Technical Appendix

Data Processing

More than 70% of Hong Kong is open space or undeveloped, including country parks and reservoirs. We excluded these areas because they comprise a very small working population and a very small number of jobs. Next, we generated street block (SB) centroids from the remaining urban areas. We divided the working population and job numbers within each tertiary planning unit (TPU) into corresponding SBs in proportion to their areas.

From the census data, data on the working population and job numbers were extracted in conjunction with the transportation data to estimate job accessibility across Hong Kong. The census data were provided at the TPU level. To enable a more geographically detailed estimation of job accessibility, we split the TPU-level census data into SBs using the area-weighted approach, as we also did for the working population and number of jobs.

Since the census data only provided working population and job numbers for 2001 and 2011, we focused on the transportation networks in these years. For the road and bus networks, we collected hardcopies of maps of the road network in 2001 (Hong Kong Directory, 2001) and bus service (lines and stops) in 2004 (Public Transport Atlas, 2004) and 2010[1] (Public Transport Atlas, 2010) from Hong Kong's local atlas of transportation systems and manually digitized these maps. Then, we integrated the digitized bus maps into the mass rapid transit (MTR) networks (by establishing pedestrian links between the two) to represent the public transportation networks in 2001 and 2011.

In the Hong Kong Travel Characteristics Survey (TCS), commuters (i.e., those actively employed, aged 18 years or above, and having commuted on the day of the survey) constituted our main sample pool. Close scrutiny of the data revealed some cases with wrongly coded commute records (e.g., inconsistency in reported trip origin or destination) and other cases where individuals traveled only to non-workplaces. We also removed cases of possible incorrect geocodes and cases involving mixed use of public transportation and private vehicles, both of which are rare in Hong Kong. In

addition, we focused on cases where trip making started and ended at home, which represent the most common scenario. We ultimately retained 20,352 cases from 2002 and 27,036 cases from 2011. Because a comprehensive data set of walk trips from 2011 was not available, we omitted walk trips in the analysis, which may in part have reduced the observed proportion of non-commute travel in the sample.

Modeling Commute Duration

The following equation was used to specify the model for commute duration:

$$C = \beta_j A + \beta_t T + \beta_p X_p + \beta_h X_h + \beta_n X_n + z_1 \quad (1)$$

where C is commute duration; A is job accessibility; T is a dummy variable that represents residing in the new towns; X_p, X_h, and X_n are personal, household, and neighborhood characteristics, respectively; and z_1 is the error term.

Modeling Non-Commute Travel Duration

The structural component of SEM can be expressed in the following form:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (2)$$

where η is the vector of endogenous variables; ξ is the vector of exogenous variables; B is the matrix of coefficients of the endogenous variables; Γ is the matrix of coefficients of exogenous variables; and ζ is the matrix of residuals of the endogenous variables.

In the current study, the relationships between non-commute travel durations and other independent variables can be expressed as three separate equations including Equation (1); the other two are

$$NC = \beta_c C + \beta_p X_p + \beta_h X_h + \beta_w W + z_2 \quad (3)$$

$$W = \beta_p X_p + \beta_h X_h + z_3 \quad (4)$$

where NC is the non-commute travel duration and z_2 and z_3 are the error terms. The rest of the symbols have the same meanings as in Equation 1.

Estimation of Job Accessibility

We used Shen's (1998) gravity-based model to measure job accessibility at the SB level in 2001 and 2011. Note that information on jobs and the working population was not available for 2002, which is why we estimated job accessibility in 2001 to obtain an approximate estimation of the situation in 2002. The equations used to calculate job accessibility by public transportation and private vehicles are as follows:

$$A_i^{pt} = \sum_j \frac{E_j f(c_{ij}^{pt})}{\sum_k [\alpha_k P_k f\left(c_{kj}^{pv}\right) + (1-\alpha_k) P_k f(c_{kj}^{pt})]} \quad (5)$$

and

$$A_i^{pv} = \sum_j \frac{E_j f(c_{ij}^{pv})}{\sum_k [\alpha_k P_k f\left(c_{kj}^{pv}\right) + (1-\alpha_k) P_k f(c_{kj}^{pt})]} \quad (6)$$

where A_i^{pt} and A_i^{pv} are job accessibility by, respectively, public transportation or private vehicles in a given SB, with *i* as commute origin; E_j is the number of jobs in SB, with *j* as commute destination; P_k is the number of workers living in any SB, with *k* representing job seekers; α_k is the proportion of workers who live in SB *k* and commute by private vehicles; and $f(c_{ij}^{pt})$ and $f(c_{ij}^{pv})$ are the impedance functions based on the travel costs of public transportation and private vehicles, respectively, for commuting between SBs *i* and *j* (and between SB *k* and *j* for $f(c_{kj}^{pt})$ and $f(c_{kj}^{pv})$). For Hong Kong with N SBs in 2001 and 2011, $i, j, k = 1, 2, \ldots, N$.

The impedance functions are specified as an exponential form with the base of natural logarithms; that is, $\exp(-\beta T_{ij}^{pt})$ and $\exp(-\beta T_{ij}^{pv})$. β is specified as the inverse of the average journey time[2] by public transportation or private vehicles in Hong Kong, and T_{ij}^{pt} and T_{ij}^{pv} are the commute times of the two modes, which are estimated as the shortest network-based travel time using the OD matrix module in ArcGIS.

References

Hong Kong Directory. (2001). *Hong Kong directory* (7th ed.). Hong Kong: Universal Publications, Ltd. (in Chinese).

Public Transport Atlas. (2004). *Public transport atlas* (1st ed.). Hong Kong: Universal Publications, Ltd. (in Chinese).

Public Transport Atlas. (2010). *Public transport atlas* (6th ed.). Hong Kong: Universal Publications, Ltd. (in Chinese).

Shen, Q. (1998). Location characteristics of inner-city neighborhoods and employment accessibility of low-wage workers. *Environment and Planning B: Planning and Design*, *25*(3), 345–365.

Notes

[1] The 2004 and 2011 bus-network maps were the closest versions for 2001 and 2011, respectively, that could be found at the time of this research.

[2] According to the results of the travel characteristics survey (Transport Department, 2014), the average travel times by public transportation and car were 43 and 24 minutes, respectively, in 2002, and 43 and 26 minutes, respectively, in 2011. These data were used to calculate job accessibility in 2001 and 2011.

