoretically the ones with high correlations contribute most to group separation in the function. ‘Living cost’, ‘property price’, ‘neighbourhood safety’ and ‘local employment opportunity’ load highly on the first function, which means they contribute most to group separation in Function 1 (as shown by the dark grey background colour). Therefore, as calculated in Equation 37, the group whose members indicated high values on these dependant variables in the questionnaire generally has a high score on Function 1. ‘Community harmony’, ‘daily commuting convenience’, ‘commercial and service facilities’, ‘community population change/floating population’, ‘land development, urban image and open spaces’ load highly on the second function, which means they contribute most to group separation in Function 2 (as shown by the light grey background colour). Similarly, the group whose members indicated high values on these dependant variables in the questionnaire has a high score on Function 2. These analysis results will be explained in more detail below in reference to Figure 6.4.

<table>
<thead>
<tr>
<th>Structure Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceived impact of transit effects on the local neighbourhoods</strong></td>
</tr>
<tr>
<td>Living cost</td>
</tr>
<tr>
<td>Property price</td>
</tr>
<tr>
<td>Neighborhood safety</td>
</tr>
<tr>
<td>Local employment opportunity</td>
</tr>
<tr>
<td>Community harmony</td>
</tr>
<tr>
<td>Daily commuting convenience</td>
</tr>
<tr>
<td>Commercial and service facilities</td>
</tr>
<tr>
<td>Community population change/ floating population</td>
</tr>
<tr>
<td>Land development, urban image and open space</td>
</tr>
<tr>
<td>Pedestrian environment</td>
</tr>
<tr>
<td>Noise</td>
</tr>
</tbody>
</table>

Table 6.9: Structure matrix: discriminant analysis of perceived transit effects on the local neighbourhoods
Figure 6.4 plots the scores of Function 1 and 2 for each person, grouped according to their income level, as defined in Table 6.1. The function scores are calculated as shown in Equation 37. The centroids of the four groups are shown by the black squares. The values of the centroids on the x and y-axis are the mean scores of function 1 and 2, respectively, for each group. Groups with centroids of opposite signs (positive or negative) on the x or y-axis are being discriminated by the function. For example, looking at the horizontal distance among the centroids, function 1 discriminates the lowest income group, group 1, from the highest income group, group 4. By looking at the vertical distances among the centroids, function 2 differentiates the mid-low income group, group 2, from group 4 and group 1. But this difference is not as dramatic as for function 1, because, as explained in Table 6.7, function 2 explains 25.1% of the total variance while function 1 explains 60.7%.

In conclusion, ‘living cost’, ‘property price’, ‘neighbourhood safety’ and ‘local employment opportunity’ contribute to the differentiation of groups 1 and 4. The centroid of group 1 has the highest value on the x-axis of function 1. As calculated in Equation 37 and also explained above, this means that the evaluation of the impact of these factors by the lowest income group is higher than by the highest income group. This suggests that the lowest income group is most sensitive to these changes in their living environment.

‘Community harmony’, ‘daily commuting convenience’, ‘commercial and service facilities’, ‘community population change/ floating population’, ‘land development, urban image and open spaces’ contribute to the differentiation of group 2 from groups 1 and 4. The centroid of group 2 has the highest value on the y-axis of function 2. This means the evaluation of the impact of these factors by the mid-low income group is higher than the other groups. Again, as in function 1, the highest income group assigns its lowest value to these factors. However, to explore in more detail the specific impact on different groups, and the extent of this impact, the necessary descriptive graphs are combined for analysis in the following section.
Figure 6.4: Canonical discriminant functions of perceived importance of transit effects on the local neighbourhoods

6.5.2 The perceived rail transit effects on individuals’ lives

As well as perceiving the impacts of rail transit developments on their neighbourhoods, individuals also perceive these impacts on their own lives. To study this further, a MANOVA analysis was used. The factors ‘impact of property price rising’, ‘importance of pedestrian environment improvement’ and ‘importance of weekend travel convenience improvement’ were removed due to multi-collinearity, and the remaining factors were used, as listed in Table 6.11.

Using Pillai’s Trace (Table 6.10), we see that there is a significant effect of income level on differentiating people’s perceptions of rail transit effect on their individual lives, $V = 0.258$, $F = 6.57$, $p = 0.000$. 
For the perceived effects of rail transit on individuals’ lives, discriminant analysis also reveals three discriminant functions. As shown in Table 6.11, the variables ‘impact of property price rising’, ‘impact of living cost rising’, ‘importance of employment opportunity increase’, ‘importance of commercial and service facilities improvement’, and ‘importance of neighbourhood safety improvement’ have a high correlation with the first function and thus contribute most to group separation in function 1. The variables ‘importance of land development, urban image and open space improvement’, ‘importance of daily commuting convenience improvement’, and ‘importance of community harmony improvement’ have a high correlation with the second function and contribute most to group separation in function 2.

**Table 6.11: Structure matrix: discriminant analysis of perceived impacts or importance of transit effects on individuals’ lives**

<table>
<thead>
<tr>
<th>Perceived impacts or importance of transit effects on their lives</th>
<th>Discriminant Functions</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of property price rising</td>
<td></td>
<td>0.780</td>
<td>0.322</td>
<td>-0.111</td>
</tr>
<tr>
<td>Impact of living cost rising</td>
<td></td>
<td>0.651</td>
<td>-0.362</td>
<td>0.178</td>
</tr>
<tr>
<td>Importance of local employment opportunities</td>
<td></td>
<td>-0.381</td>
<td>0.272</td>
<td>0.373</td>
</tr>
<tr>
<td>Importance of commercial and service facility improvement</td>
<td></td>
<td>0.329</td>
<td>-0.057</td>
<td>-0.267</td>
</tr>
<tr>
<td>Importance of neighborhood safety improvement</td>
<td></td>
<td>0.205</td>
<td>-0.111</td>
<td>-0.062</td>
</tr>
<tr>
<td>Importance of land development/urban image/open space improvement</td>
<td></td>
<td>0.009</td>
<td>0.560</td>
<td>0.125</td>
</tr>
<tr>
<td>Importance of daily commuting convenience improvement</td>
<td></td>
<td>0.223</td>
<td>0.392</td>
<td>-0.080</td>
</tr>
<tr>
<td>Importance of community harmony improvement</td>
<td></td>
<td>-0.013</td>
<td>0.210</td>
<td>-0.198</td>
</tr>
<tr>
<td>Impact of community population change/floating population increase</td>
<td></td>
<td>0.238</td>
<td>-0.063</td>
<td>0.715</td>
</tr>
<tr>
<td>Impact of noise</td>
<td></td>
<td>0.012</td>
<td>0.004</td>
<td>-0.173</td>
</tr>
</tbody>
</table>
Figure 6.5 shows that function 1 discriminates group 1 from group 4 (as indicated by the horizontal distance between the centroids of the two groups). The centroid of group 1 has the lowest value on the x-axis (function 1). This suggests that the evaluation by the lowest income group on the impact/importance of this set of dependent variables on their lives is the lowest (those variables being ‘impact of property price rising’, ‘impact of living cost rising’, ‘importance of employment opportunity increase’, ‘importance of commercial and service facilities improvement’, and ‘importance of neighbourhood safety improvement’). This suggests that the impact/importance of these variables on/for group 1 might be negative, particularly in contrast to the highest income group, for which the centroid has the highest score on the x-axis.

Meanwhile, function 2 differentiates group 2 and 3 from group 4, as the vertical distance shows. The centroids of groups 2 and 3 have the highest values on the y-axis (function 2). Thus the evaluation of the middle-income groups on the impact/importance of this set of dependent variables on their lives is higher than other groups (those variables being ‘importance of land development, urban image and open space improvement’, ‘importance of daily commuting convenience improvement’, and ‘importance of community harmony improvement’).
Comparing perceived effects on the neighbourhood and individuals

Next, it is important to compare side-by-side people’s perceptions of transit’s effects on their neighbourhood with their perceptions of effects on them as individuals.

Function 1 variables are plotted in Figure 6.6 against the different income groups. Regarding the perceived transit effects on the neighbourhood of rises in property price and living costs, the lower income group attribute a more positive impact value than the higher income group (left panel, Figure 6.6). In contrast, the evaluation of the impacts of these variables on themselves as individuals is much more negative in the lower income group than the higher income group (right panel, Figure 6.6).
This reversal of impact scores corresponds with what we might expect: that the lower income groups perceive that the transit investment has had a large impact on the rise of surrounding property prices and living costs, but that these effects have not been of benefit to them. Some of them don’t own a property (rural migrants) or desire to buy one better than the one they are living in. Rising property prices are therefore a bad thing for them. The assessment of neighbourhood safety improvement by the lower income groups is also much higher than the higher income groups, but the evaluation of its importance for themselves is much lower.

Regarding perceptions of local employment: in Table 6.11, one notes that the coefficient of ‘importance of local employment opportunities increase’ to individual lives in function 1 is negative (−0.381). This means that this dependent variable (local employment) differentiates groups in an opposite direction from the other dependent variables. As shown in Figure 6.6, the lower income groups give it a higher rating than higher income groups in terms of impact on the neighbourhood, and also a higher level rating of its importance on themselves. This reveals the importance of the local employment opportunities to the lowest income group.

---

34 It is also important to note that, in the questionnaire, the question about local employment was asked in a slightly different way: ‘how important is local employment to you’, as opposed to ‘what is the impact of [other aspect] on you’.
Similarly, function 2 variables are plotted in Figure 6.7 against the different income groups. Here, there is more consistency between the perceived 'neighbourhood' and 'individual' impacts. Generally, the middle-low income group expresses a higher level of perceived transit effects on the local neighbourhood (left panel, Figure 6.7). Although impacts on 'commuting', 'community harmony' and 'urban image and open space' are fairly similar across the income groups, the middle-low and middle-high income groups still attribute more positive impacts or greater importance on their lives than the other two groups (right panel, Figure 6.7).

More obvious differences are seen for the variables ‘population change’ and ‘commerce and services’, where there are large discrepancies, with perceived positive impacts for the neighbourhood and negative impacts for the individual. Many of these issues are quite culturally sensitive as the community population
changes and the ‘floating’ population increases. In responding to the migrants associated with transit-led development, the lower income groups exhibit more awareness of these factors. At the same time, the lowest income groups perceive that they receive the most adverse impacts.

In general, the findings of the research largely support the hypothesis made at the beginning of this thesis. It appears that it is the middle-income groups who look most favourably on rail transit developments. Their evaluations of the effects of the function 2 variables are more positive than the other groups, both for their local neighbourhoods and for their individual lives. In contrast, those in the lowest income groups look least favourably on these developments. Their evaluation of the effects of the function 1 variables on their individual lives is much more negative than the other groups (for example, rising rent, property prices and living costs).

Figure 6.7: Function 2 plotted against income group
6.6 Discussion

There are still some inevitable limitations with the methodological approach used in this study. These are acknowledged explicitly here, and possible improvements are also discussed.

Firstly, concerns about spatial variation in the social equity dimension of rail transit should have been assessed in the primary survey. In other words, the social impact of transit should have been assessed with comparison among different locations. Initially, the questionnaire was designed to include locational differences. However, the sample size was unfortunately not large enough to carry out the analysis in terms of spatial variations. There was an uneven distribution of samples across different areas and it was therefore not suitable to include locational differences in the model. Instead, therefore, social equity was explored in terms of variations between different income groups, using the whole sample. Although the spatial variation in the social equity of transit's indirect impacts could not be investigated here, it is an important avenue that should be explored in future research with more abundant data.

Secondly, in this study, social equity is measured by the perceived impacts of people, which is inevitably a subjective measure. However, it was considered the optimal way to assess transport equity given the limitations of the data that have already been discussed.

Thirdly, the unequal distribution of impact is assessed by only a single variable — the income level in the MANOVA and discriminant analysis. There may be more appropriate approaches for assessing benefit distribution and measuring inequity. For example, benefit distribution can be assessed by another index other than income level (such as age and rural migrants) or a combination of several socio-economic variables.
6.7 Conclusion

There is an important nuance to the aggregate increase in employment in Daping: most of the growth in jobs is taken by people residing outside the region and commuting to the region; hence the employment growth has not been taken up by the local residents. These findings support an emerging body of evidence that suggests that there are important spatial equity impacts of new infrastructure investment, and that the low income groups often bear the most adverse impacts (Agyeman et al., 2002, Mitchell, 2005, Jones and Lucas, 2012, Beyazit, 2015). For example, Jones (2015) found that the impacts of the Jubilee Line Extension (JLE) in London tended to favour the wealthier newcomers to the area, and not the lower-income established residents.

Whilst transit investment in Chongqing does seem to have resulted in significant social equity impacts, there are also subtle differences to the London experience. In Chongqing, it is the lower income groups that tend to use urban transit, and presumably benefit from increased levels of accessibility to employment and other activities. But the redistribution effect of the transit results in people moving into the areas where there are already low-income residents. The migrants are attracted by the opportunities found in these areas, such as lower property rent and public transport accessibility around the station. The Daping old city is an example of this type of low-income area.

The lowest income groups, though being frequent transit users, also suffer most from the adverse impacts associated with rail transit provision, such as rising property prices, rent and living costs. The community population change and increased floating population is also concerning for the established residents of the area. The benefit from travel convenience is therefore diluted by the adverse impacts that residents experience. As a result, the lowest income group gives the lowest evaluation of the impact of new rail transit on their lives.
In Chongqing, the established population — often from the lowest income group — have proximity to rail transit stations, but may lack the skills or knowledge required to make use of increased employment opportunities. The level of unemployment is therefore much higher than in other population groups. With land redevelopment around the station, increased jobs are mostly either low-income service jobs, in restaurants and shops, or higher income office jobs. Not capable of taking the new office jobs, the incumbents are also reluctant to take the service jobs, which are considered by them to be more suitable for rural migrants. Combined with their economic constraints, many established residents would rather take subsistence allowances from the government than seek a job far outside their living area. This may be a major reason why their commuting need is significantly reduced. In contrast, the middle-income group make full use of the transport provision to leverage their capabilities and take better jobs.

This is a similar finding to that found with the JLE in East London (Jones, 2015), where the skills mismatch of local residents meant that the greater access to new employment opportunities was not realised. It was expected that access to job opportunities from the area of high unemployment would also be improved. However, JLE did not seem to benefit local communities in this way. For “stayers” there was no evidence of a significant shift in the pattern of destinations visited, for work, shopping, leisure or social activities. The established population did not receive the benefit that was predicted by (incorrect) assumptions about benefit distribution. Intensive interviews of the local residents suggested that it was not only the lack of explicit benefit delivery to them, but also their inactivity and inability that prevent them from receiving their distribution of benefit from the transit system (Lane et al., 2004).

If actual and potential social-spatial mobility can be conceptualised as an ‘asset’ (Kaufmann et al., 2004), possessing insufficient amounts of this asset represents a
form of social inequality. In this case, it is not the lack of access to basic resources (transport, money and time) that make the situation worse, but the lack of access to activities, opportunities, and destinations for interaction or commuting that matters. Behind these factors, the essential problems may be a lack of the necessary skills and ability, and a lack of the social aspiration needed to appropriate the employment opportunities, both locally and in enhanced job search areas.

