Policy Library: Informing Transport Policy Through Gender-Informed Approaches in Pakistan

BS Electrical Engineering

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By

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INTRODUCTION

In Pakistan, female mobility is significantly low due to cultural norms and safety concerns, limiting women's independence and access to public spaces. To help solve this problem, we developed an agent-based model in NetLogo representing the Lahore Bus Rapid Transit (BRT) to implement and test various policy combinations to determine which ones most effectively enhance female mobility. This document presents policy recommendations based on the NetLogo simulation analysis to improve female mobility within the Lahore BRT system. We analysed three scenarios: business-as-usual, high awareness with low crime, and increased gender parity with low social stigma.

- Business-as-Usual refers to the current state of the Lahore BRT without any policy changes.
- High awareness, low crime simulates increased public awareness and reduced crime inspired by Tokyo's transit system.
- Increased gender parity, low social stigma represents a scenario with improved gender equality and reduced social stigma, modelled after New York City.

Policies are implemented for each scenario to test the effectiveness of policy combinations in improving female mobility. The most effective policy combinations are recommended to policymakers to create a more inclusive and equitable transit environment. Additionally, the variables utilised in our model are adaptable, allowing for the modification and analysis of other potential scenarios to derive similar insights, thereby broadening the applicability and impact of our research.

EXPERIMENTAL PROCEDURE

In order to conduct a policy analysis using the final simulation setup on NetLogo, three scenarios and a total of 15 policy combinations were used. Scenarios were created by varying world settings at the initialization stage.

To conduct a scenario and policy analysis, it is vital that the agentset being used for each case is identical. To do this, the "random-seed" function is called in setup to initialise a pseudo-random number generator which generates a sequence of numbers with properties approximate to that of a sequence of random numbers. Incorporating this line of code into the model ensures that every time random numbers are generated in the model, they follow the same sequence and ensure that the agentset at initialization will always have the same attributes.

In our final model, there are four policies that can be implemented. These policies can be implemented alone or in combination with one another. There are 15 possible combinations for these four policies as listed in table 1. All 15 policy combinations will be run on the business-as-usual scenario to determine how different policies interact with one another. However, for the other two scenarios, only the standalone four base policies will be implemented due to computational and time constraints.

To run the model for all scenarios and policy combinations, BehaviorSpace will be used.

Table 1 POLICY COMBINATIONS

Policy No.	**Policy Combination**
P1	Capacity-check
P2	Gender-segregated Buses
P3	Awareness-campaigns
P4	Safety-check
P5	Capacity-check, Gender-segregated Buses
P6	Capacity-check, Awareness-campaigns
P7	Capacity-check, Safety-check
P8	Gender-segregated Buses, Awareness-campaigns
P9	Gender-segregated Buses, Safety-check
P10	Awareness-campaigns, Safety-check
P11	Capacity-check, Gender-segregated Buses, Awareness-campaigns
P12	Capacity-check, Gender-segregated Buses, Safety-check
P13	Capacity-check, Awareness-campaigns, Safety-check
P14	Gender-segregated Buses, Awareness-campaigns, Safety-check

P15	Capacity-check, Gender-segregated Buses, Awareness-campaigns, Safety-check

BEHAVIORSPACE

NetLogo's BehaviorSpace is designed to conduct experiments within NetLogo's modelling framework. We will be using BehaviorSpace to observe the model's behaviour by parameter sweeping, i.e., conducting a sensitivity analysis to assess the impact of varying parameters on the model outputs and identify parameters which significantly impact agent behaviour.

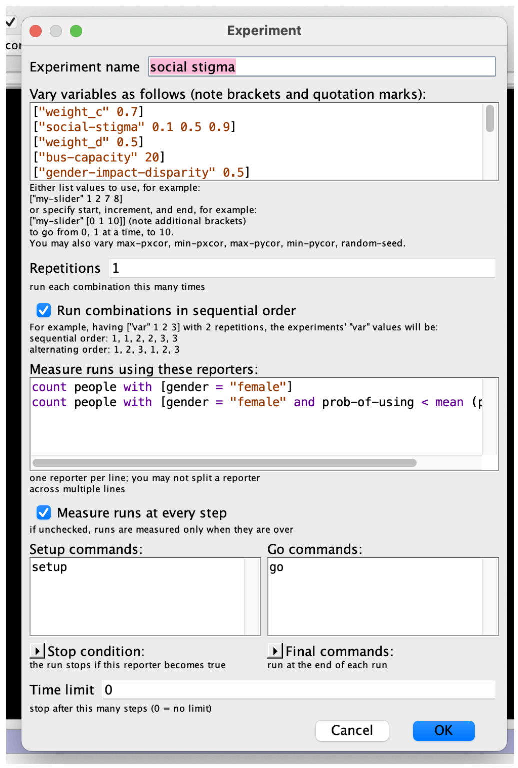

Fig. 1 BehaviorSpace in NetLogo

BehaviorSpace records the values of specified variables at each time step. These variables can then be recorded and compared across different scenarios and policy combinations. To measure the change in "female-mobility" over time, the following variables were recorded using BehaviorSpace: "no-days", "total-trips-women", "total-trips-men", "women-stopped", and "women-intention". "Women-stopped" refers to the number of women who wished to use the BRT at any time but could not do so as their BRT-use score was below the threshold. "Women-intention" records the total number of women who wished to use the BRT at any time.

Using these two variables, a percentage (female mobility) is calculated and then visualised with time.

Fig. 1 shows the interface of BehaviorSpace when defining a new experiment. For each policy or scenario combination, a new experiment needs to be defined. A total of 26 experiments were conducted – three base case scenarios, 15 policy combinations for the business-as-usual scenario, and four policy combinations each for the "high awareness, low crime" and "increased gender parity, low social stigma" scenarios.

BUSINESS-AS-USUAL SCENARIO

The business-as-usual scenario aims to model the Lahore BRT as accurately as possible and establish a baseline against which potential improvements brought by policy changes can be measured. This simulation is designed according to the literature review.

The parameters for the business-as-usual scenario are shown in Table 2. The variables below are carefully assigned values to balance model accuracy and computational feasibility. We will be running all fifteen combinations of the policies discussed in chapter 4 to determine which are the most successful in improving female mobility.

