CARS
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Decarbonising Urban Mobility: Insight from the Adoption of Flexible Working Arrangements in Greater Klang Valley

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Challenges in urban transport

- By 2050, the urban population is expected to grow by over 40 percent
- Due to rapid urbanization, 70% of the world's population living in the big city
- There will be a greater demand for travel for work, education, social services, and recreation resulting in exponential growth of passenger transport demand by nearly 75 percent from 2019 to 2050.

- Increase of GDP and purchasing power that increases private motor vehicle ownership.
- Private vehicles offer higher movement flexibility that results in decreasing in public transport use.

Figure 1: Traffic congestion in Bandar Sunway

The burden of car-centric urban mobility

- Climate change: transport is world's largest source of GHG emissions, contributing 23% of global greenhouse gas emission
- Between 60-70 percent comes from land transportation
- Air quality: air pollution levels exceed safe levels in many cities, leading to premature deaths
- Noise: 40% of city dwellers are exposed to dangerous levels of road traffic-related noise, impacting mental health and well-being
- Congestion: the average person living in Kuala Lumpur spends 81 hours in traffic congestion yearly, leading to a loss of productivity.
- Congestion and other externalities cost $5bn per year

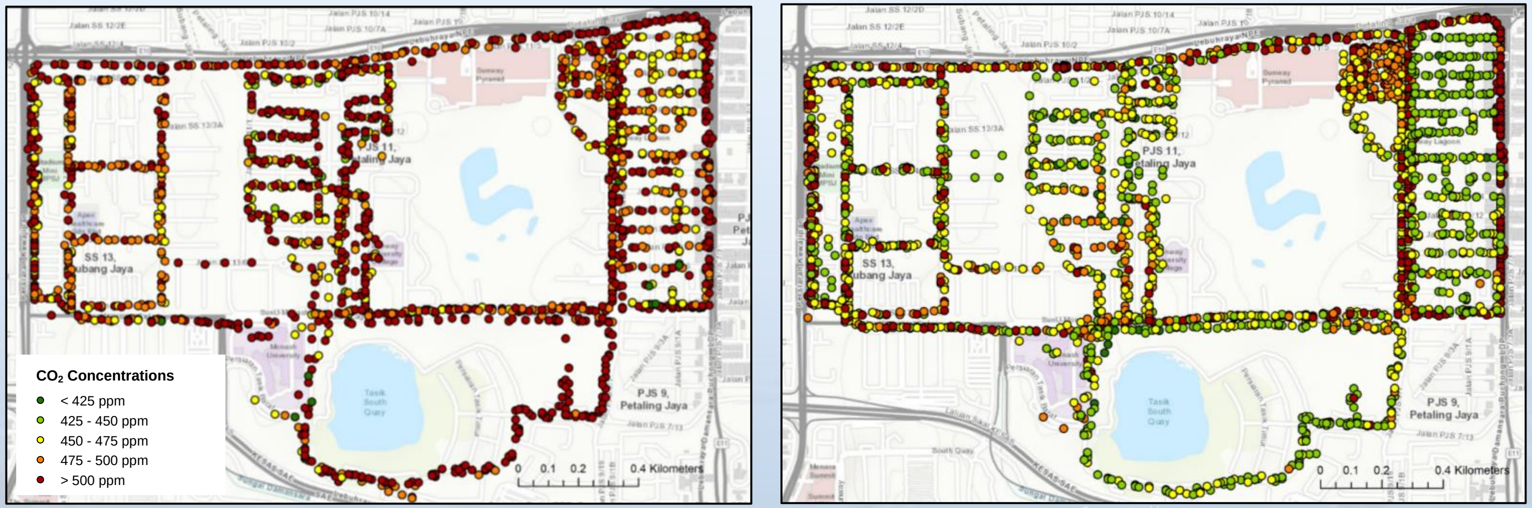


Figure 2: Observed CO2 concentration in Bandar Sunway during morning and evening peak hours

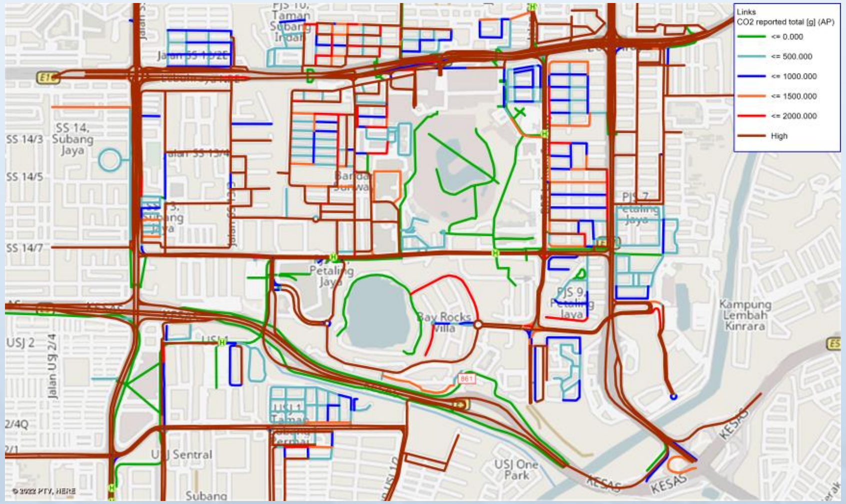


Figure 3: Observed CO2 concentration in Bandar Sunway from traffic simulation

Urban transportation transformation

Paradigm shift from a vehicle-centric approach to a people-centric approach

	Old paradigm – vehicle centric	New paradigm – people centric
Definition of transportation	Mobility (physical travel), mainly automobile travel	Accessibility
Modes considered	Mainly automobile	Multimodal, walking, cycling, public transport automobile, telework and delivery services
Objectives	Congestion reduction, roadway cost savings, vehicle cost savings, reduced crash and emission rates per vehicle-kilometer	Congestion reduction, road and parking savings, consumer saving and affordability, accessibility for non-drivers, safety and security, energy conservation and emission reductions, public fitness and health, efficient land use (reduced sprawl)
Impacts considered	Travel speeds and delay, vehicle operating costs and fares, crash and emission rates	Various economic, social and environmental impacts, including indirect impacts (health etc.)
Favored improvements	Roadway capacity expansion	Improve transport options (walking, cycling, public transit etc.). Transportation demand management, more accessible land development
Performance indicators	Vehicle travel speeds, roadway level of service (LOS), distance based crash and emission rates	Quality of accessibility for various groups, multimodal LOS, various economic. Social and environmental impacts

Introduction

Malaysian traffic is becoming worst with the passage of time.