With the rapid urbanisation trend in China, many farmers have left their farmland and moved to the city, becoming migrant workers. This is a controversial part of the urbanisation process, and has led to multiple problems in Chinese society. As well as the ‘working poor’ group of rural migrants, an underprivileged population in Chinese society has been created by the laying-off of employees of state-owned enterprises. The social stratification between different social groups inside the cities has been accompanied by an overall increase in social inequality.
Chapter 7. Key actor interviews

7.1 Introduction

This chapter aims to offer further, comprehensive explanations for the results of the previous chapters, as well as to identify causes of the emerging problems and discuss possible solutions. In this chapter, the underlying obstacles that limit the developmental and regenerative potential of urban rail transit systems are studied in more detail. These obstacles are multi-dimensional, relating to both institutional and political factors that can inter-relatedly and synthetically be responsible for the emerging inequity problems across space and population groups. These factors may explain why some station catchment areas can better utilise the opportunities a new transit system brings, and enjoy faster development, while other areas seem not to benefit as much. They may explain what institutional problems have limited developmental benefit, and what discrepancies in power and interest may impede the value uplift from the transport investment in the long run. Finally, they may also explain the reasons for the disproportionate distribution of benefit across different population groups; what causes certain population groups to have their needs unidentified or ignored; and what prevents them from being properly compensated and protected.

In order to further understand what causes discrepancies in benefit distribution, both spatially across the city, and across population groups, intensive interviews were carried out (as described in Chapter 3). Interview questions dealt with how the different stakeholders perceived the impacts of the rail transit schemes, how the impacts influenced their decisions, and any other influential factors from their perspectives. Interviews also focused on revealing the cooperation, competition or even conflict among different stakeholders, relating to their differing interests and levels of power.
As a result of the interviews, the relationships among different bodies have been disentangled. The existing problems and their causes can be primarily be attributed to the divergent intentions and uncoordinated actions of different stakeholders, in relation to different interests and levels of power. Secondarily, a lack of a powerful coordination body, an absence of a comprehensive evaluation system, and a system of inflexible institutional regulations further exacerbate the situation. This chapter is structured to cover the following key aspects of this complex area.

Firstly, to address these problems, a supporting institutional framework should be defined as a prerequisite (Liu and Smith, 2006, World Bank., 2010). At the strategic level, it is suggested that the review and approval process is better to be inclusive: allowing the full participation of relevant agencies such as transport, energy, environment, and urban development (Gwilliam, 2002). As divergent motives always exist among different levels and sectors of government, and affect the efficiency of development, this chapter explores how to coordinate the diverse concerns of stakeholders and promote cooperation between them. It identifies the importance of sufficient institutional capacity and an effective intra-governmental linkage, such as a statutory planning framework with a specialised development agency (Bertolini et al., 2009).

Secondly, for many developing countries, there is neither adequate integration of urban transport strategy to embrace different modes of travel, nor adequate integration of urban transport and the rest of development strategy (Gwilliam, 2002, Gwilliam, 2003). Among these development strategies, an integrated land-use/transport strategy is essential, to clarify the long-term direction of urban land use and transport development. This chapter also explores the methods of institutionally sustainable finance of public transport operations, as subsidies have already proven unsustainable in some Chinese cities. By referring to other cities’ experiences, I explore which environments are most effective for planning and
delivery, in order to maximise the benefit of public transport investments.

Thirdly, the inclusive participation of relevant agencies is also vital to protect poor people from suffering from the adverse effects of transport infrastructure investment. The effects result primarily from demolition and relocation, but also from land value up-lift, causing property rents to rise. This chapter also explores how poverty-oriented urban transport interventions should be integrated in a broader strategy that incorporates housing, health, education, and other social services. For example, urban rail transit developments and public housing programs can be undertaken jointly (Gwilliam, 2002). Having identified reasons for these emerging problems, suggestions are made for possible policy improvements and planning interventions.

7.2 Research findings

From the intensive interviews, three main types of obstacle are identified. These obstacles synthetically contribute to the emerging inequity problems in both geographical and demographic dimensions.

The first obstacle is the poor integration of rail transit strategy and related land use strategy. Specifically, land ownership among different powerful governmental bodies can hinder integrated land use and transport development, as well as effective value recapturing. The second is the lack of a comprehensive system to assess benefits and burdens in a holistic way, limiting the ability to identify winners and losers in the benefit distribution process. The final major obstacle is the ineffective institutional coordination of power and responsibility among different stakeholders.

In fact, these three main obstacles are interlinked and can interact causally in a
chain, such that the previous one contributes to the later one. The reason for this is that land ownership is distributed to only a small number of powerful stakeholders in the city, and this impedes effective value recapture from rail transit development. A holistic evaluation system is thus difficult to establish, but is needed to identify the benefits and losses that are caused by certain stakeholders. Because of the unclear benefit distribution, an institutional coordination of responsibilities and actions of different stakeholders is difficult.

7.2.1 Disconnected planning strategies and diverse power and interests

7.2.1.1 The dilemma of integrating land use and transport: How development is harnessed in Chongqing

As was introduced in Chapter 5, there are some successful examples of integrated rail transit and land use planning in Chongqing. However, aside from some attractive case studies, it is widely observed that the integration of rail transit and land use planning is still lacking in most rail-impacted areas in Chongqing. This illustrates a great difference between the situation in Chongqing and in other big cities in China with rail transit systems (e.g. Shenzhen), where there is better integration of rail transit and land use planning. The reason for this disconnection between rail transit and land development in Chongqing is the unique land reserve system, which was initiated in 2002.

Since 2002, eight municipal governmental investment groups have been set up by the Chongqing government. The eight investment groups act as the proxies of the municipal government in financing and investing urban development projects.

---

35 Land reserve is analogous to land banking. In China, it means different levels of government acquire the land use right of an inventory of land by means of recovering, purchasing, requisition and so on. They reserve the land, before releasing it to development at a later date.
Among the eight groups, only the Chongqing City Construction Investment Group and the Chongqing Land Group were endowed with land reserve rights as quasi-governmental entities created by the municipal government. More specifically, the two groups have the right of land requisition, demolition and site preparation, and have a land reserve function. The groups can then use this land as collateral for the banks, in order to take loans. The loans borrowed from the banks are then used to build infrastructure, public housing, etc. When the value of the land appreciates, these groups sell the land and pay back the loans to the banks. Legitimately, they can either put the reserved land up for sale through a bid, auction and listing process to other developers, or participate in the procedure as developers themselves. This system is the most important part of the land banking system in Chongqing. Except for these two investment groups, another principle stakeholder of land banking is the local district government. To date, this system has worked quite efficiently in Chongqing. With such a system, land and infrastructure developments in the city have been carried out rapidly in recent years, providing a great number of infrastructure and social housing projects. Considering the benefits of providing infrastructure and public housing and adding revenue to the local finance, the land banking system in Chongqing is considered as an institutional innovation.

However, although it has demonstrated some positive achievements, the system has already also exhibited its negative influence on integrative land-use transport strategy. On the one hand, this system makes the land ownership in Chongqing quite diverse. Except for the municipal and local governments, the eight investment groups participate as another powerful body of land ownership. However, this also makes an integrated development around the transit station much more difficult. Furthermore, this land banking system has left a great number of pieces of land in the city undeveloped for a long time, and inflexible, because they’re already linked to specific projects. Sometimes old buildings on the land have already been demolished, but the land is kept vacant. Just within a short period, this land banking
system has largely resulted in very rigid land use in the city.

Land use development is conventionally regarded as the most significant indirect impact a transit system can have. However, as discussed in the previous chapters (except for a few key stations), there isn’t significant development around most stations in Chongqing. Most of the station catchment areas haven’t been developed to their full potential. On the surface, this is because of a lack of integration between transport and land use planning. However, at a deeper level, it is likely that it is the lack of coordination between different stakeholders, due to their diverse and varied interests, that results in the disintegrated development. This highlights the importance of the ‘planning’ factor in the transport investment and spatial impact equation. Without the effective planning of development around the station and, in this case, without an appropriate governance framework, there is likely to be little impact following the transport investment. The land in a transit station catchment area may be owned by three kinds of land-holders: i) the two municipal governmental land reserve groups; ii) the local district government; and iii) the Chongqing Rail Transit Group Co. Ltd., which only owns the land above the station, through a land assignment procedure by the government. In this diverse land ownership structure, the municipal land reserve groups play the dominant role in the development of the city. The Chongqing Rail Transit Group isn’t endowed with land development rights. This results in its inability to coordinate the land development around the station.

In China, the official ‘Urban Master Plan’ is revised once every ten years. It’s also modified constantly via a ‘Regulatory Plan’. However, Chinese cities have developed rapidly in the past decades, and the Rail Transit Network Plan should probably, therefore, be changed in line with the pace of development. Sometimes the route of a transit line is adjusted several times before it is eventually built, and when the construction begins it proceeds very rapidly — perhaps faster than in other countries. This results in a situation where the Rail Transit Network Plan is often
decided in the period between the finalisation of two Regulatory Plans. It is not unusual, therefore, for the Rail Transit Network Plan to be in contradiction with the existing Land Regulatory Plan, and there is thus an urgent need for the integration of the two plans. As Haizhou Liu, an expert in the Chongqing Transport Planning Institute, has said:

“This situation often happens when the land around the rail transit station has been assigned with other functions in the Land Regulatory Plan and [this has] impeded the development in respect of the influence of the station. Often an adjustment [on] the side of the Land Regulatory Plan is appropriate and necessary.”

Haizhou Liu, Chongqing Transport Planning Institute

In the Chinese urban planning system, the land above a station is assigned to the local Rail Transit Group (e.g. for Chongqing) and indexed as ‘public facilities’. If the land is to be developed for commercial use, the index should be changed to ‘commercial’. Then the land shall be put through the ‘bid, auction and listing’ procedure. However, in this bid, auction and listing procedure, the Rail Transit Group often isn’t able to offer as competitive a bid as those from other bodies. When the plan for the first stage of Line 2 was released in 1999, the eight investment groups hadn’t been established yet. The above-station sites were all directly assigned to the Rail Transit Group to develop, without the need to go through the procedure of bid, auction and listing. As a result, all of the above-station sites were developed into commercial and residential properties by the Rail Transit Group, either as the sole developer or in cooperation with other developers (as discussed in Chapter 5). However, by the time construction began on the other three lines, the eight investment groups were in existence. The assignment of land to the Rail Transit Group therefore became much more difficult.

There has been constant pressure from the Rail Transit Group and the Urban Planning Bureau for the index of the land around stations to be adjusted to enable
development. Among the 99 stations, along the four existing lines, there are 28 stations around which there is potential for development, and where an adjustment of the Land Regulatory Plan could be justified. The physical condition of these pieces of land means they have the potential to be developed for commercial, residential or other use. For the new lines that are currently being constructed, the situation may be even brighter. The Urban Planning Bureau has requested that the government assign the land use index to these areas as ‘comprehensive development land’. This would avoid the procedure of changing the index from ‘public facilities’ to ‘commercial use’. Alternatively, the municipal government may directly assign the land around the station to the Rail Transit Group. This would give the Rail Transit Group the privileged right to develop the area above and around the station, and could reduce institutional obstacles to land ownership.

However, despite the effort made by the Rail Transit Group and the Urban Planning Bureau, there are still huge obstacles from bodies on the other side of the land reservation process — including the municipal land reserve groups and the local government. One issue is that some of the land has already been made available as collateral to the banks for loans. These have been used to pay for construction, in the city, of infrastructure (for example, roads and bridges) that is regarded more important than the benefit from development around the stations. Another issue is that the municipal government isn’t always enthusiastic to facilitate land reservation for transit development. As was mentioned by an anonymous interviewee in the ‘Pre-stage’ department of the Rail Transit Group, there’s always a sceptical attitude from the municipal government towards the Transit Cooperation. The government apparently assume that, if given sufficient development rights, the Rail Transit Group will always aim to make their own profit. The government is therefore reluctant to allow the Rail Transit Group to own extra land outside the station site. A number of academics who were interviewed suggested that, if only the land within 200 m radius of the station could be developed by the Rail Transit Group, the situation would be much better.
7.2.1.2 Rail transit development in Chongqing: lessons learned from other cities’ experiences

As explained above, innovation in land use policy is critical to maximise the potential value uplift from rail transit investment in Chongqing, as well as to promote effective revenue capture, to support the rail transit development in the long run.

**Comparative experience in Shenzhen**

The Shenzhen government implemented innovative reform of the Land Management Policy in the third phase of rail transit network planning. This is part of an experimental program of reform, hoping to improve the unsustainable land leasing system in Chinese cities. The aim is to find sustainable solutions for long-term methods of land revenue capture, and to provide the government with a constant source of return from transit investment, from land value uplift and property development (Chongqing Rail Transit Group Co. Ltd., 2013c). Generally speaking, the aim is to establish a long-term tax system to substitute the unsustainable land banking system in China. In order to effectively implement the reform, the Shenzhen government directly led the role of preparing the regulatory plan and coordinating the related stakeholders. The target areas of the plan include those along the metro lines, especially the station catchment areas (Chongqing Rail Transit Group Co. Ltd., 2013c).

Before the reform of Land Management Policy was implemented in the city, the government already had a set of policies to promote the effective development of land. For example, in the second phase of rail transit network planning in Shenzhen, the government set conditions on the bid, auction and listing procedure to make sure that the Shenzhen Metro Corporation and its partners would acquire the lands. The government set the condition that “the revenue of the land development should be wholly or partly used for the metro construction”; and therefore only the Shenzhen Metro Corporation could meet this criterion (Chongqing Rail Transit Group Co. Ltd., 2013c).
Following the reform of Land Management Policy, in order to fully exploit the value generated by the new lines, and to ensure transit-oriented development (TOD), the Shenzhen government froze the lands within an 800 m radius of the stations, rigorously controlling their development, or transforming them before the rail transit network plan was finalised. The land reserve policies have made sure that the rail-impacted areas along the metro lines are directly reserved by the government. This is considered tremendously important, to guarantee that the land resources in the city are rationally, orderly and intensively utilised, and to ensure that the value created by transit investment is recaptured by the government.

Finally, the Shenzhen government injects capital into the Metro Corporation, as a share in the value of the corporation, held by the government. The corporation uses this capital to buy the reserved lands from the government for metro construction, paying the original price for the land, before the metro construction. This policy avoids the Metro Corporation going through the bid, auction and listing procedure, and allows it to gain the land at a low price. Meanwhile, the government doesn’t specify the exact start and end dates of the project. In this way, it endows the Metro Corporation a high level of flexibility to carry out transit-led land development. The Shenzhen government has made it clear that the cost of the construction of the metro system must be totally raised from property development along the lines. For this purpose, the Shenzhen government has established the Property Development Corporation (affiliated with the Metro Corporation) to work as a financial platform.

In summary, the success of land development associated with Shenzhen’s rail transit development relies on the coordination role of the municipal government, innovative land policies, special land reservation rights endowed to the Metro Corporation and an established financial platform.
Comparative experience in Shanghai

Unlike Shenzhen, there isn’t a complementary land reservation scheme along the rail transit lines in Shanghai. Neither is there institutional or financial assistance from the government for the Metro Corporation to directly get the rights to develop land. Nevertheless, it still has a set of favourable policies to ensure that the Metro Corporation gets land development rights via the bidding procedure. It also has a mature system of joint development to finance land development.

In the central city the local government is the principle investment body, and has a privileged position to develop land along the metro line, and take responsibility for land acquisition and preparation. In the suburbs, the situation is quite different. The Metro Corporation and local investors can cooperate to bid for the land and share the benefits from the land development. In the bid, auction and listing process, a favourable policy of ‘bid, auction and listing with project’ secures the development rights of the Metro Corporation in the land leasing procedure. This is achieved by the government setting the compulsory requirement that, in the bid, auction and listing procedure, the developer must have a complete and professional development plan. Besides, it is stipulated that the developers who participate in the bidding have the right to prepare a comprehensive regulatory plan, which is authorised to be implemented if they win the bid for the land. The Shanghai Metro Corporation has the ability to organise a team of design corporations to prepare a comprehensive land development plan. All these are policies to help ensure that the Metro Corporation succeeds in bidding for the land (Chongqing Rail Transit Group Co. Ltd., 2013b).