- Number of People (num-people): As per the Punjab Mass Transit Authority, 135,000 commuters use the Lahore BRT daily on average [1]. To reduce the computational load of the simulation, we have scaled down this value using a ratio of 1:0.00037. Therefore, num-people is set to 50, which represents 135,000 people.
- Simulation Duration (no-days): The duration of the simulation is set to 5 days to minimise the computational load, observe trends, and record meaningful data.
- Bus Capacity (bus-capacity): The Lahore BRT system consists of 64 buses, each with an approximate capacity of 150 passengers [2]. In the simulation, this is scaled down to a single bus using the ratio 1:0.00037. Therefore, the bus-capacity is set as 4 and represents a scaled version of the total capacity of 9,600 passengers.
- Social Stigma (social-stigma): Social stigma can impact public transport usage and female mobility, particularly among women in countries with conservative social norms, such as Pakistan. Classifying Pakistan as a high social stigma area, "social-stigma" is set

as 0.8 which captures the impact of societal barriers on public transport use amongst women.

- Gender Gap Index (gender-gap-index): Gender-gap-index is assigned a value of 0.6 since Pakistan has a Gender Gap Index of 57.5% according to the World Economic Forum's Global Gender Gap Report 2023 [3].
- Harassment Prevalence (harasser-percentage): Harasser-percentage is set at 70% to observe noticeable changes and trends within five days and since 70% of Pakistani women using public transport report daily harassment [4].
- Harasser Impact (harasser-impact) and Overcrowding Impact (over-crowding-impact): Harasser-impact and over-crowding-impact are set at 2 (the maximum value) to see the maximum impact in the simulation and ensure meaningful trends are visible within five days.
- Safety Weight (weight_a): According to the Urraan survey, safety is the most important concern for women using the Lahore BRT. Therefore, weight_a is set as 0.8 to obtain meaningful results within 5 days and due to prevalent safety concerns among women in Lahore, where crimes against women are common and legal accountability is often lacking.
- Urgency Weight (weight_b): Weight_b is set at 0.5, i.e., the middle point, due to a lack of data related to the urgency of travel needs among those who use the Lahore BRT.
- Social Norms Weight (weight_c): Weight_c is set as 0.8 due as the Urraan survey demonstrates the strong influence of social norms on behaviour in Pakistan, especially in the context of gender roles and public presence.
- Income Disparity Weight (weight_d): Weight_d is set as 0.3 to incorporate the impact of income inequality within the Lahore BRT system. It is based on the GINI Index for Pakistan, which was projected to be 30.7% for 2022-23 according to The World Bank [5].
- Awareness Weight (weight_e): Weight_e is assigned a value of 0.5 indicating moderate levels of public awareness. This is due to low literacy rates in Pakistan [6] and inaccessibility of information regarding routes, times and other details of the Lahore BRT as ascertained by the Urraan survey.

Table 2 PARAMETER VALUES FOR BUSINESS-AS-USUAL

Parameter	**Value**
num-people	50
no-days	5
bus-capacity	4
social-stigma	0.8
gender-impact-disparity	0.6
harasser-percentage	0.7
harasser-impact	2
over-crowding-impact	2
weight_a (safety)	0.8
weight_b (urgency)	0.5
weight_c (social norms)	0.8
weight_d (income)	0.3
weight_e (awareness)	0.5

HIGH AWARENESS, LOW CRIME SCENARIO

The "High Awareness, Low Crime Scenario" simulates the Lahore BRT given increased awareness among women about public transport and reduced crime. This scenario is inspired by Tokyo's Toei Bus System and most parameters have been set accordingly to explore the consequences of Lahore evolving into a socio-economic and cultural context similar to that of Tokyo. This scenario will be compared against the business-as-usual scenario to see how women's mobility patterns change as awareness increases and crime decreases.

Parameters for the "High Awareness, Low Crime Scenario" are given in Table 3. The variables below are carefully assigned values to balance model accuracy and computational feasibility, drawing inspiration from but not directly copying the Tokyo case. We will be running all four policies individually to determine which are the most successful in improving female mobility.

- Number of People (num-people): As per Statistica, 195.37 million people used the Toei Bus in 2021 [7]. This comes to approximately 535,260 people per day. To reduce the computational load of the simulation, we have scaled down this value using the ratio 535260:50 and set num-people to 50 in our simulation.
- Simulation Duration (no-days): The duration of the simulation is set to 5 days to minimise the computational load, observe trends, and record meaningful data.
- Bus Capacity (bus-capacity): The Toei Bus System consists of 1400 buses, each with an approximate capacity of 78 passengers [8], and total capacity of 109,200 people per day. In the simulation, this is scaled down to a single bus using the ratio 535260:50. Therefore, the bus-capacity is set as 10 and represents a scaled version of the total capacity.
- Social Stigma (social-stigma): Social stigma can impact public transport usage and female mobility. We classify Tokyo as having medium social stigma due to cultural norms which emphasise conformity and traditional gender roles, impacting women's behaviour and perceptions in public spaces. Therefore, social-stigma is set as 0.5 in this scenario.
- Gender Gap Index (gender-gap-index): Gender-gap-index is assigned a value of 0.6 since Japan has a Gender Gap Index of 64% according to the World Economic Forum's Global Gender Gap Report 2023 [3].
- Harassment Prevalence (harasser-percentage): Harasser-percentage is set as 0.3 to observe noticeable changes and trends within five days and since 30% of women in Tokyo have expressed safety concerns about travelling on public transport [9].
- Harasser Impact (harasser-impact) and Overcrowding Impact (over-crowding-impact): Harasser-impact and over-crowding-impact are set at 2 (the maximum value) to see the maximum impact in the simulation and ensure meaningful trends are visible within five days.
- Safety Weight (weight_a): In this scenario, weight_a is set as 0.3, lower than the value in the business-as-usual scenario to identify meaningful trends over five days and since most women in Tokyo do not consider sexual harassment on public transport as a

significant issue [9].