Appendix 1: Commuting patterns by public transportation in Hong Kong (2011)

Home location		**Workplace** (% of commuters)					**Average commute duration** (min)	**% of commuters who took non-commute trips**	**Average non-commute travel duration** (min)	**Independency Index**
		SNT	ONT	HKI	KLN	ROS				
New town (N=11,846)	Tsuen Wan (N=2,964)	28.27	9.82	22.57	36.07	3.27	96.51	4.42	36.42	0.21
	Shatin (N=2,877)	18.70	16.61	20.44	41.15	3.09	106.42	3.55	30.73	0.17
	Tuen Mun (N=1,272)	5.58	36.32	18.87	34.75	4.48	127.04	3.46	38.19	0.05
	Tai Po (N=821)	7.55	27.89	17.42	42.75	4.38	121.18	3.65	29.29	0.06
	Fanling/Sheung Shui (N=830)	7.83	35.54	15.78	34.70	6.14	128.32	4.94	30.89	0.06
	Yuen Long (N=402)	8.21	31.09	18.91	34.58	7.21	115.41	3.23	36.19	0.05
	Tseung Kwan O (N=1,726)	5.45	9.91	33.89	48.38	2.38	90.49	2.49	24.33	0.05
	Tin Shui Wai (N=613)	0.49	40.46	18.60	33.77	6.69	131.06	4.89	37.37	0.00
	Tung Chung (N=341)	5.87	16.72	19.06	28.74	29.62	105.40	2.05	27.30	0.05
	Summary (N=11,846)	14.55	19.89	22.04	38.94	4.58	107.94	3.72	33.02	0.12
Urban area (N=12,567)	HK Island (N=4,943)	n.a.	6.37	69.76	22.64	1.23	84.12	4.75	30.75	0.53
	Kowloon (N=7,624)	n.a.	16.75	30.25	50.77	2.23	86.27	4.45	35.64	0.40
	Summary (N=12,567)	n.a.	12.67	45.79	39.71	1.84	85.42	4.57	33.64	0.45
Rural area (N=685)		n.a.	47.88	10.66	30.66	10.80	102.97	1.61	30.02	0.05
Total (N=25,098)		6.87	17.04	33.62	39.10	3.37	96.53	4.09	33.33	0.29

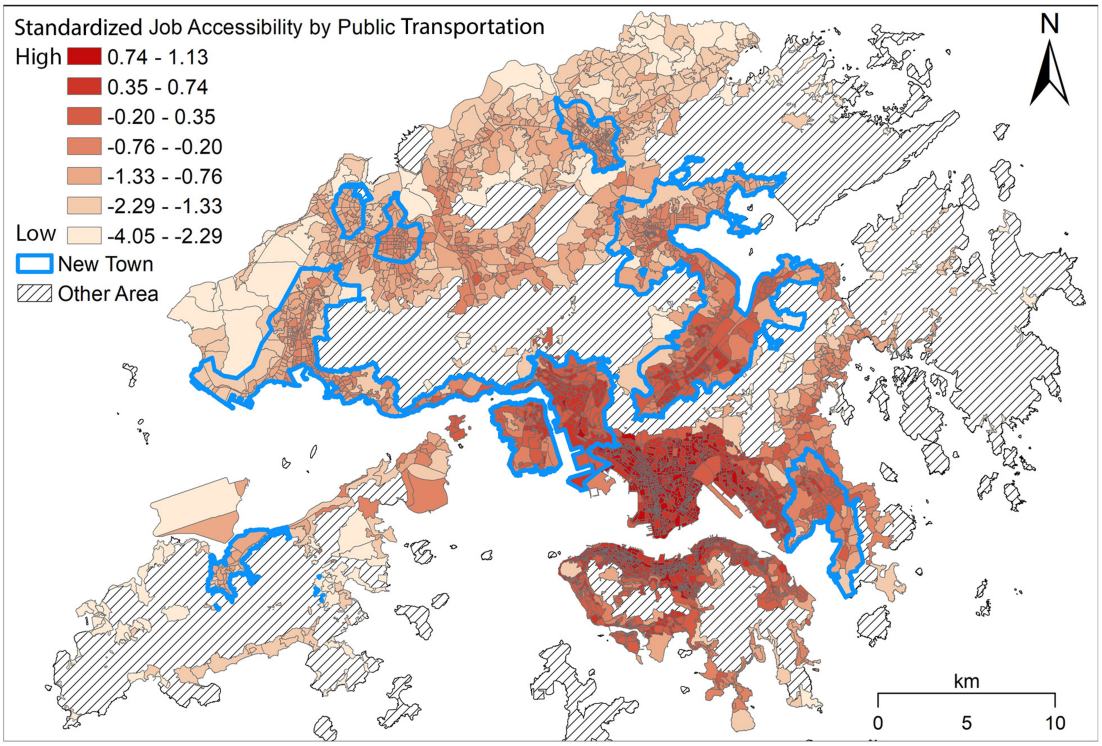
Note: SNT (same new town); ONT (other new town); HKI (Hong Kong Island); KLN (Kowloon); ROS (rural and open space).

Appendix 2: Commuting patterns by private vehicles in Hong Kong (2011)