Unlike the Shenzhen Metro Corporation, the Shanghai Metro Corporation hasn’t established a financial platform. Instead, it gets financed by forming a joint development corporation with an external partner. At the first stage, after successfully bidding for the land, it enacts the detailed building design and development plan in the Shanghai Property Right Exchange Market by the way of
transfer of equity. In this way, the Metro Corporation get the first level of value uplift by enacting the property right exchange procedure. At the second stage, when the properties are being sold in the market, it gains a second level of benefit (Chongqing Rail Transit Group Co. Ltd., 2013b).

- **Lessons for Chongqing**

There are several key points to bring forward when comparing the situation in Chongqing with the experiences of other large cities. Firstly, unlike Shenzhen or Hong Kong, in Chongqing there isn’t a specific mechanism for reserving land along the transit lines, in order to benefit from the uplift in value associated with rail transit investment. Nor is there a specific mechanism to develop the land in correspondence with the rail transit development. As a consequence, opportunities to carry out integrated land-use transport strategies are lost, and there is a failure to effectively capture the uplifted value around the stations.

Secondly, there's no powerful governmental body coordinating transport and land planning and the actions of stakeholders. Nor is there any intention to have the Rail Transit Group lead the role of integrated development around the stations. Compared to Shenzhen and Shanghai, there is also little institutional or financial assistance from the government to support the Rail Transit Group in securing land development rights through the land leasing procedure. The Rail Transit Group only has the right to bring forward a proposal of land use plan adjustment.

Thirdly, there isn't an established financial mechanism for sustainable further investment. With huge subsidies from the government, it is becoming critical that rail transit investment can operate it in the long term by generating revenue from land development and reinvesting it into the rail network (Chongqing Rail Transit Group Co. Ltd., 2013c).

Generally speaking, an issue commonly brought up by interviewees was the
divergent operations of rail transit planning, land use planning, land leasing procedures, and tax and financial systems in Chongqing. The disconnected rail transit and land use development results from the complicated land ownership system, involving three kinds of stakeholders, and a lack of a powerful coordinating body (a role often played by the municipal government in other big cities). The poor coordination of development and institutional processes, such as land leasing, reflects inflexible institutional problems. A lack of a sustainable tax system for rail transit investment has fundamentally resulted from a lack of a comprehensive revenue and benefit evaluation system. This prevents the government from effectively recapturing the value generated from their investment. The reasons given above have collectively impeded the land development associated with rail transit investment in Chongqing, thus cutting off an importance source of finance for funding rail transit development in the long-run.

7.2.2 Gaining a clear impression of the transit system's effect: properly evaluating impact

The interview used in this chapter was designed, in particular, to assess the stakeholders’ perspectives on the development and regeneration effect of rail transit. Questions were asked regarding a series of sub-aspects. This section lists some important questions and interprets the answers from different interviewees (Appendix 4: Interviewee list). The questions below are sorted in convenience for writing; thus differently from the actual sequence of asking.

Question 1: What do you think the most significant impacts of the rail transit investment are?

Especially in the urban regeneration area, such as transport and travel behaviour, economy and employment, residential and commercial development; in the short-term and in the long-term.
a) Do the rail transit-impacted areas show a greater than average/accelerated economic growth? (in GDP, productivity, etc.)
b) Do they attract more investment?
c) Do they have more land development (for the construction application)?
d) Do they attract more firms to locate there?
e) Do they show a positive trend in population and employment?
f) Do they have an impact on people’s travel behaviour?

Different stakeholders gave answers which focussed on different factors, but most mentioned the above aspects at least once in their answer. The number of times a particular aspect was mentioned by different stakeholders was tallied, and a classification of the most mentioned aspects of rail transit impact was calculated according to the stakeholders’ professional background (Figure 7.1).

For each aspect in the figure, the bar shows the composition of perspectives from different types of stakeholder. The first is aspect is ‘travel convenience, which is mentioned most frequently by both local district governments and developers. Secondly, ‘economic growth’ and ‘land development’: the former being mentioned mostly by municipal government officials and developers, the latter being mentioned mostly by local academics. Thirdly, ‘population accumulation’, which is mentioned mostly by both municipal government officials and developers. Figure 7.1 also shows that municipal government officials emphasise the rail transit’s effect on ‘economic growth’, ‘population accumulation’ and ‘employment increase’. Developers think the impacts are primarily on ‘travel convenience’, ‘population accumulation’ and ‘economic growth’ (especially in commercial development). In contrast, the local government don’t mention many other impacts except improvement in travel convenience and the environment.

Figure 7.1 shows an obvious divergence of perspectives on the rail transit’s impact between the municipal and local district governments. All three aspects that the municipal government regards as important indirect effects of rail transit (economic growth, employment increase and population accumulation), the officials from the
local district government only mention a few times. What they appear to value most is travel convenience. The developers share some common concerns with the municipal government, in aspects such as economic growth and population accumulation, and also have similar concerns to the local district government about rail transit’s impact on travel convenience.

To explain the divergence, it is necessary to try and understand the intentions of different stakeholders. The confidence of the municipal government in rail transit’s effect on economic growth and employment increase may be explained by the government’s intention to boost development by providing favourable conditions for enterprises, such as transport provision (this is also required by some investors) and

Figure 7.1: Answers from different stakeholders to the question: what do you think the most significant impacts of the rail transit investment are? The y-axis shows the mean number of mentions (number of mentions divided by number of individuals in that professional group).
mass public transport, which can provide travel convenience to their employees. Except for economic growth, the municipal government also emphasise rail transit’s impact on population accumulation (including daily floating population to the area) and employment increase, which also contributes to economic development. Travel convenience for the middle and lower class population is also a concern of the municipal government. They emphasise the effect of rail transit on transport provision to meet travel demand in the city centre. As Mr Yuan, an officer in a local housing management bureau explained, for the past two decades, the old city centre has been facing the pressure of an increasingly flourishing northern city centre. Developers were reluctant to invest in the central (old) city because of the poor transport conditions, with mountain topography and narrow and congested roads. Convenient transport links to the central city are vital to avoid the deterioration of the old city centre and promote its development. Now several bridges have been built to link the peninsula to the north and south part of the city. As Biliang Yuan puts it,

“Convenient rail transit links have also been provided to support the travel demand to and from the old centre. The rail transit investment is proved to be an indispensable support to development, by way of improving travel convenience and creating a good local environment for investment.”

Biliang Yuan, local housing management bureau

However, the reason why local governments give less credit to the effects on economic growth, employment increase, land development or population accumulation, may be closely related to their experience gained from the specific local environment. As discussed in the previous sections, the obstacles to integrated land use and transport development have reinforced their belief that the effect of rail transit is quite limited. They hold the idea that the land development, economic growth and population accumulation result from the local economic environment and locational advantage in the area, and have little to do with rail
transit development. Nevertheless, the common concerns that these developers share with both the municipal and local government actually reflect their optimistic attitudes to the opportunities and profit that rail transit can bring about to the real estate market, which can influence their investment decisions.

In answering how the rail transit system can promote the development and regeneration of local areas, it is commonly acknowledged that rail transit systems help meet and facilitate the travel demand that the city has, rather than generating new passenger flows (Shengliang Chen, Municipal environment bureau; Maoyu Tian, local urban planning bureau; Jun Wang, property developer). As an officer in the local planning bureau said,

“The planning of rail transit lines needs to consider the conditions of the locations they stretch to; that is to say, what kinds of places they are linking. It can only be beneficial if the residential areas and employment locations are linked by the line. Falling to do so makes the expected development from transit investment not happen.”

Maoyu Tian, local urban planning bureau

He also presented the following example. In the areas along the south part of Line 2, there is still little development and a comparatively lower property price, because the industries are largely distributed to the north region by the government.

**Question 2: What are the most important factors in influencing investment decisions?**

For this question, the interviewees were asked to list the first three most important factors that could influence investment decisions. The most frequently mentioned answers are recorded as the five categories in Figure 7.2. For each kind of category, the importance it was given by the stakeholders is marked as No.1, No.2 and No.3. The developers and local governments actually play the key roles in investment decision-making, and it is primarily their perspectives that are discussed below.
Across all the developers’ perspectives (grey bars, Figure 7.2) they put the factors of ‘local market prospect and company accumulations’ and ‘supportive policies, favourable land price and tax regulation’ as their No.1 influential factor. ‘Locational conditions and local environment’ comes in as the second most important influential factor, in which the urban development plan is always important. However, in the developers’ mind, the factor of ‘infrastructure provision and public facilities’ can only be rated as No.3.

From the perspective of the officials in the local district government (blue bars in Figure 7.2) most of them think ‘supportive policies, favourable land price and tax regulation’ is the most important factor. ‘Infrastructure provision and public facilities’ is also listed as a No.1 factor, but less frequently mentioned. ‘Locational conditions and local environment’ is listed as No.2 factor. One of the heads of the local district government also said,
“The role of transport is only to provide the fundamental infrastructure and environment for development. The only significant impact of the rail transit system is the improvement on travel convenience, rather than on investment decisions.”

Bin Tang, local district government

Sometimes the facilitation of development is considered the most important objective of transport investment, with the largest impact. Certainly, from the urban planning perspective (Figure 7.3), this is the ‘direct’ impact, the main objective, to which transit investment is one contributory factor, alongside an appropriate planning framework and governance structure, to ensure that the appropriate development is facilitated. It is only when viewed from the transport planning perspective (Figure 7.4) that this is seen as a ‘secondary’ or ‘indirect’ impact.

Figure 7.3: the urban planner’s perspective on the impact of rail transit investment
Although not regarded as one of the first two important factors by developers, this is not to say that transport doesn’t have impact on investment decisions in land development. As expressed by a developer,

“At the local level rail transit can explain about 60% of the decision.”

Jinfang Yang, property developer

Biliang Yuan of a local housing management bureau said,

“The land transaction value will be thus higher because the developers think that public transport convenience will help with selling the property. Although, when the property is open to sell, it is always found that transit advantage often doesn’t add much to the price, because the property price is also affected by a lot of other factors, such as the economic environment. However, the impact is evident on the sales of second-hand dwellings. Evidence shows that the sales of second-hand dwellings around a transit station increased after the new line was opened, but not by a considerable amount. It increased around ¥200–300 per square metre, compared to the average price of ¥7000
per square metre in Chongqing. As to the regeneration effect of the transit system, there is some, but not much.”

Biliang Yuan, local housing management bureau

**Question 3:** In Table 7.1, Please give the score of the importance of the factors for development and regeneration in the rail transit impacted areas, on a scale of 0-10.

<table>
<thead>
<tr>
<th>The factors</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic environment</strong></td>
<td></td>
</tr>
<tr>
<td>• General regional economic dynamics (upswing regional growth)</td>
<td></td>
</tr>
<tr>
<td>• Firm agglomeration</td>
<td></td>
</tr>
<tr>
<td>• Labour sources: The relationship to population centres and employment sources</td>
<td></td>
</tr>
<tr>
<td><strong>Supportive policies</strong></td>
<td></td>
</tr>
<tr>
<td>• The source of finance and the level of governmental investment</td>
<td></td>
</tr>
<tr>
<td>• The supporting legal, organizational and institutional policies and processes</td>
<td></td>
</tr>
<tr>
<td>• Necessary complementary policy actions: Grants, subsidies, tax breaks, training programs, etc.</td>
<td></td>
</tr>
<tr>
<td>• Land use policies: Intensive zoning, mixed use, floor ratio bonus, parking</td>
<td></td>
</tr>
<tr>
<td><strong>Investment factors</strong></td>
<td></td>
</tr>
<tr>
<td>• Funds availability</td>
<td></td>
</tr>
<tr>
<td>• Scale/timing/location of planned investments</td>
<td></td>
</tr>
<tr>
<td><strong>Transport conditions</strong></td>
<td></td>
</tr>
<tr>
<td>• Accessibility via the roads</td>
<td></td>
</tr>
<tr>
<td>• Accessibility by public transport</td>
<td></td>
</tr>
<tr>
<td>• The former transportation investment and the new ones</td>
<td></td>
</tr>
<tr>
<td><strong>Other prerequisites</strong></td>
<td></td>
</tr>
<tr>
<td>• Available land resources</td>
<td></td>
</tr>
<tr>
<td>• Location attractiveness: Physical settings</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1: Table of the question: Please give a score of the importance of the factors for development and regeneration in the rail transit impacted areas

The results of this question are presented in Figure 7.5. The pink bar is the average score of the different stakeholders for each category of factors. Generally, there is great divergence between the perspectives of the local government (blue bar) and
the other stakeholders, and especially when compared to the city government (black bar) and the developers (grey bar), from whom the evaluation of the different factors have almost opposite trends.

In the views of the city government and the developers, ‘supportive policies’ is valued as the most important factor in influencing an area’s development, followed by the ‘economic environment’ and ‘investment factors’. In fact, in the views of the city government and developers, ‘transport conditions’ is valued the least important in influencing the area’s development. In contrast, the perspective of the local government is that ‘supportive policies’ is the factor valued least, while ‘transport conditions’ and ‘other prerequisites’ (such as available land resources and locational attractiveness) are valued much more highly.

Figure 7.5: Results of the question: The importance of the factors for development and regeneration in the rail transit impacted areas

To explain this difference, an official from a local Urban Planning Bureau said,

“The development of an area is influenced simultaneously by many factors. The most
important factors for development are supportive policies (including land price and tax) and market prospects. The infrastructure factor is a fundamental and essential condition, but just a supplementary factor.”

Maoyu Tian, local urban planning bureau

Another local academic expressed similar opinions on the necessity of supportive policies. He held the idea that, if significant development effect was expected in the rail transit impacted areas, other crucial factors, such as planning policies should also be in place (Zheng Yang, local academic). Mr Yuan held the idea that the impact of rail transit won’t be significant unless there are already development dynamics there.

“The land development and rising land value largely follow the locational advantage in the city, which depends on the driving effect of industrial development planning by the government. Consequently the residential development follows the distribution of the employment locations.”

Biliang Yuan, Local housing management bureau

7.2.3 A lack of an assessment system of benefit distribution

7.2.3.1 Identifying the power and interest of different stakeholders

In the second round of interviews, seven interviewees (the composition of the interviewees is in Table 3.7) were asked to score the ‘power’ (decision making power) and ‘interest’ (interest in the rail transit investment) of the different stakeholders in the process of urban rail transit development, on a scale of 0–10.

Six different kinds of bodies were identified as having the closest relationship with rail transit development. They include potential beneficiaries of the public facility investment, such as the local residents and developers. They also include different
levels of government, such as the municipal and local level government, and different levels of government agencies, such as the Chongqing Rail Transit Group, the Urban Planning Bureau, the Environment Bureau, the Construction Commission and the Development and Reform Commission. The results are presented below in Figure 7.6.

From the perspective of the interviewees, the level of interest in the rail transit system is concentrated within the range 7–10, which indicates a generally high level of interest among the stakeholders. In contrast, the assessment of power was distributed across the whole range 0–10. According to these results, the municipal government has the highest power and a relatively high interest in implementing transit development. The relevant municipal government bureaus and commissions also enjoy a very high level of power. However, they have a much lower level of interest, perhaps because rail transit doesn’t relate much to their benefit from the investment. Specifically, the Development and Reform Commission has the critical power of authorisation over rail transit projects. Other bureaus, such as the Environment Bureau and the Urban Planning Bureau, also have power over important planning and assessment procedures. As a municipal government agency, the Rail Transit Group has a level of power in the middle, as do the local government. The local government has a level of interest comparable with the municipal government. They also believe that rail transit investment will bring profit to their jurisdictions.

In contrast, the residents and developers both have high level of interest. The residents are interested in the rail transit investment because most of them believe it will bring them travel convenience. The developers also welcome it because they believe it will increase the value of their property investments, as discussed in the previous section. However, they almost do not have any decision-making power at all, with a value close to zero, indicating that they effectively do not participate in the decision-making process.
However, the level of power owned by different stakeholders is not equal to the level of their rights and responsibilities. The following part of this section will explore the benefit distribution of the investment and the results of deficiencies in the assessment system.