- Urgency Weight (weight_b): Weight_b is set as 0.7 due to high levels of labour force participation rates among both men and women in Tokyo [10]. This setting contrasts with Lahore, where labour force participation rates and consequently the urgency associated with commuting is lower.
- Social Norms Weight (weight_c): Weight_c is set as 0.3, reflecting the minimal impact of social norms on behaviour in Tokyo where low crime rates and a robust public transport infrastructure significantly enhance women's mobility [11].
- Income Disparity Weight (weight_d): Weight_d is set as 0.3 to incorporate the impact of income inequality within the Toei Bus System. It is based on the GINI Index for Japan, which is projected to be 30.1% for 2024 [12].
- Awareness Weight (weight_e): Weight_e is set as 0.9 indicating high levels of public awareness in Tokyo. This is due to high literacy rates in Japan and the widespread availability of information regarding routes, times, and other specifics of the Toei Bus System [13].

Table 3 PARAMETER VALUES FOR HIGH AWARENESS, LOW CRIME

Parameter	**Value**
num-people	50
no-days	5
bus-capacity	10
social-stigma	0.5
gender-impact-disparity	0.6
harasser-percentage	0.3
harasser-impact	2
over-crowding-impact	2
weight_a (safety)	0.3
weight_b (urgency)	0.7

weight_c (social norms)	0.3
weight_d (income)	0.3
weight_e (awareness)	0.9

INCREASED GENDER PARITY, LOW SOCIAL STIGMA

The "Increased Gender Parity, Low Social Stigma" simulates the Lahore BRT given increased gender parity and reduced social stigma. This scenario is inspired by New York City's Metropolitan Transit Authority (MTA) Bus System and most parameters have been set accordingly to explore the consequences of Lahore evolving into a socio-economic and cultural context similar to that of New York City. This scenario will be compared against the business-as-usual scenario to see how women's mobility patterns change as gender parity increases and social stigma decreases.

Parameters for the "Increased Gender Parity, Low Social Stigma" are given in Table 4. The variables below are carefully assigned values to balance model accuracy and computational feasibility, drawing inspiration from but not directly copying the New York City case. We will be running all four policies individually to determine which are the most successful in improving female mobility.

- Number of People (num-people): As per the Metropolitan Transportation Authority (MTA), 1.4 million people used the New York City Bus daily in 2022 [14]. To reduce the computational load of the simulation, we have scaled down this value using the ratio 1:50 and set num-people to 50 in our simulation.
- Simulation Duration (no-days): The duration of the simulation is set to 5 days to minimise the computational load, observe trends, and record meaningful data.
- Bus Capacity (bus-capacity): The MTA has 5,840 buses which are run multiple times per day with a capacity of 57 per bus, which comes to a total capacity of 332,880 [15]. Using the ratio of 1,400,000:50, the bus-capacity set in this simulation is 12.
- Social Stigma (social-stigma): Social stigma can impact public transport usage and female mobility. We classify New York City as having low social stigma due to minimal emphasis on traditional gender roles. Therefore, social-stigma is set as 0.2 in this

scenario.

- Gender Gap Index (gender-gap-index): Gender-gap-index is assigned a value of 0.8 since the U.S. has a Gender Gap Index of 77.3% according to the World Economic Forum's Global Gender Gap Report 2023 [3].
- Harassment Prevalence (harasser-percentage): Harasser-percentage is set as 0.7 to observe noticeable changes and trends within five days. Furthermore, this allows for a comparison with the business-as-usual scenario, helping to isolate and evaluate the effects of increased gender parity and reduced social stigma on female mobility.
- Harasser Impact (harasser-impact) and Overcrowding Impact (over-crowding-impact): Harasser-impact and over-crowding-impact are set at 2 (the maximum value) to see the maximum impact in the simulation and ensure meaningful trends are visible within five days.
- Safety Weight (weight_a): In this scenario, weight_a is set as 0.2, lower than the value in the other two scenarios as the New York Public Transport System is considered to be the safest in the world for women [16].
- Urgency Weight (weight_b): Weight_b is set as 0.7 due to high levels of labour force participation rates among both men and women in New York City [17]. This setting contrasts with Lahore, where labour force participation rates and consequently the urgency associated with commuting is lower.
- Social Norms Weight (weight_c): Weight_c is set as 0.1 since the majority of bus riders in New York are female [18] which indicates low societal pressure discouraging the use of public transport.
- Income Disparity Weight (weight_d): Weight_d is set as 0.5 to incorporate the impact of income inequality within the New York City Bus System. It is based on the GINI Index for the U.S., which is projected to be 47% for 2024 [19].
- Awareness Weight (weight_e): Weight_e is set as 1.0 indicating high levels of public awareness in New York City. This is due to high literacy rates in the U.S. and the widespread availability of information regarding routes, times, and other specifics of the New York City Bus System [20].

Table 4 PARAMETER VALUES FOR INCREASED GENDER PARITY, LOW SOCIAL STIGMA

Parameter	Value
num-people	50
no-days	5
bus-capacity	12
social-stigma	0.2
gender-impact-disparity	0.8
harasser-percentage	0.8
harasser-impact	2
over-crowding-impact	2
weight_a (safety)	0.2
weight_b (urgency)	0.7
weight_c (social norms)	0.1
weight_d (income)	0.5
weight_e (awareness)	1.0

2.3: IMPLEMENTATION RESULTS

All scenarios were simulated for five days within NetLogo's BehaviorSpace to demonstrate the transient and steady-state behaviours of the system when different policy conditions were applied. The timeframe was chosen because running the simulation for longer would have significantly increased the computational load. As shown in the graphs below, five days are sufficient to effectively observe the system's response to various policies. Small lines on the horizontal axes represent each time-period and can be used to analyse changes as time passes.

Due to computational constraints, certain variables are set to their maximum values to ensure changes could be observed within the simulation period. It is important to note that while a five-day timeframe is sufficient for demonstrating noticeable changes in the output, real-life policy impacts might not be as immediate.