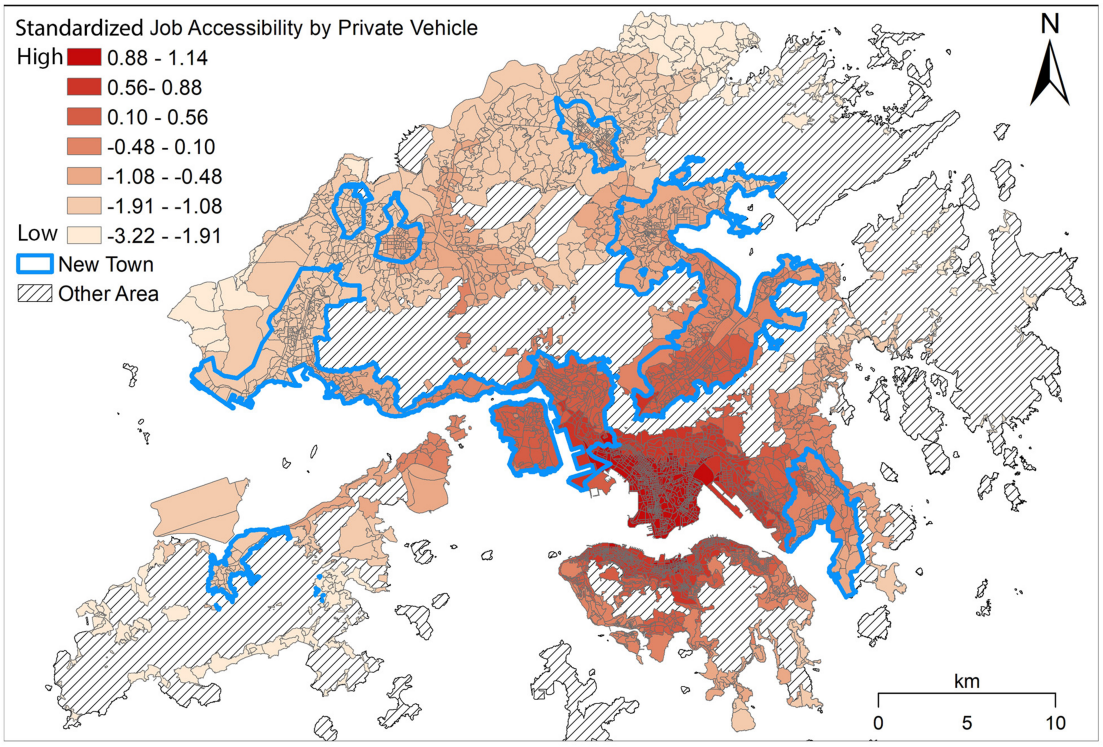
Home location		**Workplace** (% of commuters)					**Average commute duration** (min)	**% of commuters who took non-commute trips**	**Average non-commute travel duration** (min)	**Independency Index**
		SNT	ONT	HKI	KLN	ROS				
New town (N=925)	Tsuen Wan (N=164)	29.27	17.07	6.71	39.02	7.93	64.70	17.07	36.39	0.17
	Shatin (N=228)	16.23	18.86	14.47	42.98	7.46	72.04	14.04	32.81	0.13
	Tuen Mun (N=139)	22.30	28.06	12.23	26.62	10.79	79.39	8.63	48.42	0.18
	Tai Po (N=137)	23.36	32.12	9.49	29.20	5.84	73.15	10.22	24.43	0.20
	Fanling/Sheung Shui (N=68)	10.29	38.24	4.41	22.06	25.00	83.09	7.35	38.40	0.07
	Yuen Long (N=54)	9.26	48.15	7.41	11.11	24.07	64.43	7.41	40.50	0.05
	Tseung Kwan O (N=97)	7.22	20.62	13.40	54.64	4.12	75.12	10.31	29.00	0.06
	Tin Shui Wai (N=31)	0.00	64.52	9.68	6.45	19.35	74.39	9.68	56.33	0.00
	Tung Chung (N=7)	0.00	14.29	28.57	14.29	42.86	65.71	0.00	0.00	0.00
	Summary (N=925)	18.05	26.70	10.70	34.16	10.38	72.73	11.68	35.23	0.13
Urban area (N=716)	HK Island (N=342)	n.a.	13.74	61.99	23.10	1.17	63.56	13.74	32.15	0.62
	Kowloon (N=374)	n.a.	27.01	16.31	50.53	6.15	61.26	14.97	35.51	0.29
	Summary (N=716)	n.a.	20.67	38.13	37.43	3.77	62.36	14.39	33.98	0.40
Rural area (N=297)		n.a.	41.08	18.18	27.95	12.79	79.25	7.07	43.36	0.10
Total (N=1,938)		8.62	26.68	21.98	34.42	8.31	69.90	11.97	35.41	0.23

Note: SNT (same new town); ONT (other new town); HKI (Hong Kong Island); KLN (Kowloon); ROS (rural and open space).

Appendix 3: Standardized job accessibility in 2011



(a)



(b)

Appendix 4: Comparison of job numbers and commuters between 2001 and 2011

Location		**Job numbers**			**Commuters**					
					Public transportation			**Private vehicle**		
		2001	2011	Change (%)	2001	2011	Change (%)	2001	2011	Change (%)
New town	Tsuen Wan	253,622	266,613	12,991 (5.12%)	326,810	351,373	24,563 (7.52%)	26,412	20,704	-5,708 (-21.61%)
	Shatin	105,153	118,250	13,097 (12.46%)	245,269	253,424	8,155 (3.32%)	24,896	23,726	-1,170 (-4.70%)
	Tuen Mun	61,305	65,221	3,916 (6.39%)	195,465	203,935	8,470 (4.33%)	15,427	21,624	6,197 (40.17%)
	Tai Po	41,487	51,022	9,535 (22.98%)	116,541	112,983	-3,558 (-3.05%)	11,127	15,616	4,489 (40.34%)
	Fanling/Sheung Shui	30,155	31,650	1,495 (4.96%)	95,528	102,452	6,924 (7.25%)	6,072	7,014	942 (15.51%)
	Yuen Long	32,434	38,535	6,101 (18.81%)	54,192	65,699	11,507 (21.23%)	4,133	6,122	1,989 (48.12%)
	Tseung Kwan O	18,547	36,641	18,094 (97.56%)	121,403	177,191	55,788 (45.95%)	6,580	10,565	3,985 (60.56%)
	Tin Shui Wai	8349	15,245	6,896 (82.60%)	75,717	124,096	48,379 (63.89%)	3,930	6,235	2,305 (58.65%)
	Tung Chung	2,093	6,711	4,618 (220.64%)	9,341	34,366	25,025 (267.90%)	1,711	1,440	-2,71 (-15.84%)
	Summary	553,145	629,888	76,743 (13.87%)	1,240,266	1,425,519	185,253 (14.94%)	100,288	113,046	12,758 (12.72%)
Urban area	HK Island	736,719	819,159	82,440 (11.19%)	575,563	524,481	-51,082 (-8.88%)	56,615	63,192	6,577 (11.62%)
	Kowloon	863,474	999,431	135,957 (15.75%)	844,919	873,901	28,982 (3.43%)	45,210	49,175	3,965 (8.77%)
	Summary	1,600,193	1,818,590	218,397 (13.65%)	1,420,482	1,398,382	-22,100 (1.56%)	101,825	112,367	10,542 (10.35%)
Rural area		72,604	91,199	18,595 (25.61%)	155,912	182,014	26,102 (16.74%)	33,914	44,113	10,199 (30.07%)