### 7.2.3.2 Assessing the ‘winners’ and ‘losers’ and protecting the vulnerable

**Question 4: How should we balance the profits of regeneration and development between the ‘winners’ and ‘losers’, especially the concerns of the vulnerable local people? How do we ensure that development is consistent within social goals at each level, including environmental goals and social inclusion?**
Before asking the question to the different stakeholders, intensive interviews of the local residents were carried out, involving forty persons (in twenty-two interviews). Some of these interviews were carried out in the form of group discussion. Some very detrimental impacts on the local residents were revealed in course of these interviews. For example, a residential building near the station was damaged during the process of rail transit construction (see Section 5.3.1.2). Compensation should have been paid, and relocation carried out, by the local government. However, because both sides of the residents and the local government couldn’t reach an agreement, the affected residents were still living in that building at the time of interview, with nowhere to go. Meanwhile, in process of urbanisation, a large number of rural migrant workers have come to live in the central city, and they generally reside in the old buildings in Daping for the convenience the rail transit has brought. Crime has begun to rise, and this makes the established population worry a lot about their deteriorating living environment. They think the population change in their community has harmed community harmony. Segregation between the newcomers and the established residents has become more and more obvious.

As mentioned in the interview of a relevant official in the Rail Transit Group, except for the environment and landscape impact assessment, there is no other impact assessment in the Rail Transit Feasibility Report (Chongqing Rail Transit Group Co. Ltd., 2013a). Assessment on social impact in the report is quite limited. The environment and landscape impact assessments have only been required in recent years. These are now compulsory assessments for the authorisation of projects, in response to the ever-increasing environmental threats to the country. However, it is regulated that the environmental assessment only takes into consideration “the majorities’ opinions”. In reality, who “the majorities” are, is in question, and this is commonly decided by the project promoter — in this case the city government.

The publicity of planning is quite insufficient in Chongqing, as admitted by Mr Liu in the Chongqing Transport Planning Institute (which is affiliated to the Municipal
Urban Planning Bureau). There is very low public awareness or public involvement in the urban planning process. The affected minorities often don’t even know how to stand up for their rights, and there is no effective process to help them. This means that the affected are definitely at a disadvantage when trying to have their voice heard, let alone have their needs met. In summary, there is a lack of a systematic social impact assessment associated with rail transit investment.

There is also almost no assessment of the impacts on the residents who live near the transit stations. If the residents have already suffered losses for any civil project, the only policy regulation to protect them is the Compensation for Demolition Regulation. If the demolition and resettlement for transit construction is inevitable, the compensation fee is evaluated according to the price of second-hand property of similar quality in that area. However, as revealed in the interviews, the compensation isn’t always calculated in a reasonable way, and the rules can't be adjusted properly to specific situations. Specifically, the compensation mechanism doesn’t take into consideration the land price appreciation associated with the rail transit station. Besides, the compensation only covers the property owners. As was discovered in the resident interviews, some people who have for many years been living in an area, by renting a property, are affected by the rising rent and living costs associated with the transit development process. There are no measures to protect them from being affected by the gentrification process. However, as was commonly mentioned by the government interviewees, the residents nearby have already benefited from travel convenience, and the property owners are supposed to benefit from land price appreciation from the rail transit system. They admit there is no guarantee that the policy profits benefit everyone and the government can only measure the overall gain from the investment.

7.2.3.3 Coordinating different stakeholders’ power and responsibilities

*Question 5:* Who are the main beneficiaries from the development value uplift? Is
there any mechanism for the city to keep the value uplift?

**Question 6**: How can the intentions of different stakeholders be coordinated? What kind of model do you think can be exploited to improve the cooperation among different stakeholders?

On first impressions, these are questions dealing with two different dimensions. The first is aiming to explore the beneficiaries from the investment in a public facility; the second is to explore the interviewees’ opinions on how to promote cooperation in the process. However, it became apparent from the interviews and analysis that the latter question has a close relationship to the former. Therefore the two questions are presented together to interpret the results from the interviews.

By referring to the governmental documents and interviews, it was found that, although the cost of a transit line was calculated in the Feasibility Study Report for each rail transit line, there is no completed systematic cost and benefit analysis. Only ticket revenue is estimated, based on forecasts of passenger flow, and only a short paragraph interprets it in the Report. There is no holistic assessment of direct and indirect benefits. Indeed it is likely to be difficult to estimate all likely benefits, and this part of the equation thus remains incomplete. Furthermore, in comparison to the huge investment, ticket revenue is estimated to be a very small amount. There is no plan in the report as to how the investment can be paid back. As a result, the operation of the system has been reliant on large subsidies, borne by the government. The lack of assessment system for the benefits of this kind of public transport project likely results from a common recognition that the transit system (as a social public welfare project) should be provided and financed by the government. As an anonymous official from the Rail Transit Group said: in her view there is only investment input but no revenue gained (anonymous, Pre-stage Analysis Department, Chongqing Rail Transit Group Co.,Ltd).
This kind of heavily-subsidised public transport system has, in many ways, proved to be harmful to the city and has added tremendous financial burden to the government. Megacities in China, such as Beijing, Shanghai and Guangzhou have been long overdue for underground construction and operation, at a considerably high cost. It is even argued that the recent ‘Metro boom’ in Chinese cities has resulted from the convention that city officials in China tend to pursue grand projects, even if the projects do not make money, because the performance of local officials is evaluated on how much they increase local GDP rather than the necessity of the projects. For example, operating the metro lines of Beijing cost about $1.6 billion over the two years from 2011 to 2013, but for seven years (2008–2015) passengers only paid 30 cents per ride (The Economist., 2013). With this unaffordable financial burden, the government eventually had to end the tremendous subsidy in 2015, and elevated the ticket price.

It is possible that officials who work in an excessively subsidised system don’t have the correct incentives to assess the cost-benefit ratio of a project. It is also likely that the CBA method itself does not give a full enough estimation of losses and benefits, as many of these cannot be monetised (van Wee, 2012, Hickman and Dean, 2016). A lack of focus on financial efficiency may reduce the quality of assessment of potential ‘winners’ and ‘losers’ from a project, and of how the benefits of rail transit development are truly distributed in the city. What’s worse, no comprehensive mechanism has been established for the government to efficiently recapture the revenue generated by the rail transit investment. The value of the land, along the rail transit corridor and around the stations, gets uplifted by the effect of the rail transit system. However, there is currently no tax regulation dealing with the selling of the properties which gain value-uplift from rail transit development. Without clear identification of the beneficiaries, the benefit generated from public facility investment often ‘runs off’ to external stakeholders rather than to the government. This prevents the government from recapturing revenue for further investments.
When asked to define the winners and losers in the process, the interviewed stakeholders expressed quite different opinions and no definite answer. There are different levels of government, different sectors and different external stakeholders involved. At most times in the interviews (perhaps defending their own position), the interviewees accused others of benefiting from the gains generated by the rail transit investment, but failing to carry out their responsibilities. For example, an anonymous respondent in the Pre-stage Analysis Department of the Rail Transit Group regarded the ‘winner’ as the local district government, saying that they enjoyed net land value uplift in the areas around the station with little cost. However, they failed to carry out their responsibilities of demolition, relocation and compensation. The demolition fee was conventionally paid by the Rail Transit Group, trusting that the work would be carried out by the local government. Now because of the local government’s inaction, the Rail Transit Group has to pay for the demolition. Nevertheless, this accusation definitely contradicts what was said by the local district government. As argued by Mr Yuan in the local Housing Management Bureau in the central city, the demolition fee in some areas is extremely high, especially in the old city. Without a proper legal system to guarantee the revenue, it is impossible for the local district government to afford. This kind of dispute exemplifies the importance of establishing a comprehensive benefit assessment system.

Without an appropriate assessment system of benefit distribution, the rights and responsibilities of different levels of government and stakeholders are often unclear and overlapped. If stakeholders don’t receive revenue, some of them are not motivated to deliver their responsibilities. For example, without foreseeing the potential revenue gain from the transit investment, the local governments don’t carry out their responsibility of preparing land for rail transit construction, even if it is required. If the land hasn’t been leased to the developers, the local governments benefit from the land value uplift associated with the new rail transit stations and can
gain revenue through land leasing. However, if there’s no assessment system to identify the benefit they have got, they may not perceive this gain. Alternatively, if the land is already leased to the developers, the local district government may feel aggrieved if there’s no tax system to guarantee that they get revenue, or the benefit is recaptured by the municipal government. Both of these two situations can directly result in the failure of bodies to deliver their duties, and the inaction in turn affects two key areas. Firstly, it affects the necessary preparation work of demolition and land-clearance for rail transit and infrastructure construction. Secondly, it affects the protection of the safety of the existing buildings affected by route of the transit line, and the payment of compensation for destruction. The inactions of the local district government add a great burden to the Rail Transit Group, and require them to allocate additional budget to these areas. What’s worse, there can be inaction in terms of the urgent relocation of affected residents, and the payment of compensation for demolition and loss. This dereliction of duty has already caused severe social problems, as mentioned above in the interviews of local residents.

In this way, extreme difficulties can result for coordinating different stakeholders in a cooperative way.

“The lack of a benefit assessment system causes constant disputes and conflicts amongst different stakeholders, and a reluctance to participate in cooperation”

Hongfei Tang, Development Department of the Chongqing Rail Transit Group

As an illustrative example of these issues: the local district government requested to share the revenue from above-transit station development with the Rail Transit Group, if they agreed to participate in carrying out the demolition and resettlement for the transit station construction. This requirement would notably reduce the gains of the Rail Transit Group. The Rail Transit Group argued that the local district government had already benefitted from the value uplift of the lands around the station, and therefore, there was no reason for them to request more revenue.
sharing. These disputes greatly disrupted the efficiency of cooperation in the process of transit construction and relevant urban image repair, and the demolition and relocation work. In order to avoid disputes, the sites above some stations were not even developed. As a consequence, the value brought about by the rail transit investment hasn’t been completely realised.

As to the obstacles of coordination among different stakeholders, from Tang’s perspective the essential conflict between different stakeholders originates from the segregation of the Rail Transit plan and the Land Regulatory plan, and disagreements over land use situation in local areas. In other words, cooperation is not efficient because of the unequal rights and responsibilities of stakeholders in specific situations. The Rail Transit plan and Land Regulatory plan are formulated by the municipal government, over which the local district government has no decision-making power of adjustment. When carrying out their responsibilities, the local district government has met considerable obstacles. In one case, in the central city the situation of the station-impacted areas is very complicated and this has added considerable difficulty to the work of the local district government. There is a high density of established residents from lower social strata, who have been living in their dilapidated dwellings for decades. There are also a lot of public or private corporations affiliated with different sectors, and a large number of entrepreneurs in businesses of a variety of scales. If properties near the stations, belonging to the above groups, are to be demolished and the land cleared, the local district government lacks the power and influence to coordinate all the various groups affected. It is also too expensive to afford the financial cost of this complex work. In another case, for the station areas in the suburbs, there is less diverse property ownership. However, most of the lands have been leased to the land reserve groups of the municipal governmental. Thus development can be carried out solely by them and the local district government has no rights to take part in the development. The unequal rights and responsibilities result in the difficulties in cooperation among different stakeholders.
7.3 Conclusions

In conclusion, several key problems have been identified by qualitative interview methods, and these can be used to help explain the results of the analysis presented in the previous chapters. **Firstly, the divergent interests and motives that exist among different stakeholders, throughout the transit investment and development process, result in a lack of “joined up” thinking around land use and transit development.** As is argued in previous literature, these divergences between different levels of government and different sectors (such as transport and land use) are very common. It's important to coordinate the diverse concerns of stakeholders, and promote cooperation between them in the decision-making process (Curtis et al., 2009). In the case of Chongqing, the different levels of government include the municipal government, municipal land reserve groups and local district governments.

**Secondly, a key underlying problem seems to be the land banking system in Chongqing.** Although this system has been regarded as a creative initiative for bringing about many forms of development to the city (e.g. construction of many civic projects and low-rent public housing schemes) it has also had adverse impacts. It has led to land ownership becoming distributed from the municipal government to several powerful bodies, which has caused inflexibility of land use. Though it's necessary to integrate the land development with the rail transit plan, the government is now actually unable to do so, even if they wanted to. As discussed previously, these land reserve bodies are reluctant to give up their land ownership for transit-led land development (Chongqing Rail Transit Group Co. Ltd., 2014). Thus it is difficult to have an integrated land-use transport development plan.

Other cities in China, such as Guangzhou, Shenzhen, Nanjing and Changsha — mainly learning from Hong Kong’s experience — have developed a system to secure the value generated from rail transit investment. The most significant
advantage is gained from land reserve rights, which the municipal government endows to the Metro Corporation. Specifically, an integrated land use regulatory plan and transit development plan is prepared by the Metro Construction and Operation Corporation. Then the lands within a certain area along the transit lines are reserved in a special scheme by the municipal government. Land acquisition, building demolition and land preparation is carried out in parallel with the preparation of the feasibility report of transit development.

Thirdly, Chongqing lacks a specialised development agency powerful enough to coordinate the development. It is necessary to establish a framework for cross-sector and cross-agency collaboration. For example, a specialised development agency (such as a redevelopment authority) has been necessary in cases of successful transit-oriented development (TOD) (Bertolini et al., 2009). In the case of Chongqing, an absence of a powerful development agency has resulted in an incapability to coordinate the diverse and powerful land reserve bodies (Chongqing Rail Transit Group Co. Ltd., 2014). A Transit Office has been set up in each local government, but it doesn’t have institutional power, except for day-to-day assistance work. The two municipal land reserve groups and local governments (which have the land reserve right) actually act with divergent powers and interests. The situations in other cities such as Shenzhen, Xiamen, Changsha and Guiyang are much better. In Shenzhen, the role of the powerful coordination body is played by the Municipal Executive office of the municipal government and is directly led by the Vice Mayor. Furthermore, the Shenzhen Transit Corporation was endowed with the land reserve rights to secure the coordination process.

Fourthly, some institutional regulations are too inflexible, and they impede the value created by the rail transit investment. For example regulations state that land must be leased openly through a bid, auction and listing procedure to avoid corruption. In the case of land above a station, this can be legitimately assigned to the Metro Corporation for the purpose of rail transit construction, and given the land
use index of ‘public facilities land’. However, if it is to be developed for commercial use, the land use index must be changed to ‘commercial use land’, and the land can only be leased to development by the bid, auction and listing procedure. However, in this procedure, facing competition with other developers, the Rail Transit Group is at a disadvantage in successfully bid the land because the price it can provide for bidding is limited.

In contrast, in Hong Kong, the government assigns the land to the Transit Development Corporation by way of agreement. In Shenzhen, the government injects capital into the Metro Corporation and lets it purchase the land from the government at the price before the transit construction was announced. In this way, the government, as a shareholder of the Transit Development Corporation, can enjoy the long-term benefit of the revenue and tax gained. In Shanghai, there is a favourable policy for the Metro Corporation in the bid, auction and listing procedure to successfully secure the land. There are suggestions, reflected in the interviews in this study, that Chongqing should learn from Shanghai or Shenzhen’s experience.

A fifth important issue is that there’s no effective system to assess the benefit distribution associated with the rail transit investment. As a consequence, two main aspects of assessment are not performed satisfactorily. Firstly, there is insufficient assessment of the substantial benefits the rail transit can bring. Assessment should include identifications of the direct and indirect benefits that rail transit investment can bring about. Rail transit not only brings about travel convenience, but also economic, urban, environment and social changes. Secondly, an assessment system is lacking for identifying to what extent the different stakeholders gain benefit. This is required in order to coordinate their actions and responsibilities within a supervision system, and to assess the winners and losers of the investment in relation to the social equity dimensions discussed in this thesis.