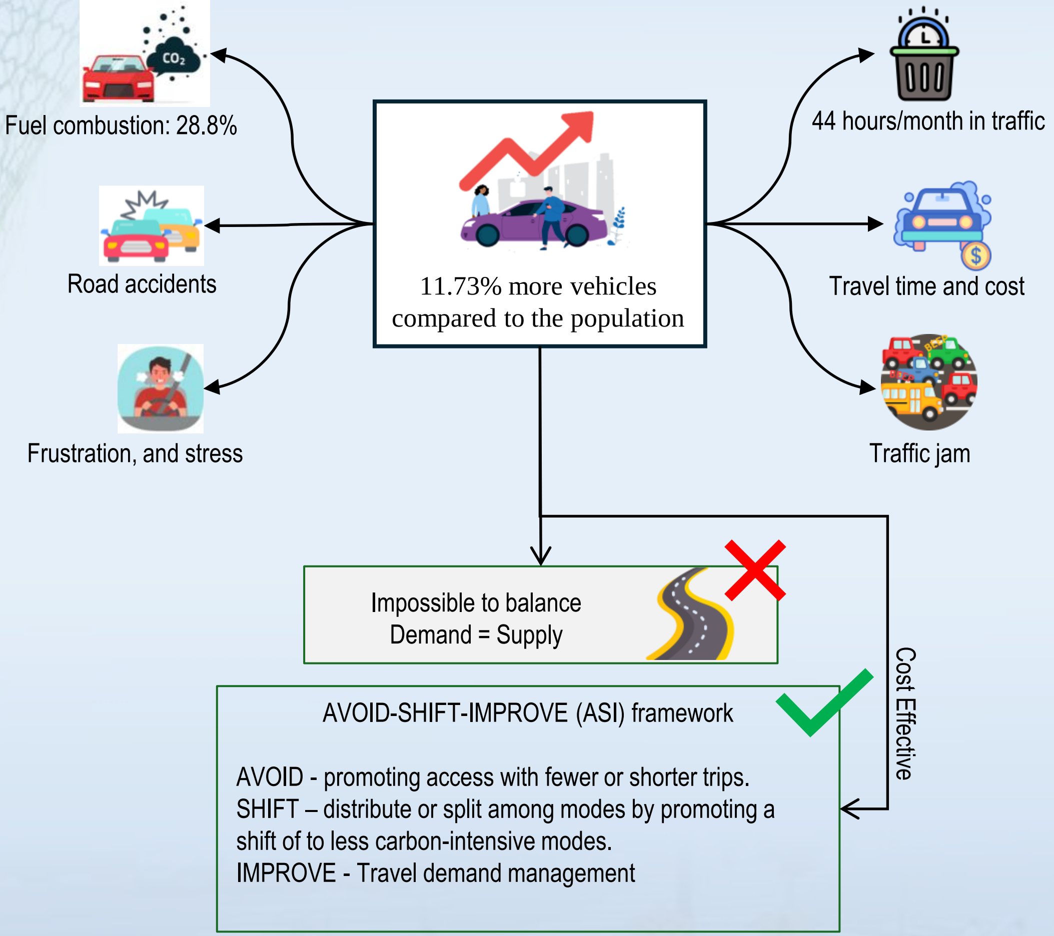


Figure 4: ASI framework

COVID-19

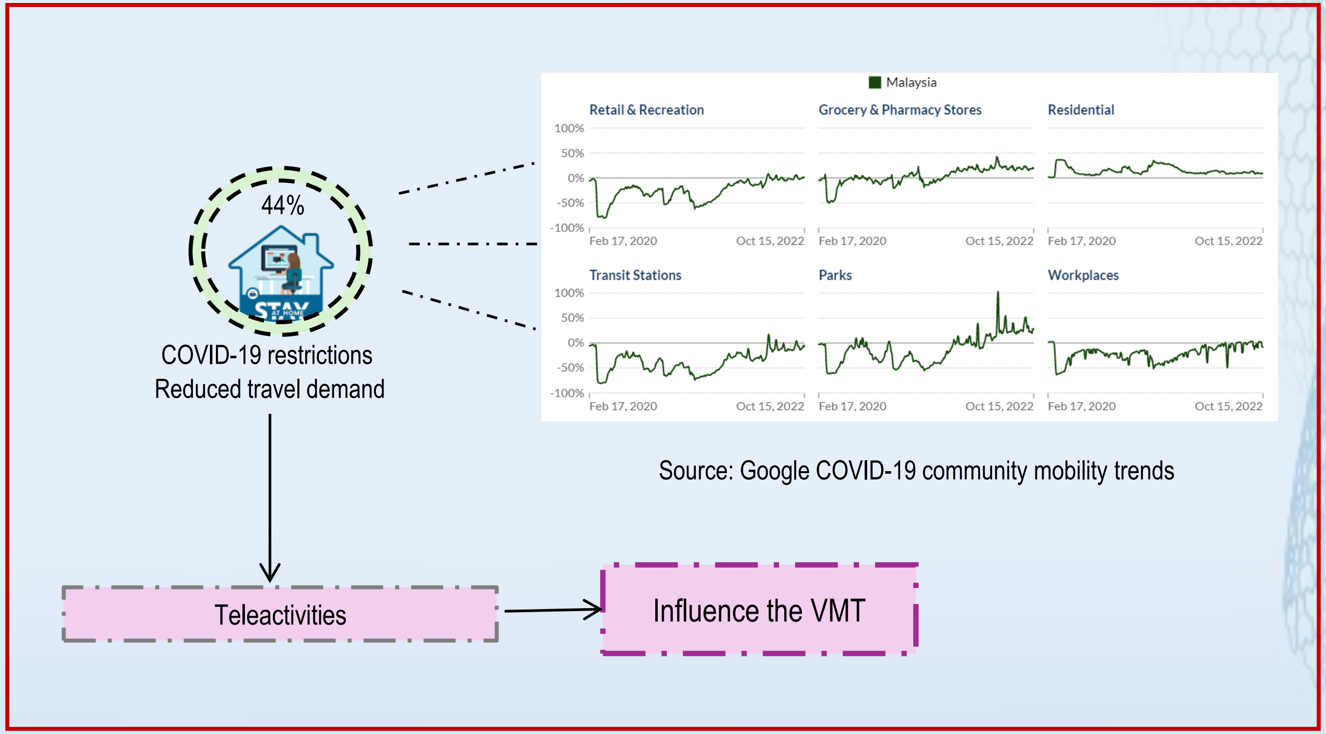


Figure 5: COVID-19 Travel Demand

AVOID measures - Teleactivities

Teleactivities are activities that can be performed remotely that promote access with fewer or shorter trips

1. Substitute trips: a location-based trip is replaced by a virtual one such as work from home.
2. Complement trips: engaging virtually can lead to additional trips that would have not occurred otherwise.
3. Modify trips: there is no replacement or additional trips but there are changes in timing, modes, and so on.
4. Be neutral: the use of teleactivities does not impact another personal activity.