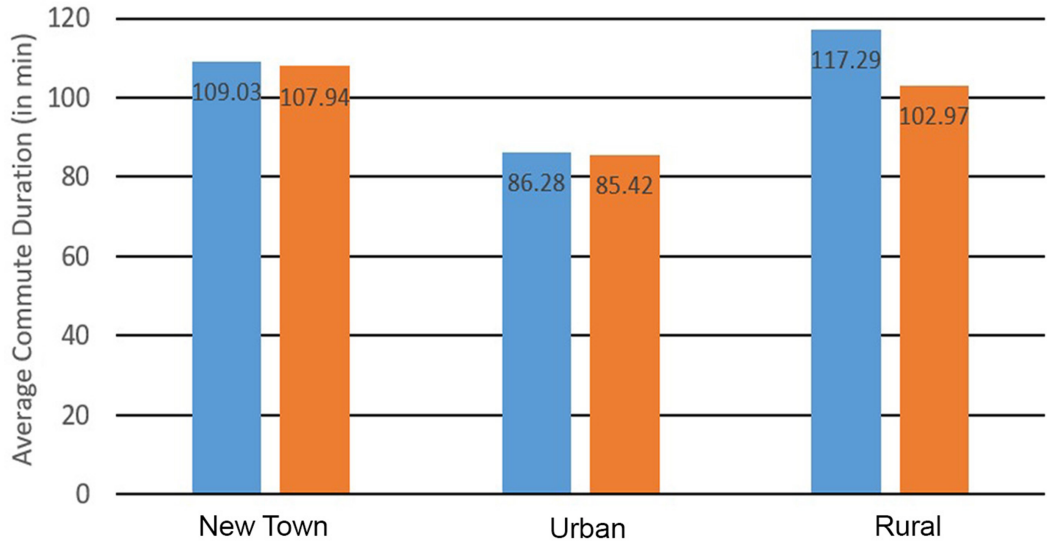
Data source: 2001 and 2011 Census

Appendix 5: Descriptive statistics of the samples

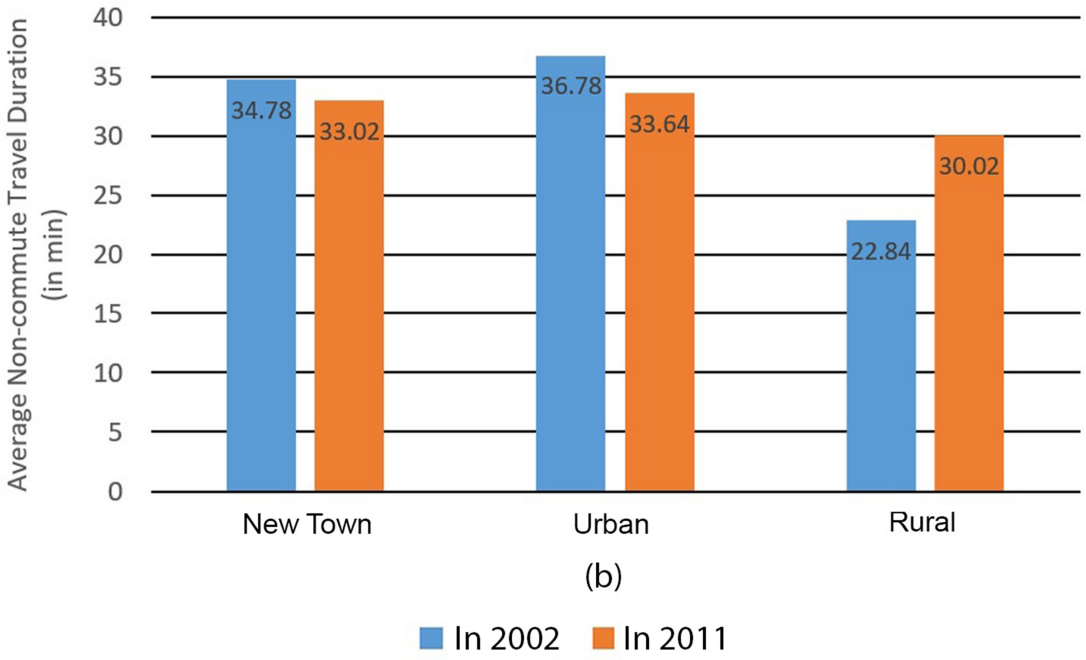
Characteristics	**Year**	
	2002 (N = 20,352)	2011 (N = 27,036)
	Average (or %)	Average (or %)
Personal characteristics		
Male	56.95%	55.25%
Female	43.05%	44.75%
Average age	37.43	40.33
Married	56.47%	55.81%
Single	43.53%	44.19%
Household characteristics		
Living in public housing estates	52.08%	47.26%
Living in private housing estates	47.92%	53.74%
Average household size	3.51	3.32
Having dependent children at home	31.97%	26.53%
Having retired elderly at home	15.12%	16.44%
Having a domestic helper at home	9.26%	10.82%
Having at least one vehicle in the household	15.97%	15.14%
Neighborhood characteristics		
Urban area	48.77%	49.13%
New town	47.01%	47.24%
Rural area	4.22%	3.63%
Average population density $^{\xi}$	51,574	53,355

Note: Variables of household income were not included because more than 10% of the 2002 sample did not report their household income levels. However, we found a stronger correlation between household income and housing type. Furthermore, the modeling results that include the 2011 TCS data indicate that the inclusion of household income did not contribute substantially to the explanatory power of the models. Hence, we did not include the income variable in our final models. The average population density (ξ) is calculated at the street block level.