A lack of this assessment system results in no effective mechanism for the municipal
government to recapture revenue from a huge public facility investment. Currently, the revenue runs off to uncertain groups of stakeholders: possibly the municipal land reserve bodies, local district government or diverse private developers. Thus the government ineffectively recapture the revenue to feed the transit system and facilitate further construction in the long-run. This results in ineffective use of public funding in the city. Meanwhile, without a clear understanding of the revenue potential, the motivation to carry out appropriate demolition and relocation work by the local district government is quite low, especially when the cost is considerable, e.g. in the central city region. What's more, the impacts on the vulnerable population groups are not clearly identified. Some impacts of the processes of land acquisition, building demolition and residential relocation are detrimental. This causes social inequity problems, as revealed by the resident interviews.

**Lastly, it is also critical to emphasise the importance of institutionally-sustainable finance for public transport operations.** As is put forward by the World Bank, although in China tariffs appear affordable and subsidised through blanket subsidies, there are questions over whether these subsidies by the city are sustainable over the long-term (although these concerns are rarely brought forward to caution the national government) (Liu and Smith, 2006; World Bank, 2010). Unsustainable, overdue subsidies have already emerged in some cities, such as Beijing, where the government have had to abandon the huge subsidies on ticket prices, and have raised the metro and bus prices considerably.

**Based on these results, there are a number of suggestions that can be made for improving the situation in the future.** Firstly, given the issues of land reserve rights that affect several municipal groups and the local governments, a powerful specialized development agency should be established to make sure an integrated land-use and transport strategy can be implemented efficiently. It can play a crucial role in coordinating land development around stations and along the lines, as per the experiences of Shenzhen, Foshan and Hong Kong. Some
innovation of the institutional regulations is also necessary.

An urgent requirement is to establish a comprehensive benefit assessment system, to assess the benefits or losses of different stakeholders, as well as the different population groups. Only if this comprehensive assessment system is established can the benefit acquired by each body be made clear. Different stakeholders would be required to deliver their responsibilities under the supervision of this system, and revenue recapture by the municipal government could be realised by way of revenue share and tax takings. In this way, a coordination of different stakeholders could be made possible.

The requirement of establishing a financing platform for transit-led land development is crucial. The amount of profit from ridership revenue is not sufficient to support this system. Revenue from secondary benefit must be captured in an effective way, especially through integrated land development. The establishment of a comprehensive tax system should also be considered. Around the station, there can be higher tax for development on the new land, and a tax on sales of second-hand properties in the old city area. The aim of these initiatives is to find a long-term strategy to support the rail transit system, in an effort to have its benefit distributed evenly, especially spatially and demographically, to the various disadvantaged areas and groups.
Chapter 8. Conclusions

8.1 Current Debate

Appraisal frameworks for assessing the impacts of specific funding proposals and addressing the three sustainability dimensions of impact — economic, ecological and social — were first developed by institutions such as the World Bank in the 1990s. Since then, these three dimensions have been increasingly addressed in transport policy appraisal systems in countries such as the U.K. and the Netherlands (Geurs et al., 2009). The impact of transport investment and policies is commonly said to have four widely-recognised aspects, namely, the direct effect of travel convenience, and the three aspects of indirect effect: economic, urban, and social (Banister and Berechman, 2003, Banister and Thurstain-Goodwin, 2011). In practice, plenty of evidence has indicated that all four aspects are internally connected, and that the first three aspects all have social effects. Furthermore, transport has an effect on reshaping the spatial form of the city, and often this is the most important impact of transit investment in a large city. Evidence suggests that within the typical context of transportation and urban development, new transport not only tends to reinforce the established axes, but can also powerfully transform the relative positions of different centres along them (Hall, 1995b).

Besides these four dimensions of investment impact (transport, economic, environmental and social), another dimension, the ‘distributional effect’, is argued to be an independent dimension worthy of discussion, rather than an issue affecting each of the three dimensions separately. For instance, certain disadvantaged groups can be negatively distributionally affected by all of the other effects simultaneously (Jones and Lucas, 2012). The distributional effect directly points to the equity issues of a project, and makes it clear that there are trade-offs between equity and any other dimension. In the attempts to operationalise sustainable
development and sustainable transport programs, these trade-offs should be balanced (Feitelson, 2002). There is a need to integrate a social justice perspective into the discussion of sustainable urban mobility (Banister, 2008, Gossling, 2016). Issues of social equity should be raised, which means honestly addressing the implications of the cumulative distributional effects resulting from public programmes of investment.

In this context, two major gaps in the previous literature are identified. Firstly, the assessment of transport investment has traditionally focussed on particular aspects of transport provision as primary evaluation methods (such as journey time reduction) over other less tangible or less well-understood aspects (Lucas et al., 2016). This leads to a very ‘transport-centric’ perspective — as if this intervention then leads to a series of impacts, some clearer and more direct than others. These traditional methods of evaluation have not been very successful in accounting for the non-transport benefits of transport investment, which are becoming increasingly important — especially in large cities experiencing rapid development and regeneration. Furthermore, in developed countries in particular, even the transport benefits of new rail investments (as measured in terms of journey time savings) are limited. This is often because the network is already dense and there are unlikely to be major improvements in accessibility or speed as a result of adding a new or upgraded link (Banister and Berechman, 2003). It has therefore been argued that it is not appropriate to justify new rail investments solely according to financial analysis, or by using the traditional evaluation methods of transport benefit. Wider social, environmental and economic factors should also be included (Banister and Thurstain-Goodwin, 2011). Perhaps the appraisal should be carried out from the urban planning perspective, assessing the quality of the development being provided, and, as part of this, the transport investment needed to support this.

Secondly, the traditional transport appraisal methods do not sufficiently capture social dimensions of rail transit’s impact. They generally ignore the distributional
effects of a transport decision/investment — meaning how the decision/investment affects different regions and social groups, differently. Social justice in transport is closely related to core concepts that underlie social justice more generally: fairness in the physical distribution of goods; accessibility for people; affordability of all types of services; and redistribution in the interest of equality of opportunities (Lucas, 2006, Lucas, 2012, Beyazit, 2011, Martens, 2012, Martens et al., 2012, Gossling, 2016). The unequal resource distribution of benefits and burdens of transport among areas and population groups has potentially caused problems of social injustice. Meanwhile, academic discourse has increasingly moved from studying unequal resource distribution, to trying to understand inequalities related to gender, ethnicity, sexuality, and age (Fainstein, 2010, Gossling, 2016).

From the methodological perspective, the traditional ethical framing of transport policy evaluations is broadly based upon the principles of utilitarianism — where the aim is to maximise the sum of benefits of an investment for all members of society — rather than a specific desire to achieve greater societal equity from that investment. It is argued that there should be alternative approaches identified, as a separate and necessary step, to redistribute transport resources towards currently disadvantaged population groups and deprived areas; specific addressing the promotion of equality of opportunity and social inclusion. Understanding this is highly relevant for policy makers to understand the impacts of their transport investment decisions (Lucas et al., 2016).

Having identified these two gaps in the literature, one can adjudge that the least-researched area is the unequal distribution of indirect benefits of transport. This factor, in particular, potentially leads to problems of social injustice. Injustices in urban transport are conventionally thought of in terms of: exposure to traffic risks and pollutants; distribution of space (use of areas, accessibility and infrastructure allocation); and valuation of transport time (Gossling, 2016). However, the unequal distribution of the benefits and burdens of transport's indirect effects are less
frequently mentioned; for example, the differential effect on various individuals, groups and societies of increases in land and property prices.

8.2 Differences in context between the Western experience and China

Before drawing conclusions for the thesis, it is necessary to discuss the important contextual differences between Western countries and China. Any reference to the experience in another context should be cautious, since the solution to any emerging problem is sensitive to the specific context.

The role of the state and the market in economic development in China differs from the Western democratic states, in which the political system promotes the freedom and equal rights of its members in the market. In contrast, as a socialist state, the Chinese economic system has, for decades, put emphasis on collective ownership of resources, and reliance on the state to manage and control these resources. From the early 1950s to late 1970s, the role of the market in development was extremely controlled and limited by the state.

However, the level of development in China since the ‘reform and opening up policy’ of 1978 shows how it has experienced a transition from a Soviet-style centrally-planned economy towards a hybrid economy, which is based on a state-owned sector and an open-market economy — often described as a “socialist market economy with Chinese characteristics”. The share of Chinese gross industrial output coming from state owned enterprises is only about 25% in recent years, dropping greatly, from more than 75% in 1978. The constant drop in this share highlights the fact that China is in its transition from a centrally-planned...

---

36 https://www.bloomberg.com/view/articles/2014-10-14/private-companies-are-driving-china-s-growth
economy to a market economy (Wei, 1999, Zhang, 2002). Since early 1990s, the entrepreneurial-like behaviour of municipal governments has also shown that the state is playing positive roles in supporting the market to achieve improvements in efficiency (Wu et al., 2015).

China had a GDP growth rate of more than 7% from 2011 to 2014, which declined to just below 7% in the last two years (6.9% in 2015 and 6.7% for the first three quarters of 2016). This is very high compared to some developed countries, such as the US, where the growth rate is 2.6%, and the UK, where it is 2.2% (2015 data). Although the GDP growth rate has slowed in recent years in China, the absolute value of GDP is still large.

China is also still in its rapid growth period. The urbanisation rate in China was 56% by 2015; compared with more than 80% in developed countries (e.g. US and UK). There is therefore still much space for urban population growth in Chinese cities. Meanwhile, the central government is still aiming to boost the urbanization rate to 60% by 2020. However, the surplus of young, under-employed workers from the countryside (seen since the 1970s) is no longer as available. The working-age population has been in decline since 2011, with a continuous drop in birth rate. The demography in China has therefore shown an aging trend, as many developed countries have also been experiencing.

Private ownership of land is quite common in the Western World. For example, land in the United States can be owned by the government (federal, state or local), or by private citizens. The federal government owns about one-third of total U.S. territory, but much of the remaining land is privately-owned. However, only the state can own

38 http://fortune.com/2016/10/19/china-gdp-growth/
40 http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS
land in China, except for certain land in rural areas that is owned by ‘collectives’ of peasants. The growth of cities in China relies heavily on the mechanisms of the state land monopoly. The monopolistic land ownership of the state endows government the legitimacy to aggressively acquire land owned collectively by peasants in rural areas. They can expropriate rural land easily and at a little cost (Wu, 2015). What’s more, it gives municipal authorities the ability to use land as collateral to raise capital through the private market (Wu et al., 2015). As a result, the amount of land classified as urban has more than doubled since 2000, and 40% of new urbanites are peasants who were absorbed when cities engulfed their villages (The Economist., 2015a). It is the state dominance in land supply that lays down the foundation of this mode of development, named “land-based finance”. The monopolistic land ownership of the state provides a necessary condition and the tax-sharing system provides the financial incentives for governments to promote land development in Chinese cities (Wu et al., 2015).

In the biggest cities, with populations of more than 10m, such as Beijing and Shanghai, the price of a 100-square-metre flat is, on average, 14 times higher than average annual household income. For cities with populations of less than 10m, this price-to-income ratio is 8 (The Economist., 2016f). However, if compared with London, these statistics are not so astonishing. The average house price in London (2016) is now 14.2 times the average annual salary. This ratio has climbed by 86% since 2009. For the second-tier cities of the UK, such as Birmingham, Manchester and Liverpool, the ratio is no more than 6 times average salary41.

In Western countries, such as in US, developers are the key driver of the urban land market, while governments use regulations to influence land development, either by changing the availability of developable lands or changing development costs (Cao

41 http://www.telegraph.co.uk/property/house-prices/house-price-affordability-london-reaches-new-low/
Planning is focused primarily on regulating development by the market. In the UK, the planning system has gradually moved away from comprehensive land use regulations and adopted a project-led approach (Wu et al., 2015). However, planning in China has its own political and economic uniqueness. The government takes an entrepreneurial approach to urban planning, to pursue land development and urban expansions, which also makes planning proactive in the development of major infrastructure. As Wu et al. (2015) argued, planning is considered the agent of economic growth and development in China. This mind-set of growth-oriented planning has been deeply embedded into society.

The Chinese cities are still growing fast, with increasing population and areas which previously had poor transport supply opened to development. The Chinese government recognises that the positive externalities from rail transit development outweigh the huge investment and subsidies to maintain the systems. With severe traffic congestion in the large Chinese cities, the government hopes that rail transit systems can provide capacity to meet the ever-rising transport demands of the increasing urban population. The aim to develop the rail transit system is consistent with that in cities like London. Moreover, it is widely recognised that the deteriorating environment in Chinese cities, especially the level of air pollution, is partly contributed by vehicle exhaust, which relates closely to the rapidly increasing use of automobiles. The government has felt unprecedented urgency to encourage the population to switch to rail transit from their private cars. Although this awareness is recognised throughout the world, it is even much more critical in China. All of these constitute the motives of the government to promote rail transit development, and are considered even more important than the economic stimulus the investments can be expected to bring to the cities.
8.3 Key findings in answering research questions:

For all urban planning studies, contextual issues such as economic environment, local policies and investment factors are important. Transport investment is only one of the factors affecting developmental change, but it is an important factor. Research methodologies vary across studies, and it has been difficult to isolate impacts, clearly establish causality, and draw general conclusions that can be used in practice. In a rapidly growing Chinese city, where the evidence is particularly scarce, the availability of ex-post (after the event) assessment is usually very limited; and any ex-ante assessment (before the event) of the developmental impacts of transit investment can often be a step into the unknown.

The work presented in this thesis has successfully addressed the research questions. In completing this research there are a number of contributions of note. This chapter concludes the thesis by summarising the main research findings in terms of the original research questions.

8.3.1 Research findings relating to research question 1

Question 1:
What direct impacts are associated with rail transit investment and how do these differ spatially and by population group?

In answering the first research question, the research findings are:

- The spatial variation of the relationship between people’s choice of rail transit as their mode of travel and their journey distance, geographic accessibility to the train, and socio-economic characteristics is measured. The variation is explained in terms of the specific local context in Chongqing.
- The benefit distribution of the direct impact of transit is accessed spatially and across population groups. The results demonstrate that the rail transit system
plays a more important role in facilitating the journeys of established residents of the areas that haven’t experienced dynamic regeneration as opposed to those developing areas that have.

- The results also reveal the potential tendency to exclude certain population groups in particular regions, which should cause concerns about the social equity of transit’s direct impact.

In order to explore the spatial variation in people’s transit mode choice, GWR analysis is utilised following a global multiple regression model. The result of GWR analysis shows that transit provision is most effective in facilitating people’s longer-distance travel in the old city centre, where the residents have relatively less income, lower car ownership and insufficient public transport provision, due to the mountain topography. It also appears that, in the old city, people living further away from stations are more likely to choose transit as their daily travel mode. The results of this research emphasise the importance of providing rapid rail transit systems in those less-developed and public transport-deprived areas, especially in the old city.

However, the results also reveal the potential tendency to exclude some population groups. Some areas have the potential to exclude the older generation, including in the less developed riverbank area in the south of the new city region and the whole old city region. To some extent the results reveal the polarisation between car owners and people with no access to cars in the old city centre. The car owners in the old city centre are the least likely to choose rail transit as their travel mode. This only emphasises the importance of transit provision in the public transport-deprived areas for those without access to cars. All of these findings are potentially calls for concern, as they may be ways in which certain groups of the population are excluded from the equal benefit distribution of public transport investment.
8.3.2 Research findings relating to research question 2

Question 2:
What wider impacts are associated with rail transit investment, including population changes, employment changes and land development, and what are the strengths of these relationships?