AVOID measures - Teleactivities

Teleworking/work from and flexible working arrangements (FWAs)

For a 10 km commute in Kuala Lumpur, what do commuters stand to save per year by adopting teleworking?

One day of working from home (Wednesdays)		
37 hours	193 MYR	170 kg
Three days of working from home (Wednesdays, Tuesdays, Thursdays)		
110 hours	575 MYR	509 kg

Figure 6. Saving per year by adopting teleworking (Tom Tom Traffic Index 2024)

The shift of workers' departure time when adopting teleworking and FWAs in greater Klang Valley

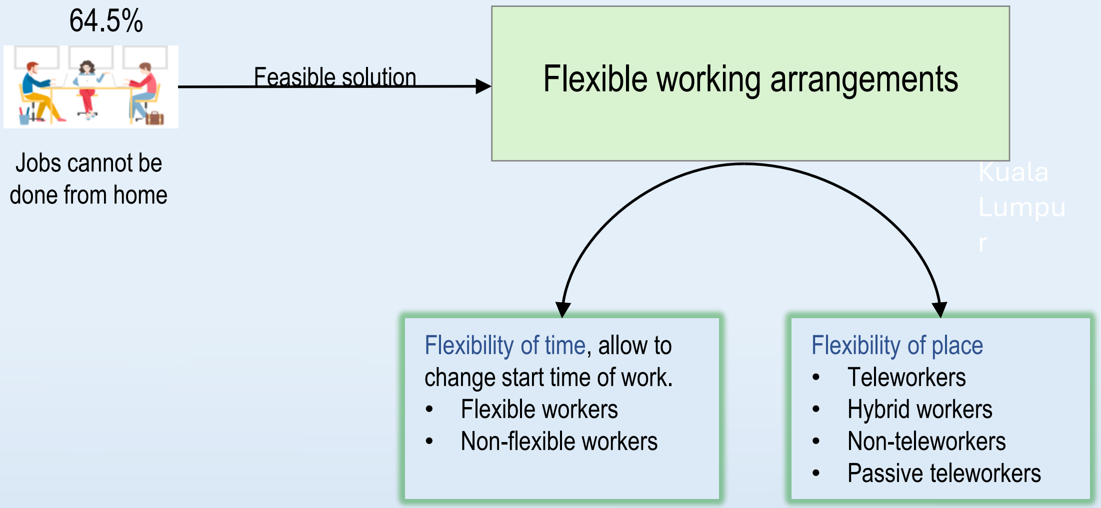
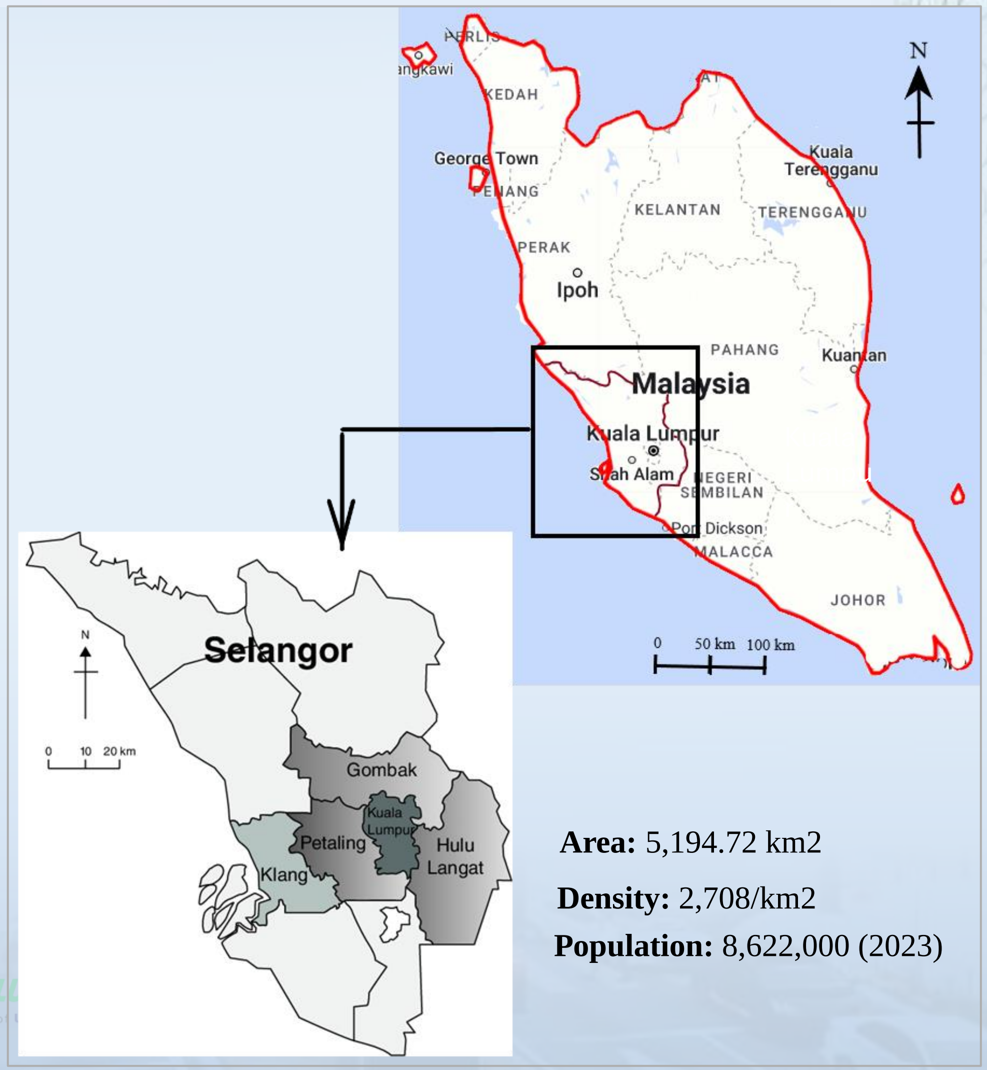