BUSINESS-AS-USUAL SCENARIO RESULTS

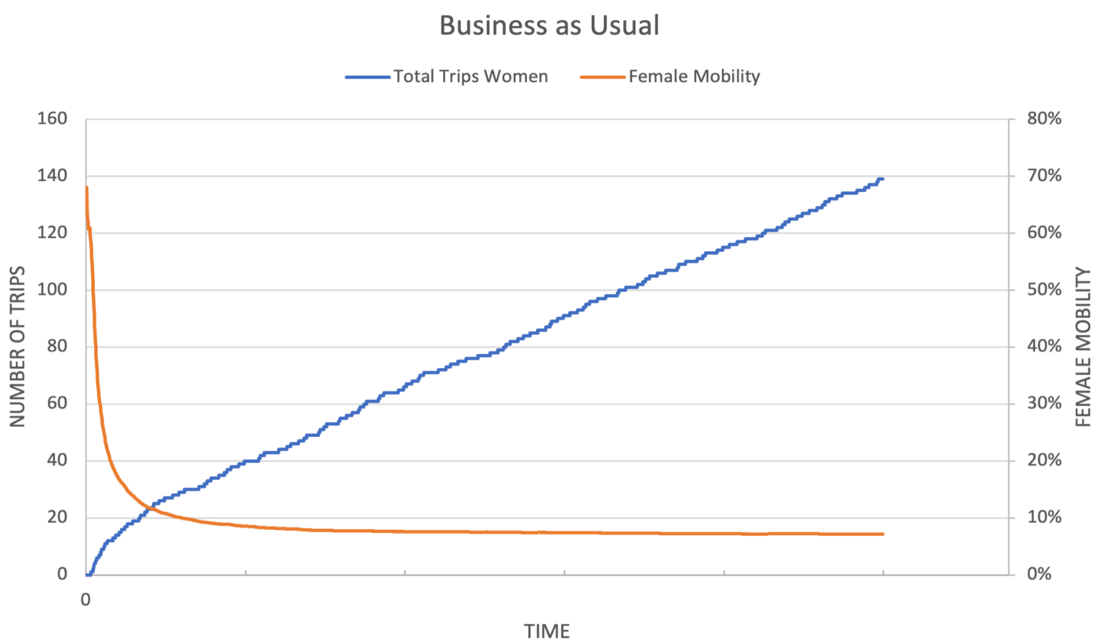

Fig. 2 Business-as-Usual Case with No Policies

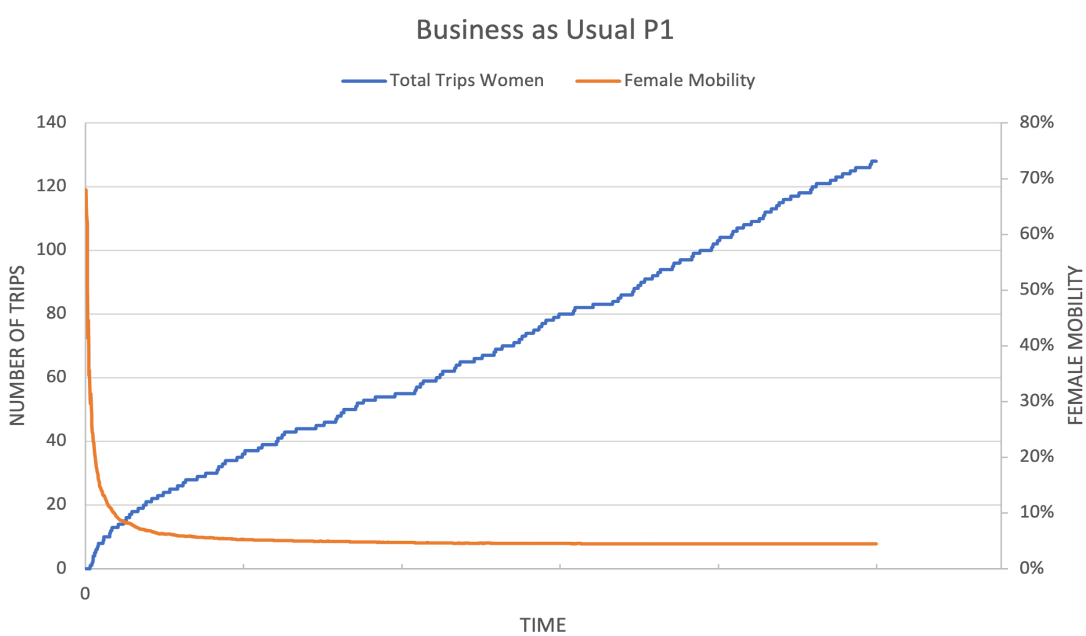

Fig. 3 Business-as-Usual Case with P1