In answering the second research question, three main findings are provided as follows:

- Transit investment has disparate impacts across different locations, in the aspects of employment, population, land development and business activities.
- Rail transit played a role in facilitating development and regeneration in the old city. It dramatically transformed the position of the multiple commercial centres in the city and helped balance regional development. Developmental differences have therefore been narrowed between some areas of the old city and new city, but also have been widened elsewhere.
- The spatial variations in development underline the importance of delivering a policy package. In the package, rail transit development should be combined with urban development strategies, especially supplementary policies (like support with land release procedures, tax concessions and grants for developers) and planning interventions, in order to best achieve the desired result.

Spatial impacts associated with transit investment have developed over decades, but the analysis in this research has considered impacts over the time period 2007–2013. The transit system has exerted a strong effect on transforming the positions of amenities in the city and balancing regional development. Lacking dynamic economic externalities and investments, the old city is often regarded as a difficult place to deliver benefit from rail transit investment (Hall and Hass-Klau, 1985, Banister and Berechman, 2003). However, in this case, massive changes have
happened in the old city areas, such that it can be compared to the fast developing area in the new city region. The change observed in the old city is also much greater than some mature, developed areas in the new city.

Understanding these spatial variations in the demographic, urban and socio-economic impacts of transit investment can be challenging. It has been argued that impact from transport will favour the locations which can take direct advantage of it (Hall and Hass-Klau, 1985). This means some preconditions are required. Economic externalities, investment factors, and political factors are necessary conditions for transit investment to take effect (Cervero, 1998, Banister and Berechman, 2003, Banister and Thurstan-Goodwin, 2011). 

To a large extent, we have seen that much of the assumed developmental impact is related to the surrounding planning strategy, and is far from an ‘automatic’ impact from the transit investment. In a given area of the city, transit provision is only part of a package of planning strategies to boost development, along with other associated planning policies. Integration of land development and public transport planning is critical to enable areas to take maximum advantage of transport provision.

If a planning strategy is well formulated, and much of the development is planned and implemented, then the developmental impact of transit investment can be large. Therefore, perhaps developing a ‘package’ of policy measures is more critical than estimating, often quite indirect, impacts of transit investment. This has interesting implications for project appraisal, as often funding is given to the projects where there are assumed high developmental benefits (indirect benefits), alongside high ‘user’ benefits (direct benefits). Feitelson and Rotem-Mindali (2015) remind us that it is the package of measures that are important; that the emphasis should be on identifying the synergetic measures that will lead to the desired impacts on the neighbourhood and city. Hence, we should seek to conceive and agree how we would like the city to develop, and to plan the transit investment, and the urban form and layout accordingly, to help facilitate this. It is the integration of
transport investment and planning strategies, the macro and city economy, the associated traffic demand management strategy, the wider provision of amenities and facilities, and education and training, that shape the nature of development change.

8.3.3 Research findings relating to research question 3

Question 3:
What social equity impacts are associated with rail transit investment, in terms of perceived impacts on the neighbourhood and on individuals themselves?

In answering the third research question, the research findings are:

- Social justice in transport is assessed via the redistribution of gains, such as increases in land and property value, and opportunities, in the interest of equity. Social equity of transit’s indirect impacts among different income groups is measured by exploring people’s attitudes towards the impact on their neighbourhoods and on themselves.

- The results indicate that the middle-income groups look most favourably on the rail transit developments, whereas the lowest income group gives the lowest evaluation of transit impact on their lives. The benefit to the lowest income residents, from travel convenience, is diluted by the adverse impacts they experience.

- The established residents do not benefit much from the development associated with the transit investment. In general, they also lack the skills and/or knowledge required to benefit from the increased local employment opportunities.

A bespoke questionnaire survey was carried out. This included a question about income level — an essential variable that was not available from the travel survey. The survey was specifically intended to explore variations in the indirect impacts of
transit on different income groups, by exploring people’s attitudes.

The results show that individuals occupying different socio-economic positions in the city perceive the impacts of new transit developments differently. The mid-income groups look most favourably on the effects of the rail transit developments, either on their local neighbourhoods or on their individual lives. They make good use of the transport provision to leverage their capabilities. In contrast, those in the lowest income groups look least favourably on these developments. Although the perceived impact on the neighbourhood by the lower income group is much higher than the other income groups, the lowest income group gives the lowest evaluation of transit impact on their own lives.

The lower income groups also have a high percentage of transit use, and presumably benefit from increased levels of accessibility to employment and other activities. But, the redistribution effect of the transit results in people moving into the areas where there are already low-income residents. The newcomers are attracted by the opportunities found in these areas, such as lower property rent and better public transport accessibility around the station. The lowest income groups, though being the frequent transit users, also suffer from the adverse impacts associated with the rail transit provision, such as rising property prices, rent and living costs. The benefit from travel convenience is therefore diluted by the adverse impacts that they experience.

Even with the fast aggregate increase in employment in Daping — a regeneration area in the old city — there is a constantly decreasing trend for local employment. Most of the growth in jobs is taken by people residing outside of the region; hence the employment opportunities are not being taken up by the local residents. The established residential population — generally from the lowest income group — have proximity to rail transit stations, but lack the skills and/or knowledge required to exploit the increased employment opportunities. Combined with their economic
constraints, many incumbents would rather take the subsistence allowances from government than seek a job far outside their living area. This may be a major reason why their commuting needs are significantly reduced. This is a similar finding to that found with the Jubilee Line Extension in East London (Jones, 2015). The established residential population does not receive the benefit as expected from an equal distributional purpose. The skills mismatch means that the greater access to new employment opportunities is not realised. It is not only the lack of explicit benefit delivery to them, but also, perhaps, inactivity and inability on the part of these residents, which prevent them from receiving the benefit distribution of the transit system (Lane et al., 2004).

8.4 Thesis contributions

- Developing a methodological framework for understanding the impact of rail transit investment on development, including direct and indirect impacts.

Except for travel convenience improvement, a new rail transit system potentially leads to economic, land use and social changes. This research puts forward a research framework that can be used to assess the direct (transport) and indirect (non-transport) impacts from transit investment (Banister and Berechman, 2003), and discusses a range of likely impacts throughout the thesis.

Evidence is provided for changes in demographic, economic and physical outcomes. A set of indicators of change is identified for measurement of the indirect impacts, including land development, local population levels, employment, income levels and business activities. This is presented with respect to the four new Metro lines opened in Chongqing over the last 12 years, via analysis of census data from the time period 2007–2013.
It is often suggested that this ‘direct’ and ‘indirect’ impact typology is a little unhelpful as it downgrades the importance of the developmental impacts. In China, and many other contexts, these developmental impacts can be the most important impacts of transport investment. The goal of planning cities is to organise activities in a way that allows an effective functioning and high quality of life. Transport investment is one element within a package of measures within the ‘master plan’. To ask the oft-asked question, ‘what impact is the transport investment likely to have?’ is really missing the point — and is taking the narrow viewpoint of the transport economist. Perhaps we should instead ask ‘what policy measures most effectively develop a particular part of the city?’

- Providing a comparative study in examination of the spatial distribution of the indirect impacts of metro investment.

It is an inarguable fact that the indirect impacts of a rail transit system vary between locations. Strong local economies, supportive planning policies, investments and the availability of attractive development sites all have an influence on the rail transit’s impact. They together contribute to discrepancies in impact across different rail transit-affected areas. In order to isolate the impact of transport on urban development relative to the supporting or associated innovations which are introduced in parallel (Hall and Hass-Klau, 1985) and other wider influences (Banister and Berechman, 2003), the approach used in this thesis is to conduct a comparative study across geographic locations. Changes across time in transit station catchment areas are compared to those in reference and control areas. Chapter 5 uses this method to explore the spatial distribution of the multiple indirect impacts of metro investment, beyond the direct transport accessibility changes. This draws on previous analysis, such as that by Banister and Thurstain-Goodwin (2011) and Jones (2015).

- Evaluating social equity in distribution of rail transit’s impacts, including benefits
The conceptual understandings of ‘equity’ in transport can be quite diverse. Equity itself is defined as the equality of outcomes, viewed in terms of net aggregates of benefits and burdens. Yet, even now, there is little clear evidence on what substantive equity outcomes are likely to arise from transport projects, on what scale, in which locations, and to whom. Social justice of transport is measured in different ways, and a lot of work has already been done in the field of accessing injustice in accessibility, travel time, and adverse environmental effects (Lucas, 2006, Lucas, 2012, Beyazit, 2011, Martens, 2012, Martens et al., 2012, Gossling, 2016). This thesis explores a methodology of viewing transport justice by measuring the spatial variations of social equity in the distribution of direct and indirect impacts of rail transit. In this way, it assesses the unequal distribution of benefit and burden spatially and across population cohorts. For the direct impact, Chapter 4 views social justice in transport by looking at spatial variations in travel mode choice, using city-wide travel survey data. For the indirect impact, Chapter 6 examines social equity in the perceived impacts of different income groups, at the neighbourhood and individual level, using bespoke local residential surveys. Reflections are also made on the policies and planning interventions which might be introduced to achieve greater equity in impacts.

- Testing the use of a range of different methods, including the use of GWR, multilevel modelling, MANOVA and discriminant analysis to examine the socio-spatial distribution of rail transit’s impacts.

From Chapter 4 to Chapter 6, a selection of different methods is used to explore socio-spatial distribution of the rail transit’s direct and indirect impacts in Chongqing. In Chapter 4, a geographically weighted regression (GWR) model is utilised to reveal the spatial variation in the relationship between the rail transit’s direct impact and people’s socio-economic characteristics. It extends beyond the previous
literature, where studies have focused on global models to explain the relationships and have lost valuable information due to the variations in local context. In Chapter 5, a multilevel model is introduced to explore whether the indirect impacts of population and employment change, associated with the rail transit development in the local area, have contributed to people's average level of income against time, before and after the transit opened. The multilevel model is specially designed to deal with the variation resulting from the specific locational condition. In Chapter 6, MANOVA and discriminant analysis are used to examine the ways in which individuals occupying different socio-economic positions in the city perceive differently the impact of new transit developments on themselves and their neighbourhoods. The methodology outlined here can certainly be applied to new cases and new data sets in the future.

- Proposing a process to help understand governments’, developers’ and other stakeholders’ views on the impacts of metro investment and development.

The qualitative study presented here consists of a series of interviews of different stakeholders, and was carried out to further provide comprehensive explanations for the emerging problems of disintegrated land use and transport development, ineffective revenue recapture, and disproportionate benefit distribution. The interviews explore how to coordinate the different intentions of stakeholders, and promote the cooperation between them, and the results and analysis are presented in Chapter 7. The primary causes of the problems are identified as the divergent intentions and uncoordinated actions of different stakeholders, which relate to discrepancies in their power and interests. Meanwhile, the lack of a powerful coordination body, the absence of a comprehensive evaluation system, and a system of inflexible institutional regulations further exacerbate the problem. They together impede the value uplift from transport development; reduce revenue recapture by the government to feed the system in the long-run; and impair the equal distribution of benefits across population groups.
Suggesting that the evaluation of transport investment is not only done by assessing ticket returns, but also factoring development gains into the assessment system, by establishing a more effective revenue capture mechanism.

Measuring the impact, indeed success, of transit investment in purely financial terms, as is often done by assessing ticket returns on capital cost, massively underestimates the benefits of transit investment. The development stimulated by transit investment can often be large, particularly if it is well planned and there are supportive macro-economic factors. This needs to be factored into the evaluation of transport investment — and is likely to be much larger for public transport investment than for highway investment, as the development densities around public transport can be much higher. Revenue from this ‘secondary’ developmental benefit should be captured in a more effective way, including through residential and business land value taxes — which can be reinvested in public transport and public amenity improvements. In France, for example, 1% of the cost of urban public transport projects is given to urban environment projects (O’Rourke et al., 2015). This type of reinvestment into the improvement of the urban environment for people is critically required in China, and in many other places.

8.5 A critique of the methodology

In this thesis, different analysis tools are used. There are some inevitable limitations with these approaches, which should be acknowledged explicitly here, and possible improvements discussed.

- Data set

Unprocessed data for local areas in Chinese cities are quite difficult to acquire, and
are most often not accessible to the public. Besides, only some categories of data are gathered in a census. Also, data collected across different administrative regions are not constant by category and can be inherently inaccurate, thus need to be excluded from analysis. The inherent limitations of the data, in terms of location, timing and categories have naturally set limitations on the analysis.

- The comparison method — reference and control area

An ideal control area and reference region, excluding all other influences, is near impossible to identify. In the fast development period of a city, areas which are adjacent in spatial location can be experiencing completely different stages of development. The control area identified in this research is actually experiencing massive land development. Therefore the changes are actually more drastic than the station catchment areas. In addition, some other parts of the reference region are also influenced by the newly built rail transit system. In this sense, the reference area and control area are not fully completing their role in excluding other influential factors. This reduces the power of the analysis, and also potentially introduces bias into the analysis, which might reduce the reliability of the results. The methodology could be improved if more suitable reference regions and control areas could be found, that had the appropriate census data available for a longitudinal study.

- Inference from the descriptive analysis

With a comparison method, one thing that needs to be borne in mind is that, even if there is an apparent difference between the station-affected areas and the reference regions after the opening of the transit, one cannot infer causality between the opening of rail transit and the discerned differences. The changes might also be caused by the other influential factors, including ‘known knowns’ (factors that are shown in the research framework), ‘known unknowns’ (factors that were ignored or un-measureable for technical or practical reasons) and ‘unknown unknowns’ (factors which were not even considered). The direction of causality also cannot be inferred from a descriptive study (in other words, differences in the locality could
have been the cause of the station being built there, rather than vice versa). Any inference of causality from the descriptive analysis therefore needs to be made with care, and with strong caveats.

- Relatively small model effect
There is a common issue that affects both the logistic model of travel mode choice and the MANOVA analysis of transit’s indirect impacts. The $R^2$ statistics are both very low. This may be because there are only relatively few socio-economic attributes entering the model from the survey data, which even together don’t account well for the actual variations in people’s travel mode choice. It is supposed that people’s travel mode choice can be influenced by many other factors, which are unknown from the limited accessible data in this research. The performance of the logistic model could certainly be improved by introducing some other key socio-economic variables into the model. In the MANOVA, it is likely that only part of the difference in people’s perceptions towards transport’s impact is caused by their income level, and thus a small model effect is to be expected.

- Model validation by spatial autocorrelation
The most important cause for concern in this analysis is the spatial autocorrelation in the model. The Moran’s $I$ value of the residual of the binomial logistic regression is as low as 0.1, which means that it is barely perceptible. A low value of Moran’s $I$ of the residuals indicates that one is missing some critical variables in the model, as a result of poor quality of data from the survey. It undermines the necessity of using GWR to explore the spatial variations. A number of improvements could be made. In particular: to use a data source with better accuracy and to reframe the model with additional predictor variables, as argued above.
8.6 Reflections on future research

Areas for future research areas are identified below, according to four main sub-headings.

- Future research area 1: Improvement in research methodology

The initial part of the research framework, which shows the factors influencing the effect of rail transit, could be improved in the future by developing a better-framed comparison methodology. For example, to explore the influence of a supportive policy on the effect of rail transit, a comparison could be carried out between two transit-affected areas, where one is favoured by the policy while the other isn’t. Alternatively, transit’s impact in isolation could be better observed with other influential factors excluded by more carefully choosing the research area and control area for comparison. In this research, because of the difficulty in finding a suitable control area, reference regions were instead identified. The boundary of the reference areas was constrained to correspond with existing demographic and administrative boundaries, to enable the use of census data. By choosing more suitable reference regions and control areas, the comparison could be validated much better, and the complexities inherent in the mechanism by which rail transit takes its effect could be better unravelled. Only if detailed exploration into the context is carried out, can greater insight into the reasons behind the apparent changes and differences be gained. Feasibly, real-time data could even be used, perhaps collected from mobile applications; then time-series comparisons could be made much more easily.