Figure 7. Flexible working arrangements

Data Collection

- Greater Kuala Lumpur: Geographical term determining the boundaries of Metropolitan Kuala Lumpur in Malaysia.
- Reason: Malaysia’s commercial, administrative, and financial hub.
- Technique: Snowball sampling
- Duration: 10th of June 2023 to 20th of July 2023.
- Collection Platforms: Online platforms, Sharing QR and link.
- Valid responses: 1597



Area: 5,194.72 km2

Density: 2,708/km2

Population: 8,622,000 (2023)

Figure 8: Map of Greater Kuala Lumpur (Hamid et al., 2017).

Data Descriptives

Table 1: Proportion and median of the variables belonging to workers categories.

Variables	Category	Overall	Non-teleworkers	Hybrid workers	Passive teleworkers
Gender	Male	44.75	39.34	53.87	52.73
	Female	55.25	60.66	46.13	47.27
Age	18–22	2.19	1.02	4.64	3.03
	23–30	23.82	24.62	24.46	18.79
	31–40	39.58	40.61	36.84	40.00
	41–50	24.06	24.75	21.36	26.06
	51–60	9.01	7.87	10.84	10.91
	Older than 60	1.33	1.14	1.86	1.21
Education	Lower level	13.09	17.64	5.57	6.06
	Bachelor's degree	39.42	43.40	35.29	28.48
	Postgraduate degree	27.82	28.93	26.01	26.06
	Doctoral degree	19.67	10.03	33.13	39.39
Occupation	Clerical or administrative support	12.77	16.75	6.81	5.45
	Hospital or healthcare	14.58	21.45	4.64	1.21
	Maintenance	4.47	4.44	5.57	2.42
	Managerial, or technical	23.67	26.78	18.27	19.39
	Manufacturing or construction	5.17	6.09	3.41	4.24
	Private business owner	2.43	1.27	4.33	4.24
	Sales or service	3.92	3.43	5.26	3.64
	Teacher, lecturer or professor	26.65	11.93	47.68	55.76
	Others	6.35	7.87	4.02	3.64
Monthly income	Under RM 2000	6.11	5.20	7.43	7.88
	RM 2001–RM 4000	26.49	32.87	17.34	13.94
	RM 4001–RM 6000	24.45	26.40	21.98	20.00
	RM 6001–RM 8000	17.55	14.47	21.36	24.85
	Above RM 8000	25.39	21.07	31.89	33.33
Total		1276	788	323	165

Variables	Category	Overall	Non-teleworkers	Hybrid workers	Passive teleworkers
Household location	CBD	3.61	4.19	3.10	1.82
	Rural	5.80	5.71	6.19	5.45
	Semi-urban	28.21	26.40	32.51	28.48
	Urban	62.38	63.71	58.20	64.24
Workplace location	CBD	11.99	14.59	7.74	7.88
	Rural	6.03	5.46	6.81	7.27
	Semi-urban	17.01	12.82	24.15	23.03
	Urban	64.97	67.13	61.30	61.82
Flex time working	Flex-time	27.43	11.93	50.77	55.76
	Fixed-time	72.57	88.07	49.23	44.24
Car ownership	Yes	96.39	97.08	95.05	95.76
	No	3.61	2.92	4.95	4.24
Travel mode for work trips	Private transport	90.05	90.99	87.93	89.70
	Paratransit	0.78	0.63	1.55	
	Public transport	7.05	6.73	8.36	6.10
	Non-motorised transport	2.12	1.65	2.17	4.20
Total		1276	788	323	165

Cox proportional hazards model

- Time frame: 24 hours
- Dependent variable: Duration until a worker leaves.

Generalised mixed-effects hazard model equation:

$$h(t; G, A, Inc, Edu, Occ, HHL, CO, TM, WL, DWFH, MT, TT, TD, \alpha_j) = h_0(t)\left[e^{(\beta_G G+\beta_A A+\beta_{Inc} Inc+\beta_{Edu} Edu+\beta_{Occ} Occ+\beta_{HHL} HHL+\beta_{CO} CO)} \times e^{(\beta_{TM} TM+\beta_{WL} WL+\beta_{DWFH} DWFH+\beta_{MT} MT+\beta_{TT} TT+\beta_{TD} TD+\alpha_j)}\right]$$

where;
t = time until the departure occurs.
$h_0(t)$ = baseline hazard, represents hazard at the time t when all covariates are zero.
β = coefficients that quantify the impact of covariates on the hazard rate.
α_j = random effect associated with the j^{th} cluster in the dataset.