Appendix 6: Average commute and non-commute travel duration in 2002 and 2011 for public transportation commuters



(a)



(b)

Appendix 7: Modeling results for commute duration for private-vehicle commuters

Variable	**Coefficient estimates**			
	2002 (N = 1,784)		2011 (N = 1,938)	
	Model 1	Model 2	Model 1	Model 2
Age	-0.068**	-0.069**	-0.008	-0.007
Female	-0.021	-0.024	-0.005	-0.008
Married	0.026	0.022	0.019	0.015
Public housing estates	0.004	0.005	0.068***	0.068***
Household size	-0.031	-0.030	-0.052*	-0.046*
Having dependent children	-0.003	-0.008	0.075***	0.070**
Having retired elderly	0.022	0.022	0.051**	0.049**
Having a domestic helper	-0.059**	-0.062**	-0.011	-0.012
Standardized job accessibility	-0.217***	-0.244***	-0.126***	-0.081
Population density (natural log transformed)	0.050	0.076**	0.058*	0.071*
Kowloon	0.022	0.024	-0.009	-0.022
Rural areas	0.017	0.017	0.150***	0.187***
New towns	0.047	--	0.079**	--
Tsuen Wan	--	0.001	--	0.001
Shatin	--	0.072**	--	0.078***
Tuen Mun	--	0.013	--	0.095**
Tai Po	--	0.065*	--	0.069**
Fanling/Sheung Shui	--	0.020	--	0.073**
Yuen Long	--	-0.058*	--	-0.007
Tseung Kwan O	--	-0.011	--	0.053**
Tin Shui Wai	--	0.001	--	0.001
Tung Chung	--	-0.050**	--	-0.007
Model summary				
F	8.95***	6.83***	8.96***	6.44***
Adjusted R^2	0.0548	0.0642	0.0507	0.0557

*** p<0.01; ** p<0.05; * p<0.1

Appendix 8: Modeling results of commute duration for public transportation commuters by main industries

	2002				2011			
Industry	**Number of observations**	**Adjusted R^2**	**Coefficient of new towns**	**Coefficient of standardized job accessibility**	**Number of observations**	**Adjusted R^2**	**Coefficient of new towns**	**Coefficient of standardized job accessibility**
Finance, insurance, real estate, and business services	3,250	0.2317	0.0683***	-0.409***	4,120	0.2489	0.131***	-0.382***
Manufacturing	2,177	0.1248	0.146***	-0.263***	845	0.1789	0.083**	-0.358***
Transportation, storage, and communications	1,833	0.1071	0.041	-0.316***	3,066	0.1066	0.116***	-0.245***
Wholesale, retail, import/export trades, accommodation, and food services	4,990	0.1358	0.130***	-0.278***	7,606	0.1461	0.107***	-0.306***
Community, social, and personal services	3,401	0.0944	0.0868***	-0.250***	6,698	0.1181	0.111***	-0.248***

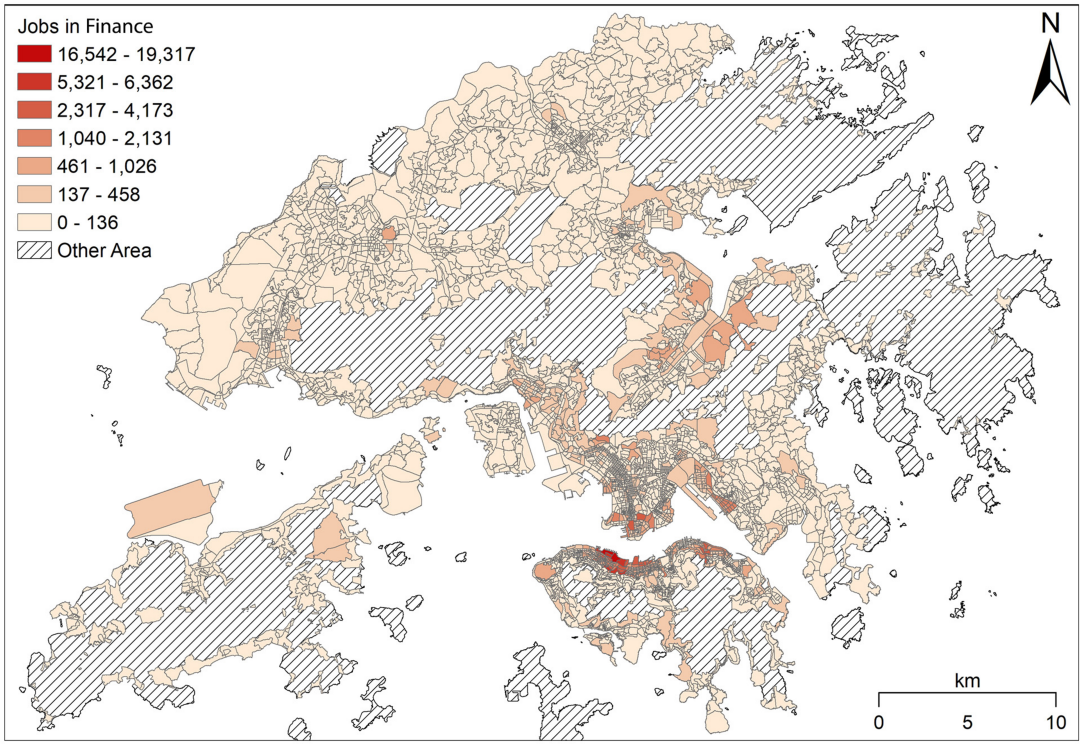
*** p<0.01; ** p<0.05; * p<0.1

Appendix 9: Modeling results for commute duration for private vehicle commuters of different industries