- Future research area 2: Improvement in data collection and analysis methods

Future research into spatial and social equity can be facilitated by using survey data that include complete socio-economic information. If people’s travel records, their
socio-economic status and spatial data can be combined, then socio-spatial equity can be better understood. In the spatial variation analysis in this research, data were drawn from the database of the official travel survey in Chongqing. Some socio-economic information is accessible from this survey, but income level was not included in the survey questions. The effect of the spatial variation in people's choice of transit mode could have been better assessed, given the inclusion of more complete social economic variables, especially a better-identified predictor of income. Moreover, with data from the next travel survey, a longitudinal analysis could be carried out by comparing these two survey results.

- Future research area 3: Spatial variations to be explored in the social equity analysis of indirect impacts

The equity analysis of transport's indirect impacts on population groups should also have assessed its spatial variations (as was done for the travel mode choice analysis). Initially, the intent was to analyse the questionnaire survey results with differentiation of spatial locations. However, due to resource limitations, the sample size of the final dataset was not large enough to carry out analysis of spatial variations. To be specific, for some locations, the sample size is much smaller than the other areas, and it is not suitable to include locational differences in the model analysis. Therefore, in this study the variations can only be explored among different population groups, using the whole sample. If the data from the attitude survey were to include spatial information, the research could be greatly improved, and this is a useful avenue which should be explored in future research, when resources allow the collection of sufficient data from multiple locations.

- Future research area 4: More appropriate approaches for measuring inequity and assessing distribution

This study looks at the spatial variations of equity in the distribution of direct and
indirect impacts separately. For the direct impact, this study looks at people’s choice of rail transit as their travel mode. However, exploring social equity in the spatial variations of travel mode choice is just a perspective to view social justice in transport. Here transport equity is measured by travel mode choice, and unequal benefit distribution is assessed according to locations and population groups. However, the choice is largely influenced by the physical distribution of transport facilities, people’s level of access to destinations and opportunities, and people’s capabilities (including budget and ability) and aspirations (Lucas, 2006, Lucas, 2012, Beyazit, 2011, Martens, 2012, Martens et al., 2012, Gossling, 2016). The model in this thesis is an over-simplification of the mechanism, and this is the likely reason for the small model effect. The method of measurement could be improved by incorporating additional factors that might affect people’s choice as predictor variables in the model.

For the indirect impacts, social equity is measured by the perceived impacts of people. This perception is inevitably subjective. However this is still the optimal way to assess this, given the data limitations involved. The measurement of equity impact is intended to be complete and thus uses a combination of indirect impacts, (living cost, land price, rent, etc.). The unequal distribution element is assessed by a single variable (income level) in the MANOVA and discriminant analysis models. However, people’s income level can only explain part of the difference in people’s perceptions towards the impact of transport, and this also causes relatively poor model fit. The actual impact could be measured via other approaches in the future. Distribution could be assessed using another index or using a combination of other socio-economic variables.

- Future research area 5: Incorporating these issues into project appraisal

Finally, further research will also be needed into the establishment of an evaluation system of the ‘winners’ and ‘losers’ of the transit investment process. Apart from
evaluating the benefit distribution on population groups, the system also needs to evaluate the gains and losses of the stakeholders. It is unlikely that all of the costs and benefits can be accounted for in an ‘all-encompassing’ CBA. Hence some form of multi-actor MCA, perhaps viewed from the planning perspective, might be a more appropriate way of appraising different development strategies. A system is also needed for more efficient benefit recapture from the investment, better integrated transport and land use development in the city, and defining a clearer set of rights and responsibilities of the stakeholders in the development process.

8.7 The key priorities for policy makers in Chongqing

This emerging research field is applied in a rapidly growing city in China. The fast economic growth in China requires that other factors also be protected — such as the environment and societal cohesion — and that there is an overarching aim of sustainable development. With the rapid urbanisation trend in China, many farmers have left their farmland and moved to the city, becoming ‘migrant’ workers within their own country. This is a controversial part of the urbanisation process in China and has led to multiple problems in Chinese society. The critical issues are to accommodate the newcomers into the city, to integrate them into urban life, and to help them live compatibly with the established urban residents. An underprivileged population in Chinese society has effectively been ‘created’, which includes these rural migrants, as well as the established residents with low income.

The following four strategies are proposed to help plan public transport investments in a more socially equitable manner. They are targeted, in the main, at improving the procedural fairness of the process, but also in achieving greater levels of formal and substantive equity:

- Carry out strong evaluation of impacts of metro investment over time, including
direct and non-direct impacts and equity dimensions. Use the evidence base to project the likely impacts at the appraisal stage.

A series of detailed *ex-post* studies should be performed on recent transit projects in Chinese cities, to examine the developmental impacts and substantive spatial equity implications which have arisen, including assessment of the ‘winners’ and ‘losers’ from investments, and the net levels of benefits and burdens. To this end, I propose the establishment of an assessment system, to assess the gains and losses for different stakeholders, and help the city better capture the value generated in the process. Currently, there is no effective system to assess the benefit distribution associated with rail transit investment (among the various groups of stakeholders and residents). Two aspects lack deserved focus in the current policies.

Firstly, there is a lack of an assessment system to identity the benefit distribution to the stakeholders. This should be established to examine to what extent the different stakeholders gain benefit from the value uplift from the transport development process, and to coordinate their actions and make sure their responsibilities are delivered. The current lack of this system actually results in inefficient revenue capturing from rail transit investment by the government.

Secondly, there is an absence of assessment of the substantive equity outcomes in the interest of equal distribution to different population cohorts. There should be an awareness that rail transit brings about, not only travel convenience, but also economic, urban, environmental and social changes. These impacts on vulnerable population groups in society are currently not clearly identified. Some impacts are detrimental — particularly in the processes of land acquisition, building demolition and residential relocation. The resident interviews have revealed that this causes social inequity problems.
A more comprehensive appraisal system can be developed, drawing on this evidence, which moves beyond questions of economic efficiency and incorporates social equity dimensions — assessing the likely equity impacts of transit projects on different population groups, including the likely benefits and burdens and spatial distribution. This should be a key requirement at the project preparation stage, before projects are authorized by central government. This is critical in a country such as China, where social equity and societal cohesion are very important as political objectives.

- Coordinate the diverse levels of power and degrees of interest of different stakeholders in the process of rail transit development, by establishing an institutional framework and a powerful coordinating agency.

This research identifies the institutional deficiencies that impede the integration of land use and rail transit development, and thus limit the return from investments. Firstly, it is the divergent interests and motives that exist among different stakeholders (among different levels of government and other sectors) that result in inefficiency in this integration. Unlike other cities, the Chongqing Rail Transit Group Co. Ltd. isn’t granted automatic rights to ‘land reserve’. This is largely a side-effect of the land banking system in Chongqing, in which the land reserve rights are held by several municipal groups and local governments. This system causes great inflexibility for the government in organising land resources, leading them to often miss time-critical opportunities for integrated development.

Meanwhile, the situation is also exacerbated by the lack of a powerful coordinating agency, when compared with Shenzhen or Hong Kong. As discussed in detail in Chapter 7, Shenzhen has a statutory planning framework with sufficient institutional capacity and an effective intra-governmental linkage. The coordination role is played by the Municipal Executive office of the municipal government, which is directly led by the Vice Mayor. In Chongqing, an institutional framework should thus
be established to facilitate cross-sector collaboration, and to establish a specialized development agency to coordinate the diverse levels of power and degrees of interest of different stakeholders. Only in this way can an integrated land-use and transport strategy be implemented efficiently.

- Better integrate public transport and land use to steer development towards the locations which are suitable for the city, so that the development gains associated with rail transit investment are captured and returned to the public sector.

It is revealed in this research that much of the expected developmental impact of transport investment is in fact related to the surrounding planning strategy, and is far from an ‘automatic’ impact. If the planning strategy is well formulated, and much of the development is planned and implemented, then the developmental impact of the transit investment can be large. With insight into the transit development situation via this ‘case study’ of Chongqing city, I suggest that a package of policy measures should be delivered to promote an integrated system for transport and land development, particularly focussing on the development strategies promoted by the government at the local scale.

Sustainable financial resourcing of public transport operations is critical, as problems of unsustainable subsidies have emerged in some cities in China, e.g. Beijing. At the end of 2014, this burden made the government abandon its subsidies for public transport (which had been introduced seven years prior) and raise the metro and bus prices considerably. As the profit from ridership revenue is insufficient to support a modern rail network in China, revenue from secondary benefit must be captured by the public sector in an efficient way. Integrated land development alongside transit development can be an effective financial resource. A comprehensive tax system should also be established to capture a proportion of the profits from sale of properties whose value has been lifted by the rail transit
system, and potentially also from a tax on businesses benefiting from the improved transport linkages.

Therefore, I suggest that some institutional regulations should be revised, in order to better capture revenue from the development process. Existing regulation states that if the land above the rail transit station is to be developed for commercial use, the land use index has to be changed from ‘public facility’ to ‘commercial’, and the development right has to be gained via bid, auction and listing. This process has constrained the efficiency of development around the rail transit station. Meanwhile, it also puts the Rail Transit Group in a disadvantaged position when bidding for the development rights. It thus makes integrated development difficult for the Rail Transit Group to accomplish.

Without gains from surrounding land development and sustainable tax returns from properties, revenue is unable to be recaptured by the public sector to feed the future development and operation of the rail network, and this causes inefficient use of public funding. In contrast, in Shenzhen, the government injects capital into the Shenzhen Metro Corporation and guarantees that it can purchase land at the original price before construction begins. In Shanghai, favourable policies exist to ensure that the land can be successfully acquired by the Shanghai Metro Corporation in the bid, auction and listing procedure.

- Introduce associated policies and planning interventions as a package of measures, with an explicit focus on how benefits can be effectively delivered to socially disadvantaged groups.

Improved methods of community participation are required for transit investment projects, whereby communities are incorporated into the decision-making process, including establishing communication channels with socially disadvantaged groups. For example, consultation with potentially affected parties should be ensured at the
project preparation stage, to help prevent and mitigate effects such as locational disturbance and resettlement arising from the urban transport construction (Gwilliam, 2002, World Bank., 2010). It is necessary, especially for those whose residences are directly affected, to make sure there are resettlement plans and/or compensation mechanisms.

Associated policies and planning interventions should be introduced — as a package of measures that are required alongside the transit investments — with an explicit focus on how benefits can be effectively delivered to socially disadvantaged groups. Specifically, joint efforts should be promoted with local employers, training organisations, and neighbourhood communities, to provide poor local residents with appropriate training and improved skillsets to benefit from the development associated with transport investment. This will help to provide people with the essential skills, abilities and aspirations in order to maximise their opportunities in seeking employment both in local areas and in areas made more accessible by new transit systems.

The scale of investment in public transport in Chongqing, and in the rest of China, is unprecedented, and it is likely that many of the future innovations in public transport project design, appraisal and evaluation will emanate from this type of context of promoting public transport development. The political organisation of Chinese cities also allows an effective integration of public transport and urban planning — and it is hoped that this thesis can help lead to a change in thinking of how best to plan rail transit investments so that economic, environmental and social policy goals can be achieved. The design of attractive cities and neighbourhoods should take prominence, with transit investment being one part of the package of measures required to achieve this. There is much to be gained. All great cities have great public transport systems, but as yet, there are still many sub-standard examples of both.
Appendices

Appendix 1: Chongqing urban household travel survey 2014

The Chongqing municipal government deployed this survey and the Chongqing Urban Planning Bureau was responsible for organising it. The survey was ultimately carried out by the different subordinate levels of the local government, namely the district, sub-district and community governments. The surveyors working in the local community collected the data from the sampled households, by using a tablet loaded with a specially developed ‘app’ (software application). Family members of those selected households were instructed by the surveyors to fill in the information on the app step-by-step. The survey contained three sections: household information for the whole family; individual information for each family member; and travel information for all the trips taken by each family member in the specific surveying day (an ordinary weekday). The indices collected in the survey are listed below.

1. Household information
   1) District name
   2) Family address
   3) Community name
   4) Number of family members in the household
   5) Number of family members who are below 6 years old
   6) Number of cars owned in the household
   7) Whether the car is parked in a permanent car park or not
   8) Petrol cost per month (only applicable for car owners)
   9) Plans to purchase a car
   10) Property type
2. **Individual information**

1) Gender
2) Age
3) Local Hukou owner or not
4) Employment/school address
5) Occupation
6) Your mobile phone operator

3. **Travel information**

*Fill in the information for each trip taken this day*

1) Departure and arrival time
2) Departure and arrival address
3) Land use index of departure and arrival address
4) Aim of this trip
5) Travel mode of this trip
6) Travel duration of this trip
7) Whether you are the driver of this trip or not
8) Number of persons in the car for this trip (only applicable if this trip was taken by car)
9) Travel cost incurred for this trip
10) Parking fee (only applicable if this trip was taken by car)
Appendix 2: Transport attitude survey

The impact of rail transit systems on urban regeneration and development in a Chinese large city

Survey questionnaire 2014

Introduction: This questionnaire is part of a research project about the effect of the rail transit system on urban regeneration in Chongqing, conducted by researchers at the Bartlett School of Planning, University College London, United Kingdom. It aims to find out what people living and working in the rail station catchment area think about their area, and whether the transit has changed the area and had an influence on them.

All your answers will be strictly confidential and used anonymously for the purpose of analysis.

Please read the instructions for answering the questions:
There are 17 questions and the survey takes about 30 minutes to complete.
• Please answer all the questions. Do not skip any questions.
• There are no wrong or right answers. We just want to know your opinion.
• For most sections you are asked to indicate your answer by ticking a box that corresponds to your opinion. Please do not tick more than one box for each question unless it is required.
Below is an example of how to give your answers.

<table>
<thead>
<tr>
<th>Impact of property price rise</th>
<th>Very bad impact</th>
<th>Slightly bad impact</th>
<th>No impact</th>
<th>Slightly good impact</th>
<th>Very good impact</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please tick the box under the statement with which you agree.

Your help in completing the questionnaire is very much appreciated!
## Section 1: Basic information

1. **What is your gender?**
   - Male
   - Female

2. **What’s your age last birthday?**
   - 24 or below
   - 25-29
   - 30-39
   - 40-49
   - 50-59
   - 60 or above

3. **How long have you lived in this area:**
   - Less than half a year
   - Half a year but less than two years
   - Two years but less than five years
   - Five years but less than ten years
   - Ten or more than ten years

4. **If less than 10 years, where are you from before residing here:**
   - Other parts within the central city area
   - Outside central city area but within the main city area
   - Outside the main city area but in Chongqing
   - Other area outside Chongqing

5. **In which of these ways do you occupy this accommodation?**
   - Own it outright (totally free or partly free as welfare from your company)
   - Buying it as commodity property (with or without the help of a mortgage/loan)
   - Pay part rent and part mortgage (shared ownership)
   - Rent private
   - Rent from governmental program
   - Live here free (including rent fee in friends’ / relatives’ property, excluding squatting)
   - Squatting
   - Other
Section 2: Perceived impact of transit effects on the local neighbourhoods

6. Below is a list of possible effects that the opening of the rail transit may have on the area. For each one please indicate to what degree you ascribe the change to the opening of the transit.

<table>
<thead>
<tr>
<th>Impact on prices</th>
<th>Very adverse impact contributed by transit</th>
<th>Slightly adverse impact contributed by transit</th>
<th>No impact contributed by transit</th>
<th>Slightly good impact contributed by transit</th>
<th>Very good impact contributed by transit</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

**Impact on area attractiveness**
- Improving land development/urban image/open space
- Improving pedestrian environment
- Increasing noise
- Improving commercial and service facilities

**Impact on neighbourhood population**
- Increasing local employment opportunities
- Improving neighbourhood safety
- Improving community harmony
- Increasing community population change/floating population

**Impact on accessibility**
- Improving daily travel convenience
- Improving weekend travel convenience
Section 3: Perceived impact or importance of transit effects on individuals

7. Below is a list of variables of possible effects that the opening of the rail transit may have on you. For each one please indicate the degree of your perceived impact or importance of these effects on yourself.