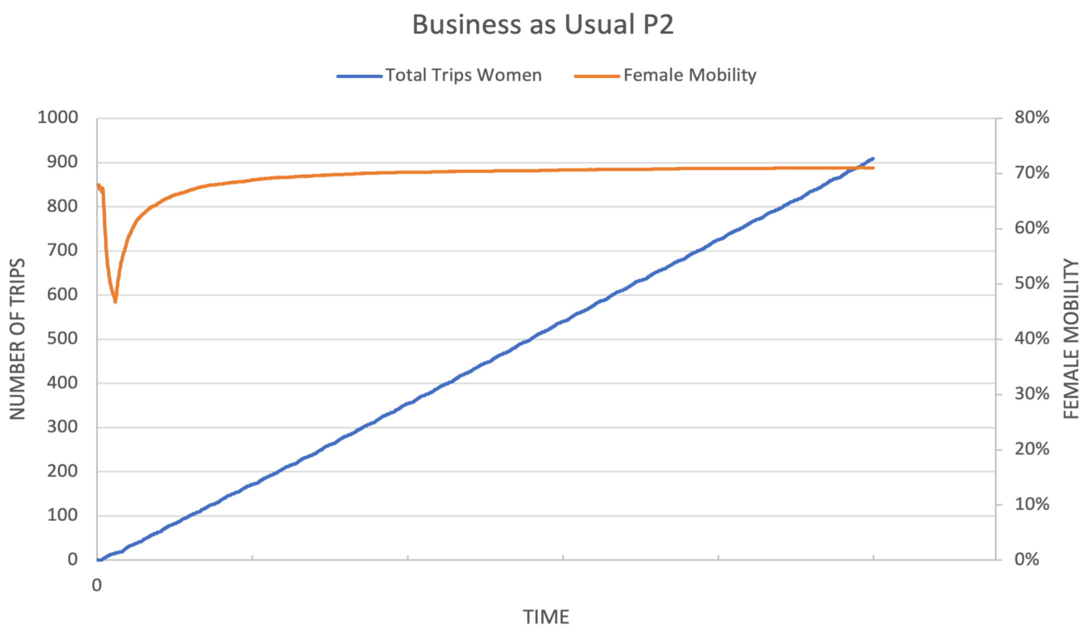

Fig. 4 Business-as-Usual Case with P2

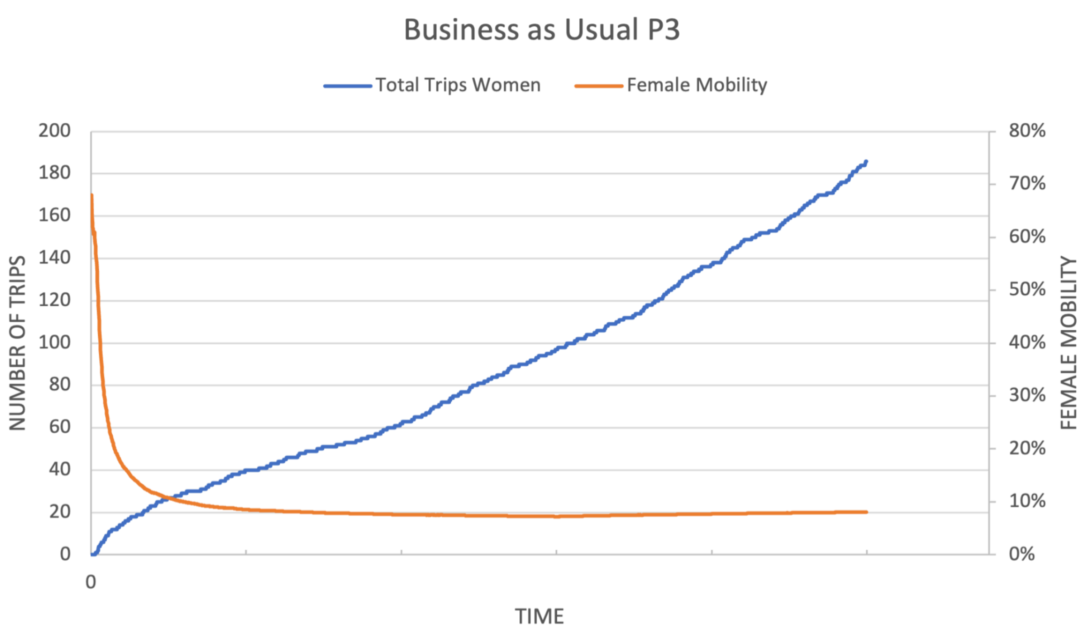

Fig. 5 Business-as-Usual Case with P3

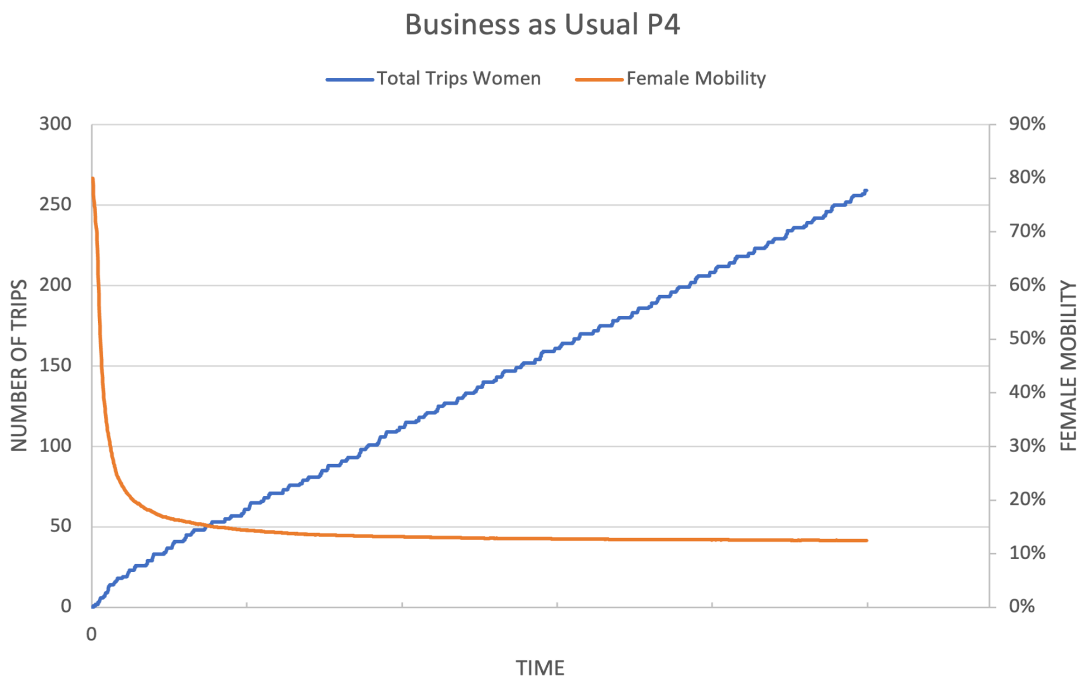

Fig. 6 Business-as-Usual Case with P4