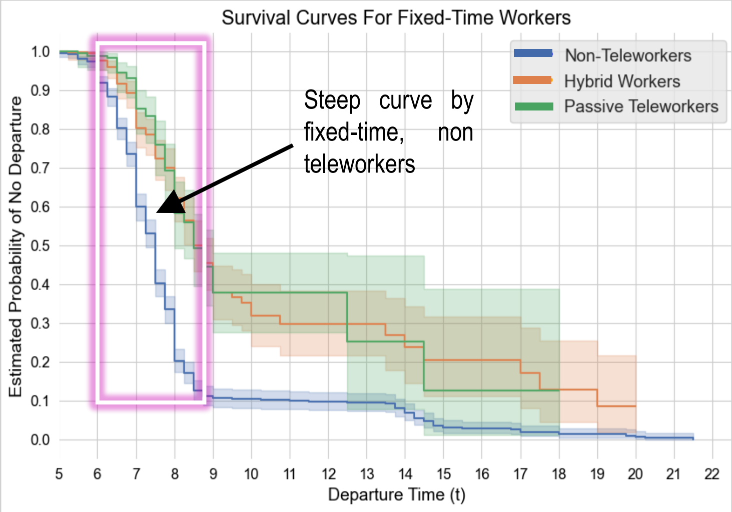
Table 2: Covariates for Cox proportional hazards model.

Variables type	Variables	Categories
Categorical covariate	G: Gender	(1) Male, (2) Female
	A: Age	(1) Younger: 18 to 30, (2) Middle: 31 to 50, (3) Higher: 51 to above
	Inc: Income	(1) Lower: 0 to 4000, (2) Middle: 4000 to 8000, (3) Higher: above 8000
	Edu: Education	(1) Lower level: High school, Diploma holder, College level, (2) bachelor's degree, (3) Postgraduate degree, (4) Doctoral degree
	Occ: Occupation	(1) Clerical or administrative support, (2) Hospital or healthcare, (3) Maintenance, (4) Managerial or technical, (5) Manufacturing or construction, (6) Private business owner, (7) Sales or service, (8) Teacher, lecturer, or professor, (9) Others
	HHL: Household location	(1) Rural, (2) Semi-urban, (3) Urban, (4) CBD
	CO: Car ownership	(1) Yes, (2) No
	TM: Travel mode	(1) Private: Private car, Motorcycle; (2) Paratransit: Taxi, Grab taxi, Rental car; (3) Public: MRT, LRT or Bus, Train; (4) Non-motorised: Walk, Bicycle
	WL: Workplace location	(1) Rural, (2) Semi-urban, (3) Urban, (4) CBD
Continuous covariate	DWFH: Number of the days WFH MT: Maximum trips per day TT: Travel duration (min) TD: Travel distance (km)	

Note: The variables notation is provided along with each variable to construct the model equation

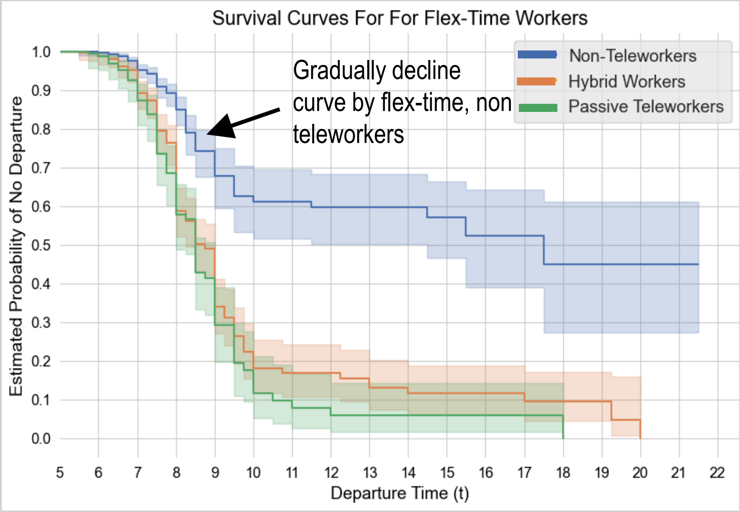
Results

Inter-worker comparison



χ^2 = 126.54, P = 0.00

χ^2 = 76.63, P = 0.00



χ^2 = 76.70, P = 0.00

χ^2 = 71.90, P = 0.00

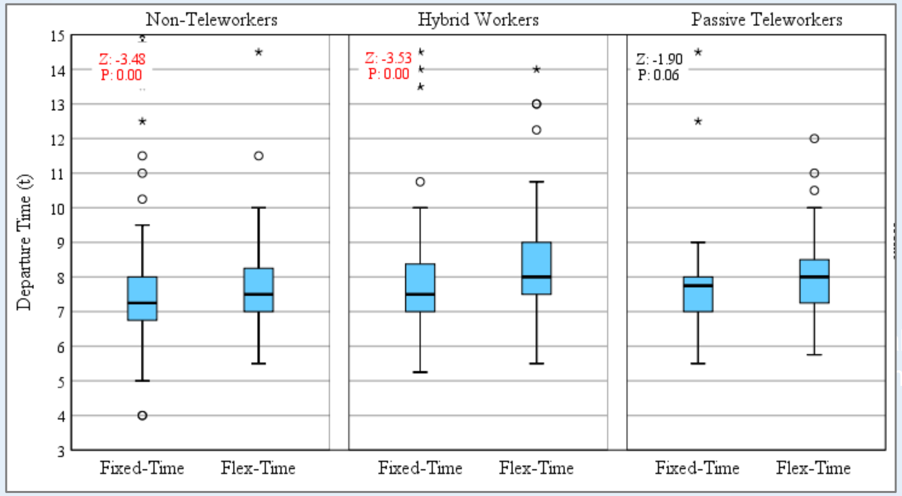


Figure 9: Box plots for fixed-time and flex-time workers.

- Peak departure time for the fixed and flex-time workers are 6:45 to 8:15 and 7:00 to 9:00.
- Around 40% of fixed-time and 5% of flex-time non-teleworkers departed from 7:00 to 8:00.
- The flex-time non-teleworkers (MT: 7:30) departed later than fixed-time non-teleworkers (MT: 7:15).
- Fixed-time non-teleworkers contribute most to peak-hour travel demand.

Results

Non-teleworkers

- All workers significantly influenced by education level, occupation, house location, and travel duration.