<table>
<thead>
<tr>
<th></th>
<th>Very bad impact</th>
<th>Slightly bad impact</th>
<th>No impact/Not important at all</th>
<th>Slightly good impact/ A little important</th>
<th>Very good impact/ Very important</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of property price rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of property rent rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of living cost rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area attractiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of land development/urban image/ open space improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of pedestrian environment improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of commercial and service facility improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of local employment opportunities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of neighbourhood safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of community harmony</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of community population change/floating population</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of daily travel convenience improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of weekend travel convenience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section 3: Perceived impact or importance of transit effects on individuals

7. Below is a list of variables of possible effects that the opening of the rail transit may have on you. For each one please indicate the degree of your perceived impact or importance of these effects on yourself.

<table>
<thead>
<tr>
<th></th>
<th>Very bad impact</th>
<th>Slightly bad impact</th>
<th>No impact/Not important at all</th>
<th>Slightly good impact/ A little important</th>
<th>Very good impact/ Very important</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in prices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of property price rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of property rent rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of living cost rise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area attractiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of land development/urban image/ open space improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of pedestrian environment improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of commercial and service facility improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of local employment opportunities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of neighbourhood safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of community harmony</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact of community population change/floating population</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessibility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of daily travel convenience improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of weekend travel convenience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section 4: Your travel information

8. For each type of activity you have undertaken before 2011 (before the opening of the rail transit), please tell me how to usually travel:
   Trip 1: your primary travel mode    Trip 2: alternative

<table>
<thead>
<tr>
<th></th>
<th>Bus</th>
<th>Rail transit</th>
<th>Walk</th>
<th>Car</th>
<th>Taxi</th>
<th>Company bus</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work trip 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work trip 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School trip 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School trip 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily shopping trip 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daily shopping trip 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luxury shopping trip 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luxury shopping trip 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation trip 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recreation trip 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. For each type of activity you have undertaken since 2011 (after the opening of transit), please tell me how to usually travel:

<table>
<thead>
<tr>
<th>Trip 1: your primary travel mode</th>
<th>Trip 2: alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus</td>
</tr>
<tr>
<td>Work trip1</td>
<td></td>
</tr>
<tr>
<td>Work trip2</td>
<td></td>
</tr>
<tr>
<td>School trip 1</td>
<td></td>
</tr>
<tr>
<td>School trip 2</td>
<td></td>
</tr>
<tr>
<td>Daily shopping trip 1</td>
<td></td>
</tr>
<tr>
<td>Daily shopping trip 2</td>
<td></td>
</tr>
<tr>
<td>Luxury shopping trip 1</td>
<td></td>
</tr>
<tr>
<td>Luxury shopping trip 1</td>
<td></td>
</tr>
<tr>
<td>Recreation trip 1</td>
<td></td>
</tr>
<tr>
<td>Recreation trip 2</td>
<td></td>
</tr>
</tbody>
</table>

10. How often do you use the rail transit?

<table>
<thead>
<tr>
<th>Frequency</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5 or more days per week</td>
<td></td>
</tr>
<tr>
<td>3 or 4 days per week</td>
<td></td>
</tr>
<tr>
<td>Once or twice per week</td>
<td></td>
</tr>
<tr>
<td>About once a fortnight</td>
<td></td>
</tr>
<tr>
<td>About once a month</td>
<td></td>
</tr>
<tr>
<td>Less than once a month but used in last year</td>
<td></td>
</tr>
<tr>
<td>Not used in last year</td>
<td></td>
</tr>
<tr>
<td>Never use</td>
<td></td>
</tr>
</tbody>
</table>
Finally, we would like to know a little bit more about you. We would appreciate it if you could share some more information about yourself:

11. What is your employment status?

- Work full time for an employer (more than 30 hours per week)
- Work part time for an employer (less than 30 hours per week)
- Self-employed
- On government training scheme/at school full time education
- Waiting to start a job already accepted recently
- Not employed right now and looking for work
- Retired from paid work
- Unable to work because of long-term sickness
- Looking after the home or family
- Others

12. What is your highest level of qualification?

- Junior school
- Senior school
- College student or having graduated
- Full-time university student or having graduated
- Master or higher degree student or having graduated
- Do not have degree

13. What is your gross household income (per year)?

- Below 50,000 yuan
- 50,000 yuan to 100,000 yuan
- 100,000 yuan to 200,000 yuan
- Above 200,000 yuan
14. Which of the following best describes your household?

- Single
- Single with parent or parents
- Couple with young child
- Couple without child
- Living with grown up child (two generations)
- Living with grown up child (three generations)
- Other

15. How many bedrooms are there in the property that you live in?

- Single room
- One bedroom
- Two bedrooms
- Three or more than three bedrooms

16. How old is the property that you live in?

- Less than 5 years
- 5 years but less than 10 years
- More than 10 years

17. Household car ownership

- No car
- One car
- Two or more than two cars

Many thanks for completing the survey! The results will be very useful to us in our research!
Appendix 3: Interview questions for stakeholders

Interview questions regarding the impact of rail transit systems on urban regeneration and development in a Chinese large city
(A case study of Chongqing)

Lixun Liu

Ph.D, Urban Planning,
Bartlett School of Planning, University College London

For City Government, Local government, Rail Transit Agencies,
Investors and developers, and Local Academics

The Interview reports will only be used for the Ph.D thesis

1. How important is rail transit investment to urban development?
   Very important     Important     Not so much     Not important

2. What do you perceive is the impact of the rail transit investment? Especially in the urban regeneration area, such as transport and travel behaviour, economy and employment, residential and commercial development; in the short-term and in the long-term.
   a) Do the rail transit-impacted areas show a greater than average/accelerated economic growth? (in GDP, productivity, etc.)
   b) Do they attract more investment?
   c) Do they have more land development (for the construction application)?
   d) Do they attract more firms to locate there?
   e) Do they show a positive trend in population and employment?
   f) Do they have an impact on people’s travel behaviour?

3. Would the development have been of a different type without the transit?

4. Do you think there are major differences of performance between the rail transit station catchment area (800 m walk) and the nearby area not served by rail? If any, how do you perceive the difference? To what extent can differences be attributed to the impact of rail transit?
5. Please give a score for the importance of the following factors for development and regeneration in the rail transit impacted areas, on a scale of 0–10.

<table>
<thead>
<tr>
<th>The factors</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic environment</strong></td>
<td></td>
</tr>
<tr>
<td>• General regional economic dynamics (upswing regional growth)</td>
<td></td>
</tr>
<tr>
<td>• Firm agglomeration</td>
<td></td>
</tr>
<tr>
<td>• Labour sources: The relationship to population centres and employment sources</td>
<td></td>
</tr>
<tr>
<td><strong>Supportive policies</strong></td>
<td></td>
</tr>
<tr>
<td>• The source of finance and the level of governmental investment</td>
<td></td>
</tr>
<tr>
<td>• The supporting legal, organizational and institutional policies and processes</td>
<td></td>
</tr>
<tr>
<td>• Necessary complementary policy actions: Grants, subsidies, tax breaks, training programs, etc.</td>
<td></td>
</tr>
<tr>
<td>• Land use policies: Intensive zoning, mixed use, floor ratio bonus, parking</td>
<td></td>
</tr>
<tr>
<td><strong>Investment factors</strong></td>
<td></td>
</tr>
<tr>
<td>• Fund availability</td>
<td></td>
</tr>
<tr>
<td>• Scale/timing/location of planned investments</td>
<td></td>
</tr>
<tr>
<td><strong>Transport conditions</strong></td>
<td></td>
</tr>
<tr>
<td>• Accessibility via the roads</td>
<td></td>
</tr>
<tr>
<td>• Accessibility by public transport</td>
<td></td>
</tr>
<tr>
<td>• Former transportation investment and new investment schemes</td>
<td></td>
</tr>
<tr>
<td><strong>Other prerequisites</strong></td>
<td></td>
</tr>
<tr>
<td>• Available land resources</td>
<td></td>
</tr>
<tr>
<td>• Location attractiveness: Physical settings</td>
<td></td>
</tr>
</tbody>
</table>

6. How can the rail transit system, in cooperation with other factors, act as a catalyst to stimulate development?

7. What are the most important factors influencing investment decisions?

**Question 8 – 11 for developers**

8. Following the previous question, how does the public transport infrastructure influence investment and location decisions?
   a) Were bottlenecks in the public transport infrastructure a determinant in past relocation or expansion decisions?
   b) Did improved accessibility influence the decisions?
   c) What is the relative importance of public transport as a determinant in possible future relocation or expansion decisions?

9. Impact on employment:
   a) Does rail transit bring about the expansion of the labour market?
b) What do you perceive was the impact of rail transit on employment brought to your firm, and of existing bottlenecks in infrastructure supply?

c) What would be the impacts if infrastructure were improved?

10. What is the travel mode share of your employees? What is the intensity of present use of public transport infrastructure in your firm and what are the satisfaction levels with it?

11. Are there other impacts from the rail transit system on the opportunities, the advantages, the challenges, the major risks, and the market prospects of your firm, in the short term and in the long run?

12. How are the intentions of different stakeholders best coordinated? (For example, different levels of public administration, the transit agencies, and different market actors, the developers, investors, and end-users).

In particular,

a) How best can one attract developers’ and investors’ interests to the rail transit impacted areas? How best can one make the general environment most functional to their interests?

b) How best can one promote the interaction among the different stakeholders? What kind of model do you think can be exploited to improve the cooperation among different stakeholders?

c) How best can one mediate between different interests. What form of development is best encouraged? What kinds of other subsidiary planning strategies should be enacted to facilitate the whole progress?

13. Who are the main beneficiaries from the development value uplift? Are there any mechanisms for the city to keep the value uplift?

14. How best are profits balanced between the winners and losers of the regeneration: in particular, the concerns of the vulnerable local people in the development?

15. In Chongqing, how can the rail transit system promote the city developing into a sustainable urban structure? What do you think is the most appropriate way of extending the city?

16. What best practice could be used from overseas? How could the system be changed?

Signature: __________
Appendix 4: Interviewee list

- Yang Li, Municipal government
- Shengliang Chen, Municipal environment bureau
- Jialong Zheng, Municipal government
- Two anonymous municipal urban planning bureau officers

- Hongfei Tang, Development department of the Chongqing Rail Transit Group Co., Ltd
- Lei Yang, Pre-stage Analysis Department, Chongqing Rail Transit Group Co., Ltd
- Anonymous, Pre-stage Analysis Department, Chongqing Rail Transit Group Co., Ltd

- Biliang Yuan, local housing management bureau
- Maoyu Tian, local urban planning bureau
- Bin Tang, local district government
- Yueying Liu, local district government
- Six anonymous local district government officers

- Jinfang Yang, property developer
- Jun Wang, property developer

- Haizhou Liu, Chongqing Transport Planning Institute
- Zheng Yang, local academic
- Zecheng Xiao, local academic
- Fenglun Tian, local academic

- Twenty two anonymous local residents
References


BANISTER, D. 2007. Land use, planning and infrastructure issues in transport. *commissioned paper for the Shadow Committee on Climate Change, Transport Studies Unit, Oxford University Centre for the Environment, Oxford*.


BOARNET, M. G. & CRANE, R. 2001. Travel by design: the influence of urban form on travel, Oxford University Press on Demand.


BODDY, M., LOVERING, J. & BASSETT, K. 1986. Sunbelt city?: a study of economic change in Britain’s M4 growth corridor, Oxford University Press, USA.


DAVIES, B. 1968. *Social needs and resources in local services: a study of variations in standards of provision of personal social services between local authority areas*, Joseph.


fotheringham, a. s., brunsdon, c. & charlton, m. 2003. *Geographically
weighted regression: the analysis of spatially varying relationships, John Wiley & Sons.


HARVEY, D. 2010. *Social justice and the city*, University of Georgia Press.


KOBYASHI, T. & LANE, B. Spatial heterogeneity and transit use. 11th world


MARTENS, K., GOLUB, A. & ROBINSON, G. 2012. A justice-theoretic approach to the
distribution of transportation benefits: Implications for transportation planning
practice in the United States. Transportation research part A: policy and
practice, 46, 684-695.

MCMILLEN, D. P. & MCDONALD, J. 2004. Reaction of house prices to a new rapid
transit line: Chicago’s midway line, 1983–1999. Real Estate Economics, 32,
463-486.

regeneration: A comparison of London’s Jubilee Line Extension and the Madrid

spatial nonstationarity in multivariate models of air toxic releases. Annals of the
Association of American Geographers, 95, 249-268.

Transportation Research Record: Journal of the Transportation Research Board,
145-153.

MITCHELL, G. 2005. Forecasting environmental equity: air quality responses to road
user charging in Leeds, UK. Journal of Environmental Management, 77,
212-226.

MULLEN, C., TIGHT, M., WHITEING, A. & JOPSON, A. 2014. Knowing their place on
the roads: What would equality mean for walking and cycling? Transportation
research part A: policy and practice, 61, 238-248.

NSS, P. 2009. Residential self - selection and appropriate control variables in land use:
Travel studies. Transport Reviews, 29, 293-324.

using Innovative Transport - Economic and financial dimensions. London:
University College London.

stations. Transportation research record: journal of the transportation research
board, 19-26.

OPENSHAW, S. & TAYLOR, P. J. 1979. A million or so correlation coefficients: three
experiments on the modifiable areal unit problem. Statistical applications in the
spatial sciences, 21, 127-144.

OWENS, S. 1992. Energy, environmental sustainability and land-use planning. In:

PAEZ, A. 2006. Exploring contextual variations in land use and transport analysis using
a probit model with geographical weights. Journal of Transport Geography, 14,
167-176.

Mobility and social exclusion in Canadian communities: An empirical
investigation of opportunity access and deprivation from the perspective of
vulnerable groups. Policy Research Directorate Strategic Policy and Research.
Human Resources and Social Development Canada.

impacts on property values and residents’ location. *Journal of Transport Geography*, 19, 200-211.


SICULAR, T. 2013. The challenge of high inequality in China. Inequality in Focus, 2, 1-5.


THE ECONOMIST. 2016e. Up on the farm. The Economist.
TIRY, C. 2003. Hong Kong’s future is guided by transit infrastructure. Japan Railway &
Transport Review, 35, 28-35.
Economic geography, 46, 234-240.
TOWNROE, P. 1995. The coming of Supertram: the impact of urban rail development in
Transport Geography, 21, 24-30.
VAN WEE, B. 2012. How suitable is CBA for the ex-ante evaluation of transport
projects and policies? A discussion from the perspective of ethics. Transport Policy, 19, 1-7.
VICKERMAN, R. 2008. Transit investment and economic development. Research in
Transportation economics, 23, 107-115.
VICKERMAN, R., SPIEKERMANN, K. & WEGENER, M. 1999. Accessibility and
VICKERMAN, R. W. 1995. The regional impacts of Trans-European networks. The
WANG, D. & CHAI, Y. 2009. The jobs–housing relationship and commuting in Beijing,
behaviour variations in Beijing, China. Journal of Transport Geography, 19,
1173-1186.
WANG, Y., FENG, S., DENG, Z. & CHENG, S. 2016. Transit premium and rent
segmentation: A spatial quantile hedonic analysis of Shanghai Metro. Transport
Policy, 51, 61-69.
WEINBERGER, R. 2001. Light rail proximity: Benefit or detriment in the case of Santa
Clara County, California? Transportation Research Record: Journal of the
Transportation Research Board, 104-113.
New York: Oxford University Press.
WORLD BANK. 1996. Sustainable transport: priorities for policy reform. Development in
Professional Geographer, 68, 338-348.
contribute to growth and development. London: The Royal Town Planning
Institute.