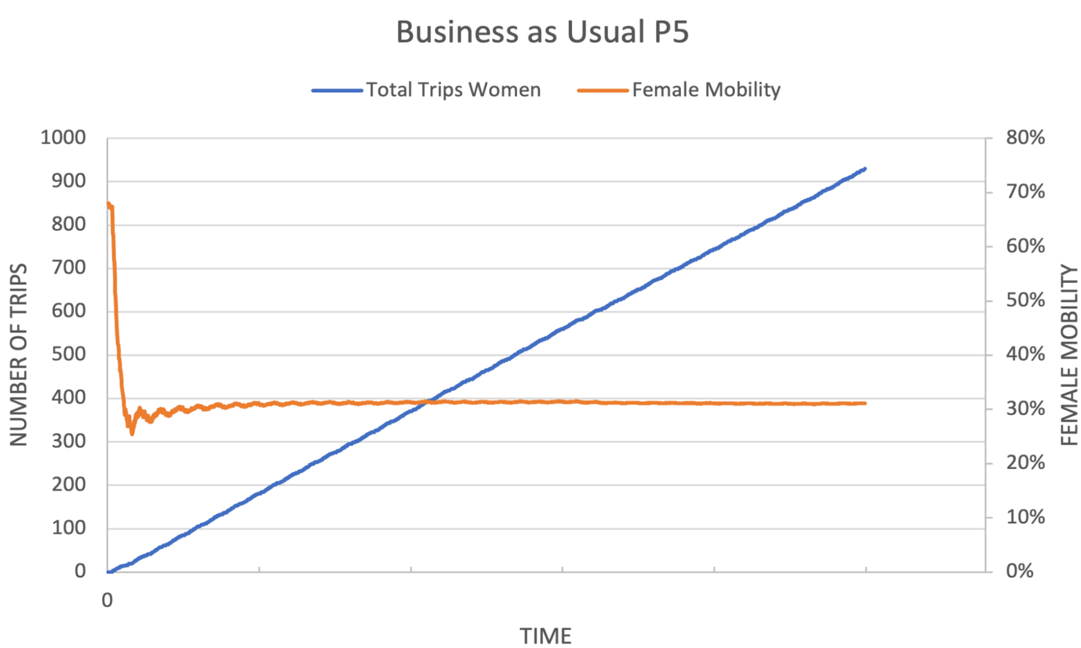

Fig. 7 Business-as-Usual Case with P5

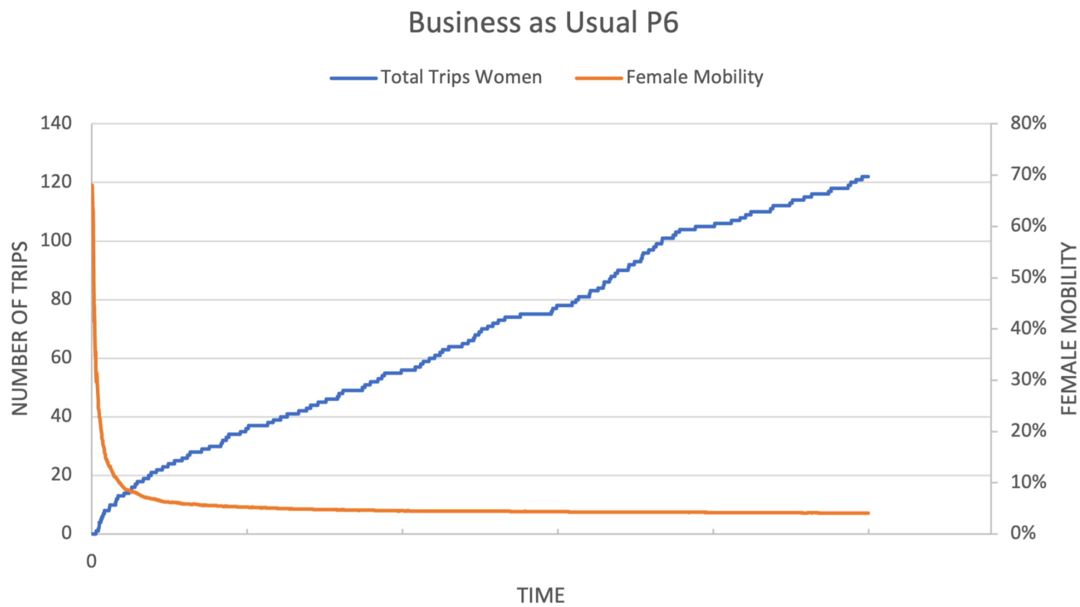

Fig. 8 Business-as-Usual Case with P6

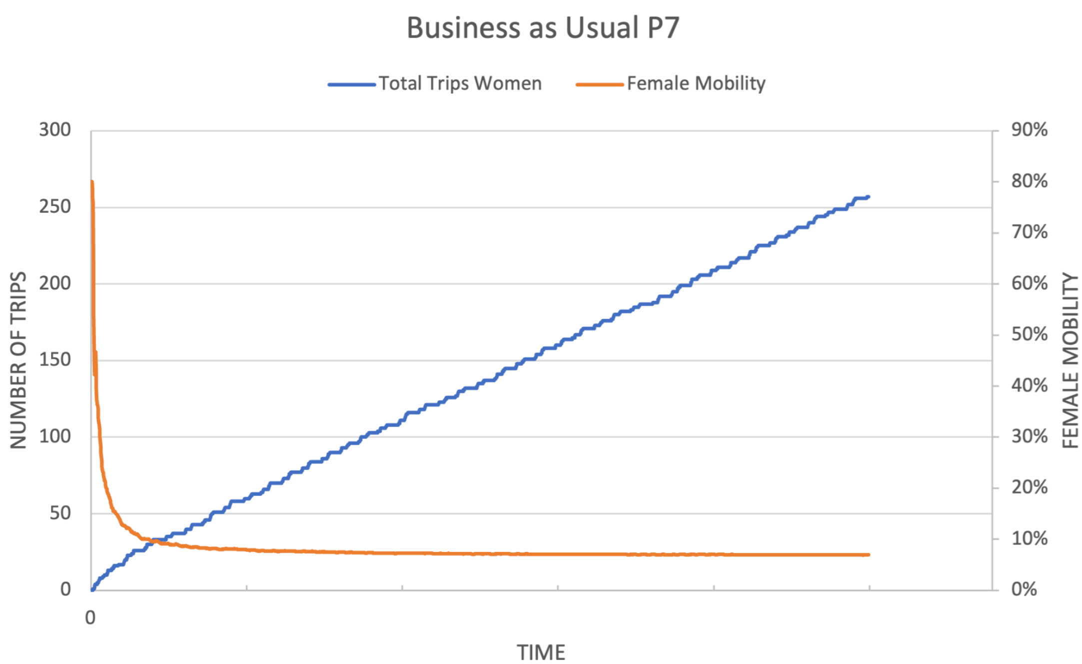