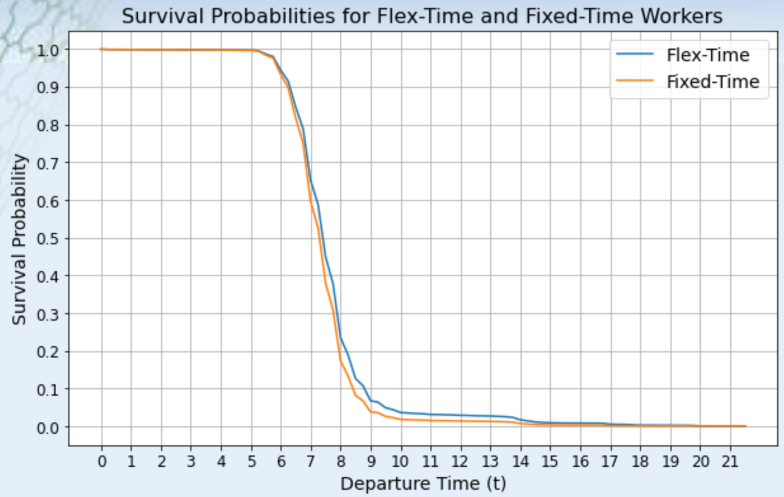
Fixed-time:

- Also influenced by travel mode and travel distance.
- Hospital or healthcare depart pre-peak shoulder hours.
- Teachers or professors likely to depart post-peak shoulder hours.
- Clerical workers likely depart during peak.
- Urban residents delay their departure than CBD residents.
- Paratransit (MT : 7:00) users likely to depart earlier.
- Longer travel distance and duration results in earlier departure.

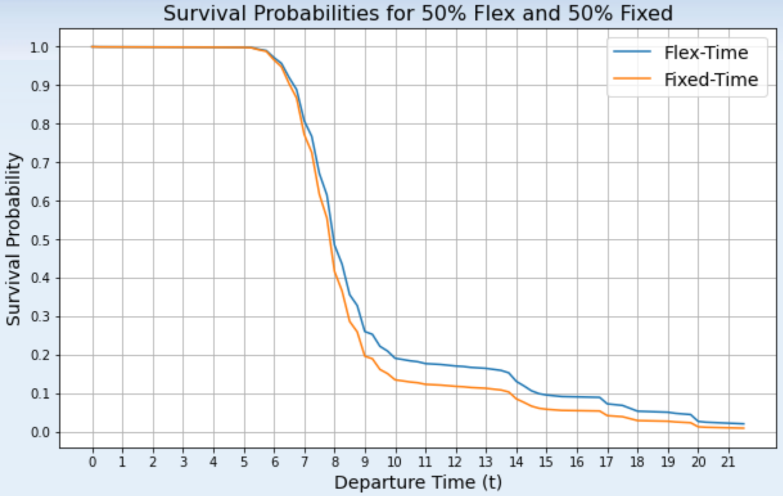
Variable	Category	Non teleworkers			
		M4: Fixed-time		M5: Flex-time	
		HR	p	HR	p
Gender	Male	🔴 0.94	0.43	🟢 1.08	0.71
Age	Younger	🟡 1.00	0.98	🔴 0.96	0.87
	Middle	Reference category			
	Older	🔴 0.86	0.23	🟢 1.51	0.14
Income	Lower	Reference category			
	Middle	🟢 1.18	0.13	🟢 1.24	0.35
	Higher	🟢 1.04	0.74	🟢 1.07	0.80
Education	Lower level	🟢 **1.62**	**0.00**	🔴 0.58	0.10
	Bachelor's	🟢 1.19	0.17	🔴 **0.64**	**0.04**
	Postgraduate	🟢 1.25	0.08	🔴 **0.53**	**0.01**
Occupation	Hospital	🟢 **1.38**	**0.01**	🟡 1.00	1.00
	Maintenance	🔴 0.67	0.07	🟢 1.51	0.26
	Managerial	🔴 0.88	0.24	🔴 0.87	0.61
	Manufacturing	🔴 0.95	0.76	🟢 2.01	0.11
	Private business	🔴 **0.54**	**0.02**	🟢 1.89	0.31
	Sales or service	🔴 0.97	0.86	🟢 1.36	0.60
	Teacher	🔴 **0.69**	**0.03**	🟢 2.15	**0.00**
	Others	🔴 0.86	0.21	🟢 1.43	0.36
Household location	Urban	🔴 **0.56**	**0.05**	🟢 **4.12**	**0.00**
	Rural	🟢 1.19	0.28	🟢 1.05	0.90
	Semi-urban	🔴 0.84	0.06	🔴 0.96	0.87
Car ownership	Yes	🔴 0.72	0.26	🟢 1.80	0.25
Travel mode	Paratransit	🟢 **4.13**	**0.02**		
	Public	🟢 1.05	0.76		
	Non-motorised	🟢 1.44	0.10		
Workplace location	Urban	Reference category		🔴 0.81	0.47
	Rural	🔴 0.73	0.09	🔴 0.98	0.95
	Semi-urban	🔴 **0.70**	**0.03**	🟡 1.00	0.99
	CBD	🔴 0.98	0.87		
Days WFH					
Maximum trips per day		stratified		🟢 1.09	0.13
Travel duration (min)		🟢 **1.01**	**0.00**	🟢 **1.01**	**0.02**
Travel distance (km)		🟢 **1.02**	**0.00**		

Note:
(1) 🟢 represents hazard > 1, meaning earlier departure than the reference category.
(2) 🔴 represents hazard < 1, meaning delay in departure than the reference category.
(3) 🟡 represents hazard = 1, meaning no difference in departure.