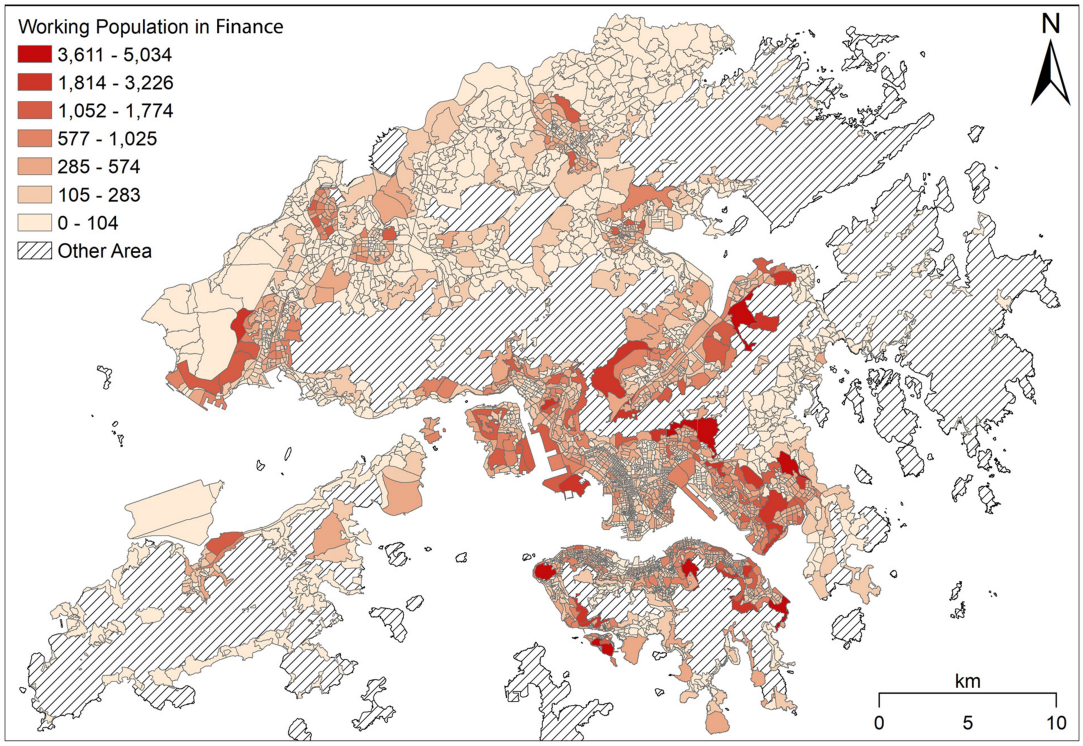
	2002				2011			
	Number of observations	**Adjusted R^2**	**Coefficient of new towns**	**Coefficient of standardized job accessibility**	**Number of observations**	**Adjusted R^2**	**Coefficient of new towns**	**Coefficient of standardized job accessibility**
Finance, insurance, real estate, and business services	173	0.2378	-0.045	-0.517***	299	0.2109	-0.006	-0.392***
Manufacturing	233	0.0335	0.143*	-0.161**	80	0.1115	0.300**	0.032
Transportation, storage and communications	185	0.0270	0.007	-0.254**	245	0.0789	-0.029	-0.218**
Wholesale, retail, import/export trades, accommodation, and food services	335	0.0689	-0.001	-0.263***	494	0.0721	0.059	-0.187***
Community, social, and personal services	492	0.0409	0.001	-0.075	525	0.0079	0.053	-0.082

*** p<0.01; ** p<0.05; * p<0.1

Appendix 10: Spatial distribution of jobs and working population in the finance industry

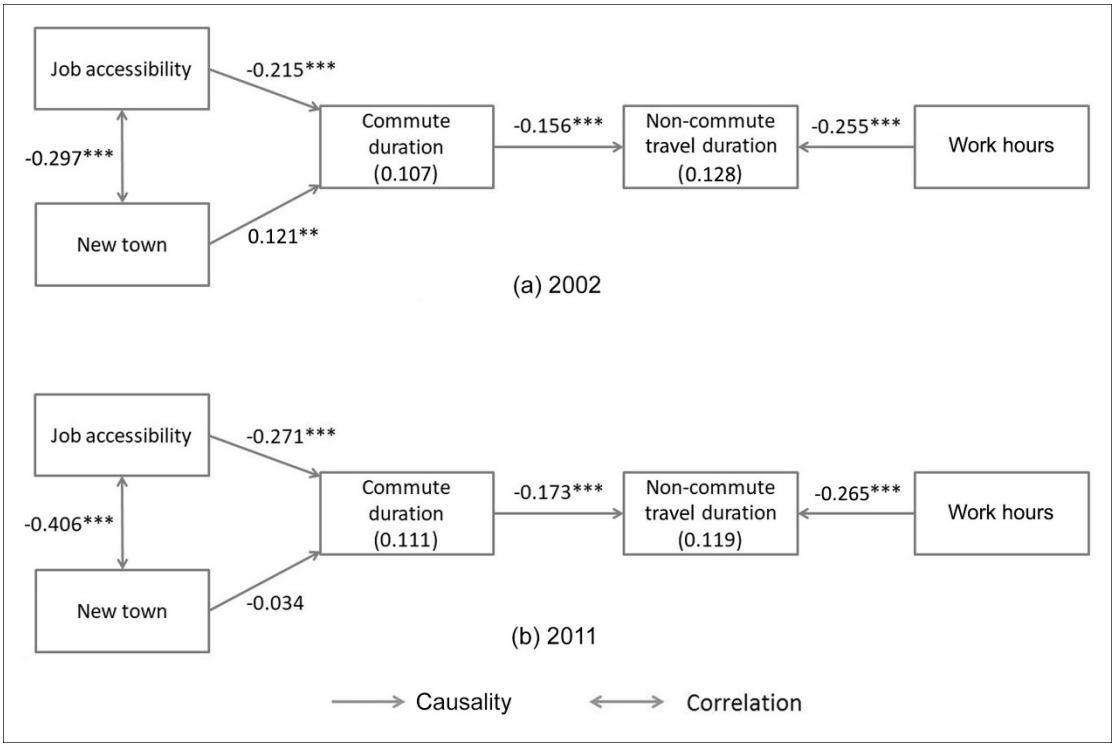


(a)