Fig. 9 Business-as-Usual Case with P7

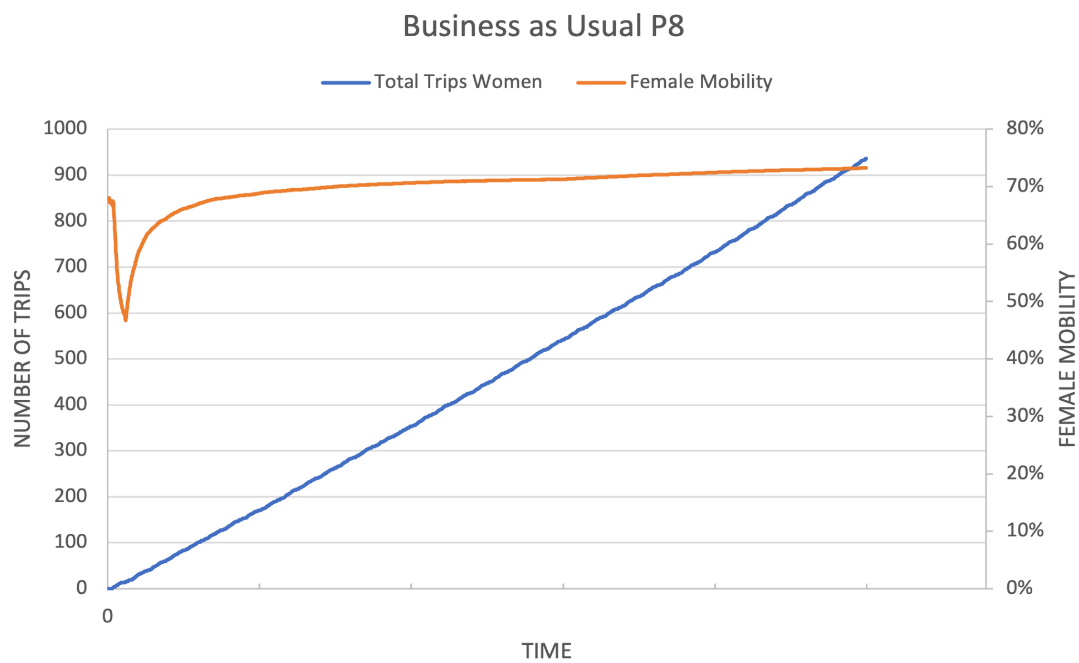

Fig. 10 Business-as-Usual Case with P8

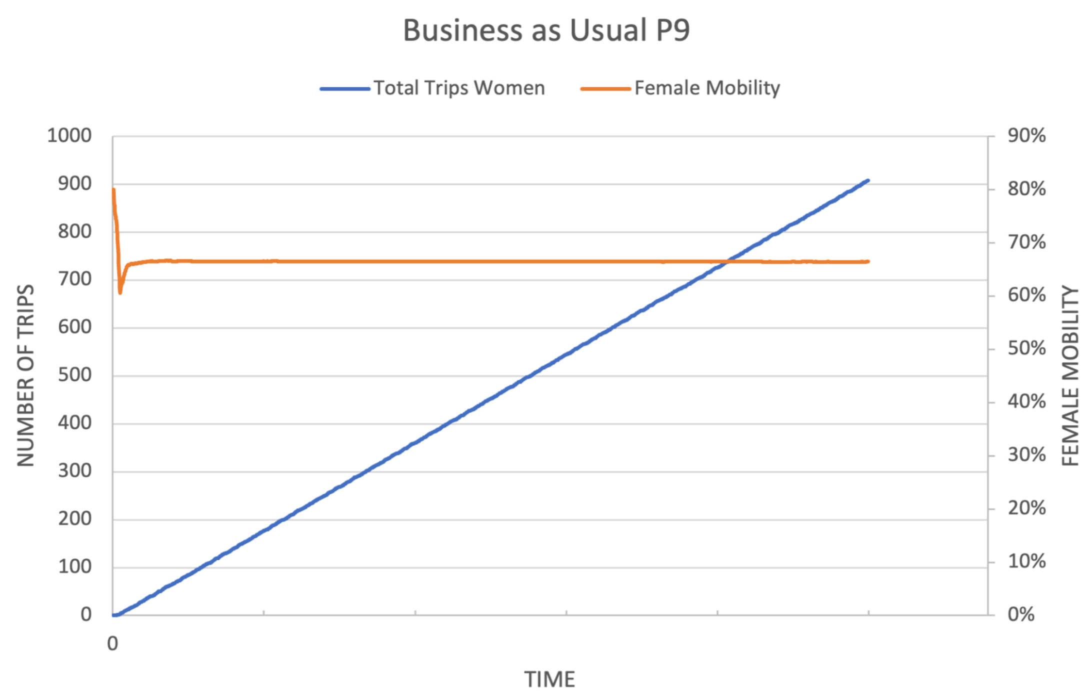

Fig. 11 Business-as-Usual Case with P9

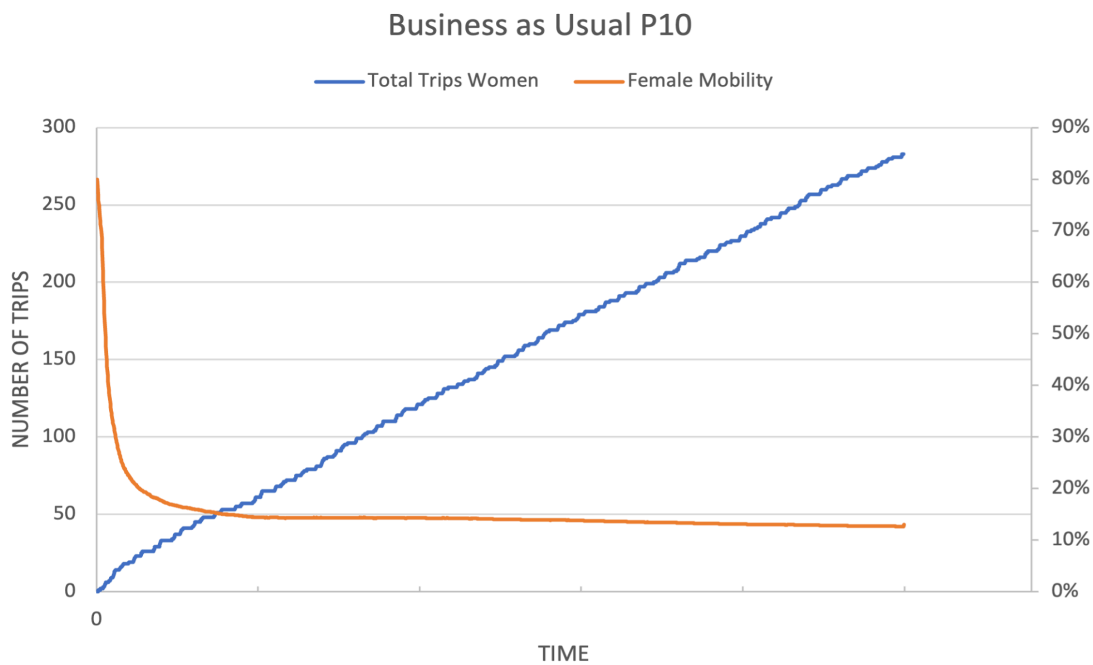