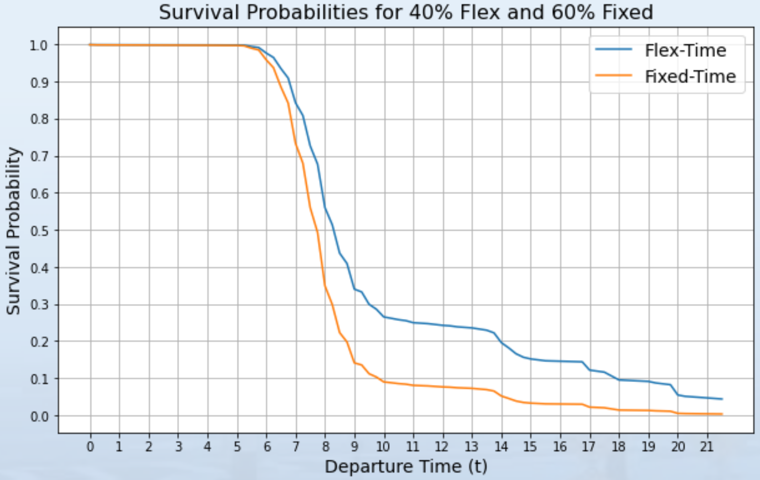
Sensitivity Analysis



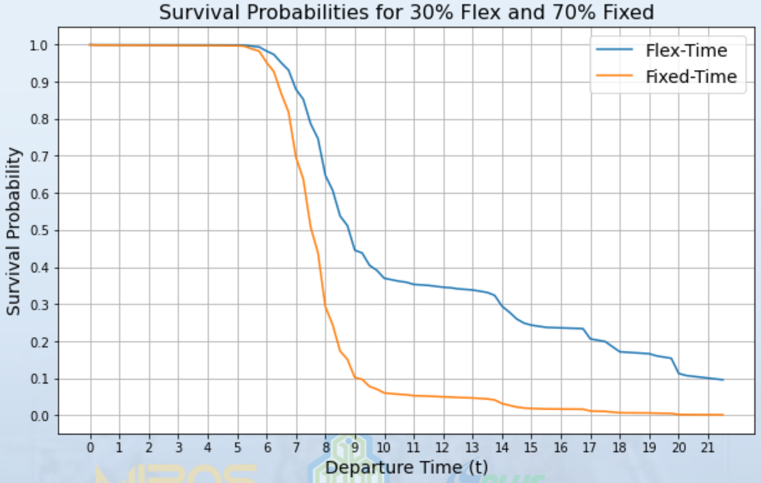
(a) Current situation



(b) Scenario 1 (50/50)



(c) Scenario 2 (40/60)



(d) Scenario 3 (30/70)

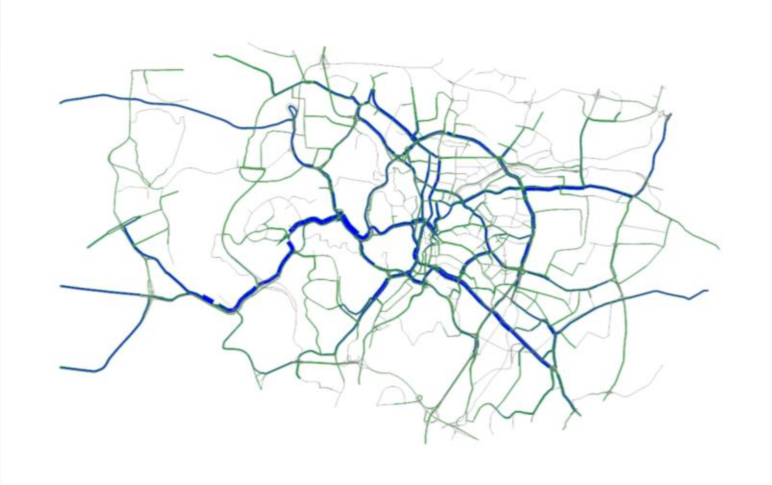
Figure 10: Potential scenarios for future implementation of flex-time arrangements.

- Sensitivity analysis conducted based on the outcome of Cox proportional hazard model.
- 50% fixed-time workers curve drops gradually.
- Survival curves in scenario 1 are close but diverge in scenarios 2 and 3.
- Increased fixed-time workers widen the gap, steepening their survival curve.
- Indicates more workers departing simultaneously, intensifying peak-hour traffic in a shorter period.
- A 50/50 split helps balance travel demand and supply.