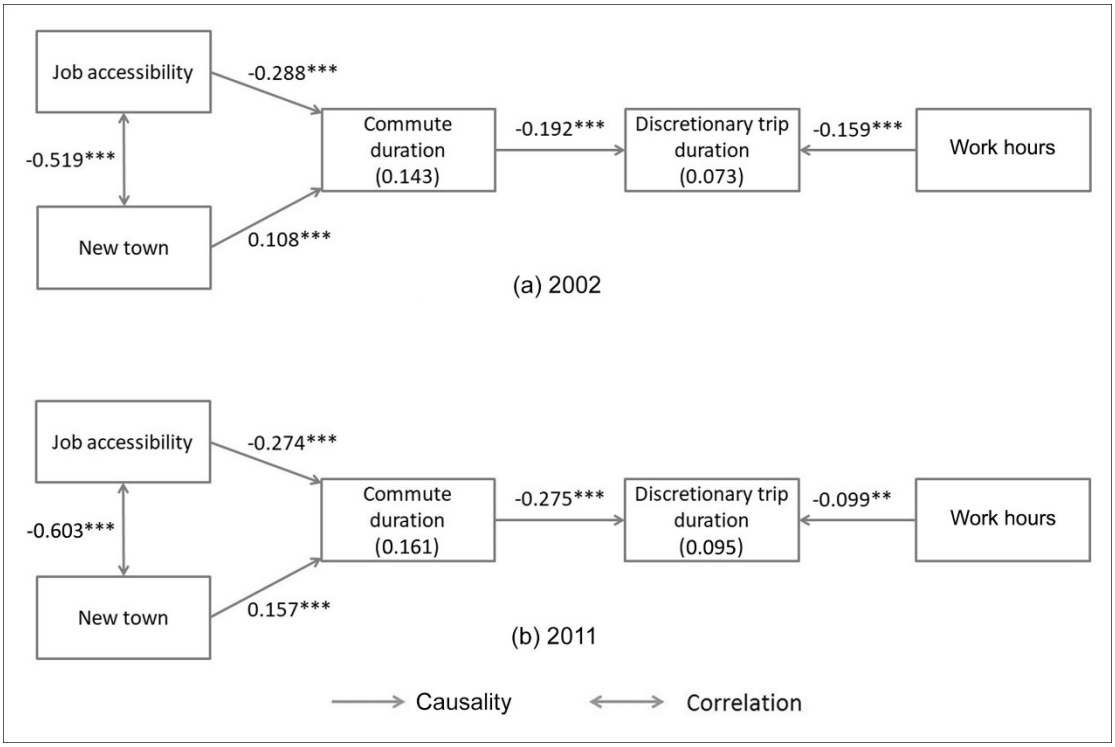
(b)

Appendix 11: Modeling results for non-commute travel duration for private-vehicle commuters



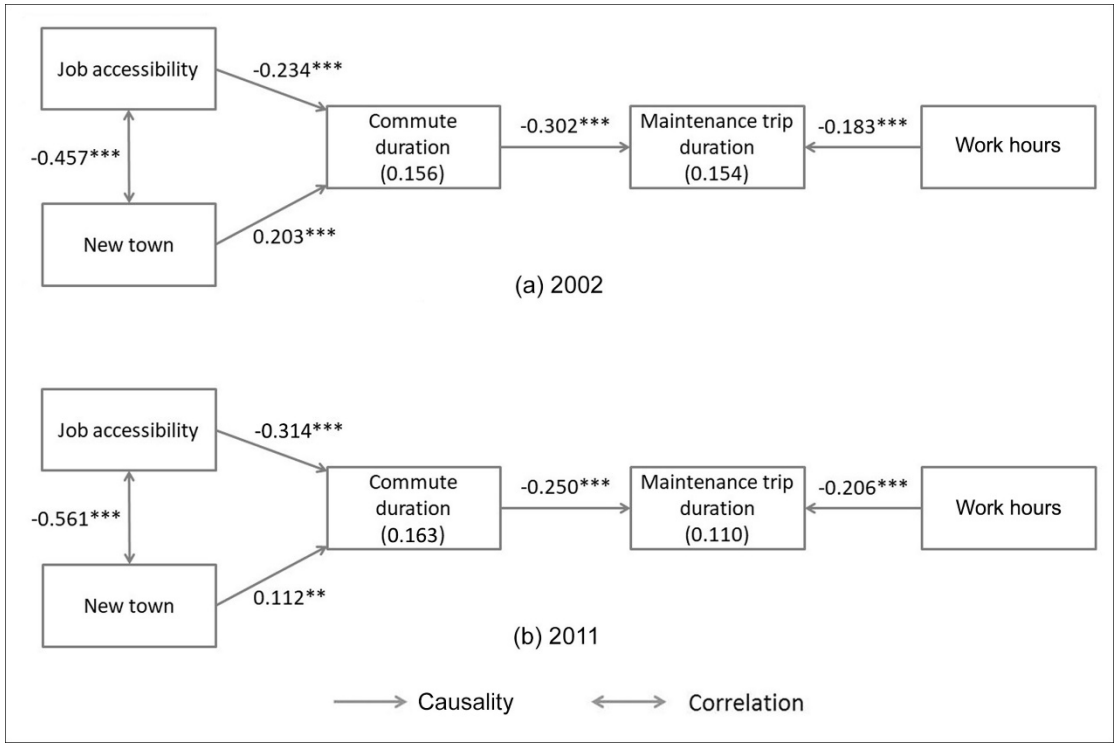
Note:
*** p < 0.01; ** p < 0.05; * p < 0.1.
Numbers in parentheses refer to the percentage of variance explained.
Model fit for Model (a): N = 367, df = 18, CFI = 0.963, RMSEA = 0.056, $\chi 2 = 38.864$, $p<0.001$, $\chi 2/df = 2.159$.
Model fit for Model (b): N = 232, df = 18, CFI = 0.934, RMSEA = 0.076, $\chi 2 = 42.146$, $p<0.001$, $\chi 2/df = 2.341$.

Appendix 12: Modeling results of discretionary trip duration for public-transportation commuters