Kuala Lumpur Traffic Model

Base 7:00

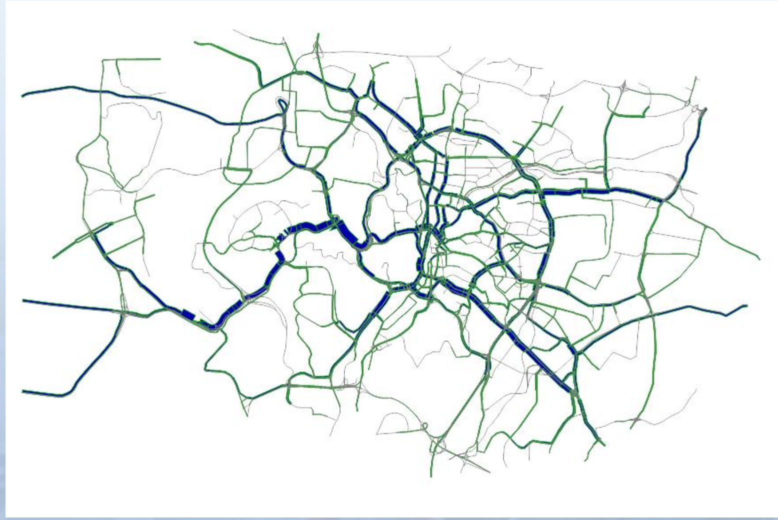
Base 7:30



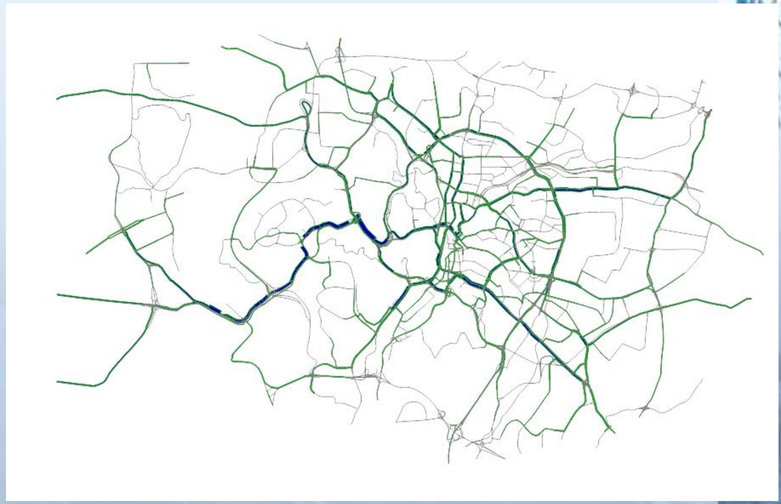
Base 8:00

10% FWA 7:00

10% FWA 7:30



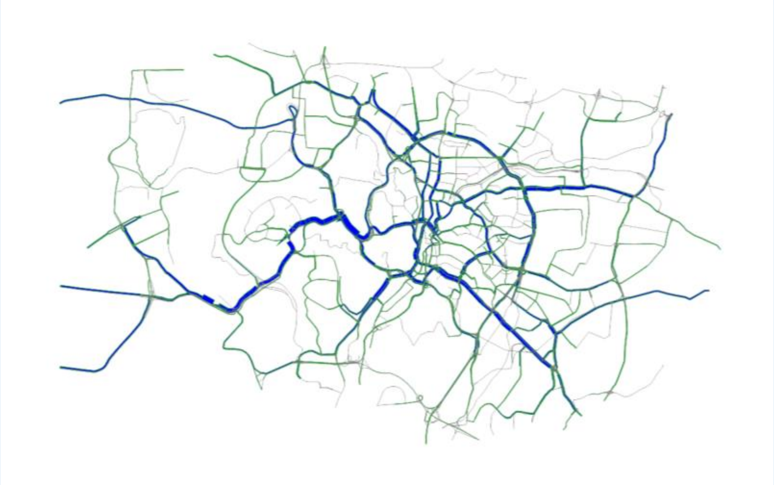
10% FWA 8:00



Kuala Lumpur Traffic Model

Base 7:00

Base 7:30



Base 8:00

50% FWA 7:00

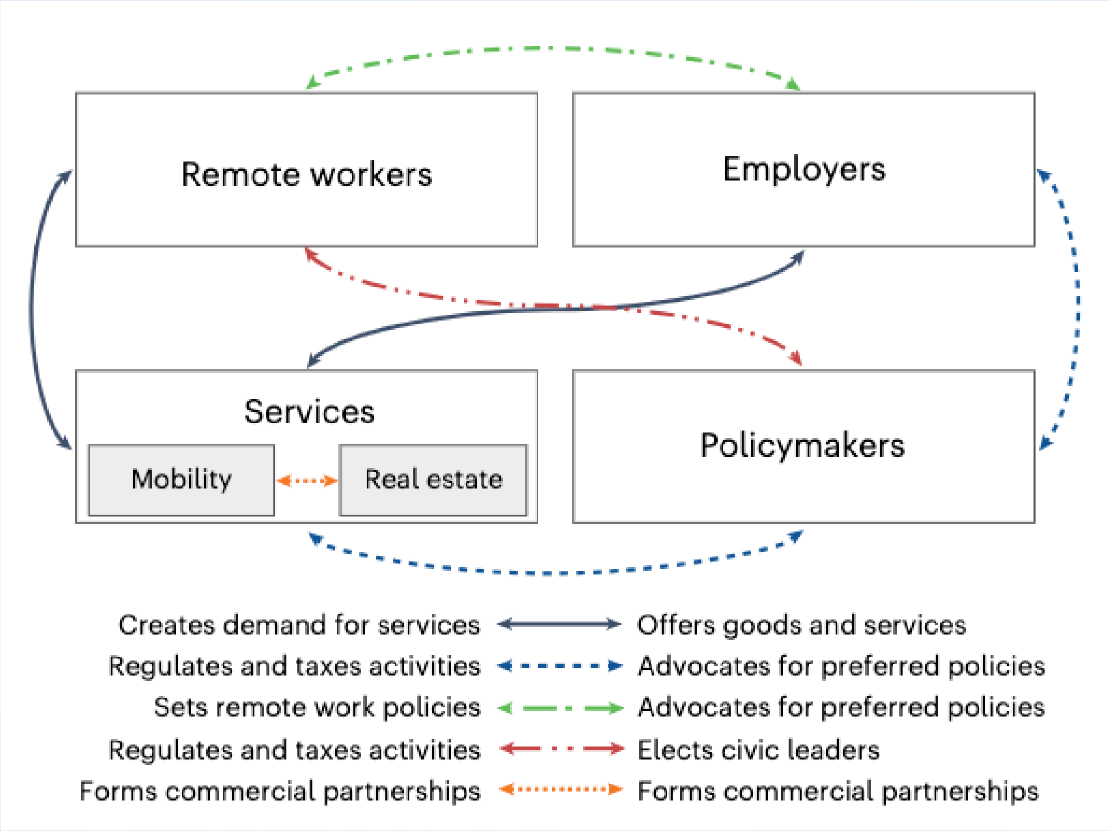
50% FWA 7:30

50% FWA 8:00

Challenges in FWAs adoption

Research on the development of FWAs and the provided outcomes			
Studies	Study Area	Type of FWAs	Outcome and impact
Lachapelle U., Tanguay G. A., Neumark-Gaudet L. (2018)	Montréal, Canada	Location-based flexibility • Working only from home • Part-day home working • Combination from other locations with home and/or workplace	Successful: full-day home working shows more favourable outcomes • Positive impact: 1. Reduction in overall travel time (by 13 minutes on average) 2. Increased non-motorised travel (walking, bicycling) 3. Reduced peak hour travel 4. Environmental benefits • Negative impact: 1. Limited physical activity (health issue) 2. Complexity of work arrangements
Wohner F. (2022)	Bern, Switzerland	Time-based flexibility • Flexitime Location-based flexibility • Telework • Hybrid	Successful • Positive impact: 1. Reduced commuting distance, less time spent in traveling 2. Avoid peak-hour commuting 3. Overall mobility management • Negative impact: 1. Increased non-work travel 2. Highly dependent on individual choices
Čiarnienė R., Vienažindienė M., Adamonienė R. (2023)	Lithuania	Location-based flexibility • Adaption of teleworking and remote work (WFH) • Using Information and Communication Technologies (ICT) to communicate	Successful • Positive impact: 1. Significant reduction in commuting (reduced peak-hour congestion) 2. Saving of time, fuel and energy 3. Reduced air pollution and climate change (reduced carbon emission) • Negative impact: 1. Increased home energy use 2. Increased wastes disposed in home

Opportunities in enhancing FWAs adoption



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