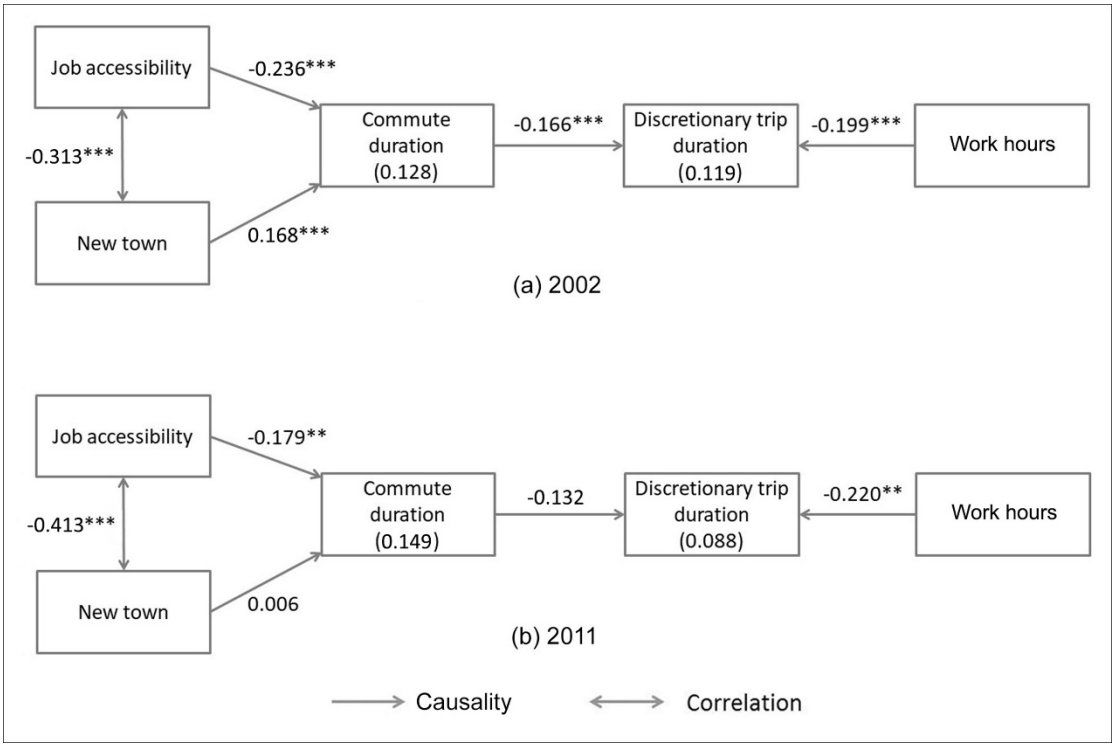
Note:
*** p < 0.01; ** p < 0.05; * p < 0.1.
Numbers in parentheses refer to the percentage of variance explained.
Model fit for Model (a): N = 917, df = 18, CFI = 0.962, RMSEA = 0.058, $\chi 2$ = 74.173, p<0.001, $\chi 2$/df = 4.121.
Model fit for Model (b): N = 643, df = 18, CFI = 0.985, RMSEA = 0.040, $\chi 2$ = 36.201, p<0.001, $\chi 2$/df = 2.011.

Appendix 13: Modeling results of maintenance trip duration for public-transportation commuters



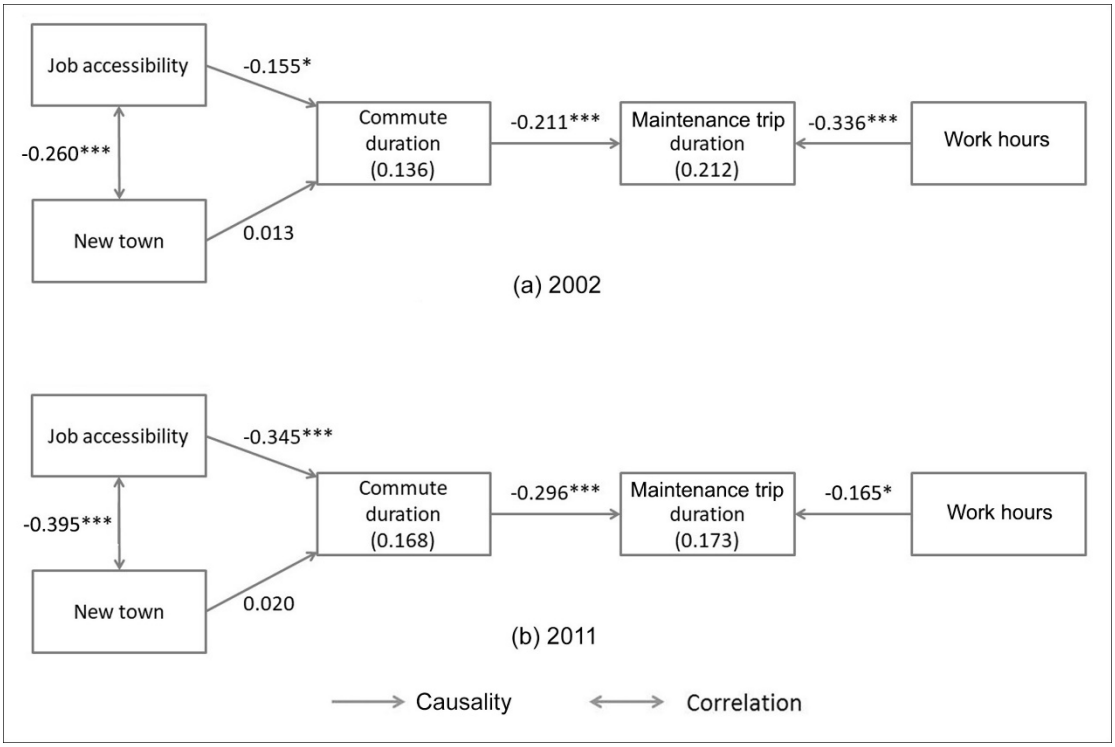
Note:
*** p < 0.01; ** p < 0.05; * p < 0.1.
Numbers in parentheses refer to the percentage of variance explained.
Model fit for Model (a): N = 435, df = 18, CFI = 0.985, RMSEA = 0.037, $\chi 2 = 28.806$, $p<0.001$, $\chi 2/df = 1.600$.
Model fit for Model (b): N = 421, df = 18, CFI = 0.990, RMSEA = 0.032, $\chi 2 = 25.665$, $p<0.001$, $\chi 2/df = 1.426$.

Appendix 14: Modeling results for discretionary trip duration for private-vehicle commuters



Note:
*** p < 0.01; ** p < 0.05; * p < 0.1.
Numbers in parentheses refer to the percentage of variance explained.
Model fit for Model (a): N = 250, df = 18, CFI = 0.983, RMSEA = 0.039, $\chi 2 = 24.923$, $p<0.001$, $\chi 2/df = 1.385$.
Model fit for Model (b): N = 136, df = 18, CFI = 0.928, RMSEA = 0.073, $\chi 2 = 31.082$, $p<0.001$, $\chi 2/df = 1.727$.

Appendix 15: Modeling results for maintenance trip duration for private-vehicle commuters



Note:
*** p < 0.01; ** p < 0.05; * p < 0.1.
Numbers in parentheses refer to the percentage of variance explained.
Model fit for Model (a): N = 141, df = 18, CFI = 0.940, RMSEA = 0.069, $\chi 2 = 30.106$, $p<0.001$, $\chi 2/df = 1.673$.
Model fit for Model (b): N = 112, df = 18, CFI = 0.844, RMSEA = 0.122, $\chi 2 = 47.663$, $p<0.001$, $\chi 2/df = 2.648$.