Fig. 12 Business-as-Usual Case with P10

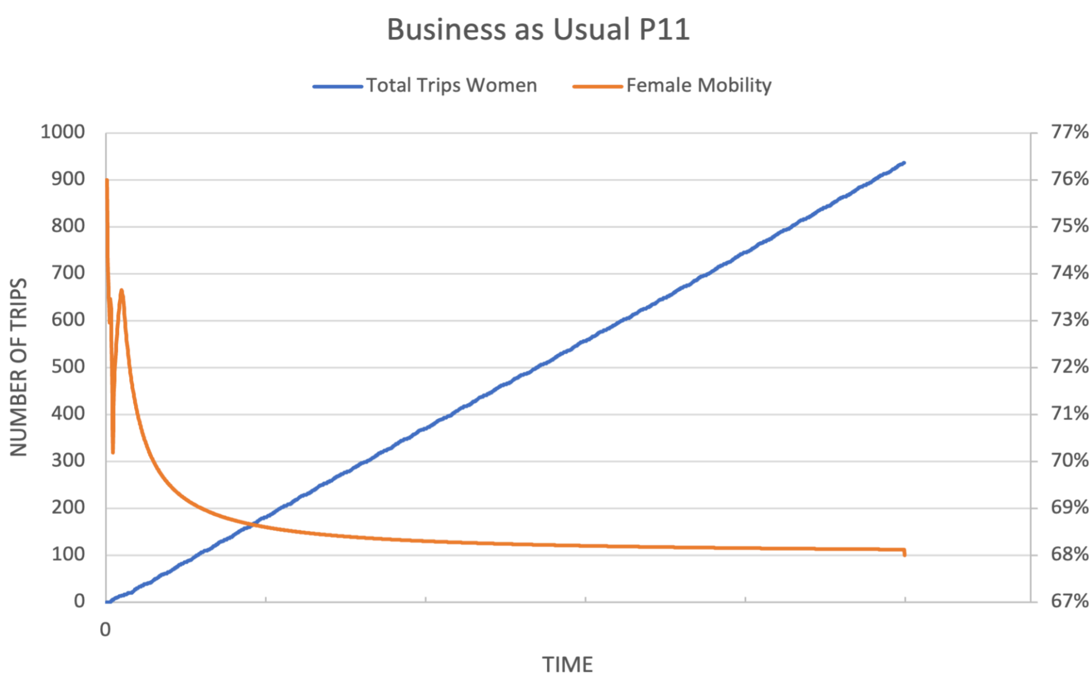

Fig. 13 Business-as-Usual Case with P11

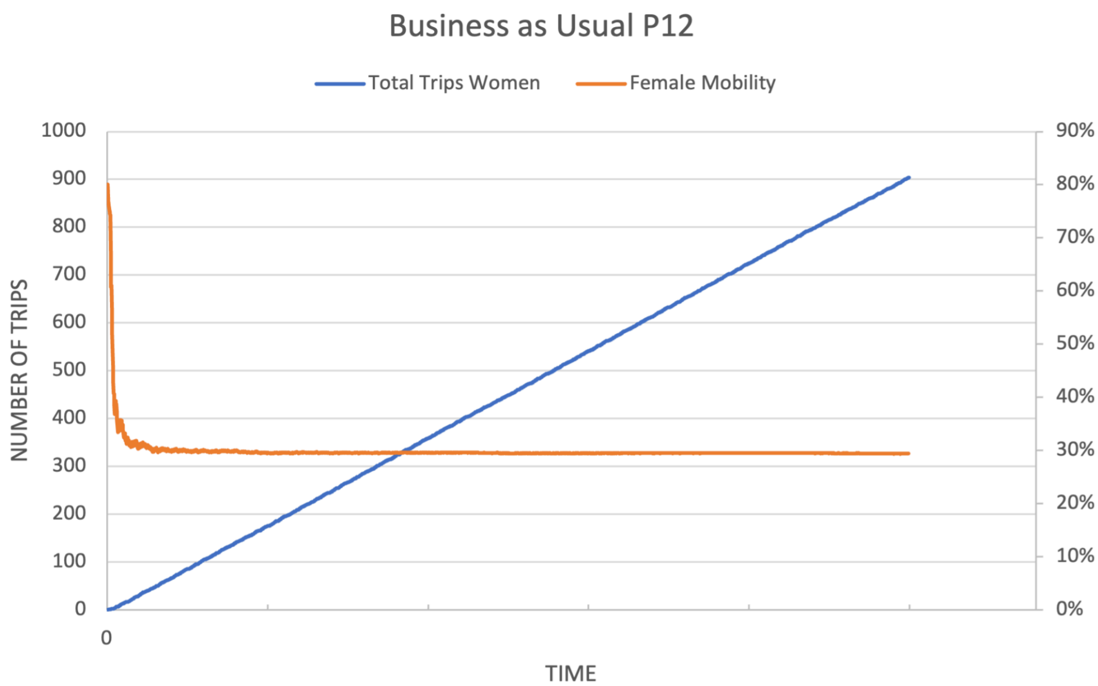

Fig. 14 Business-as-Usual Case with P12

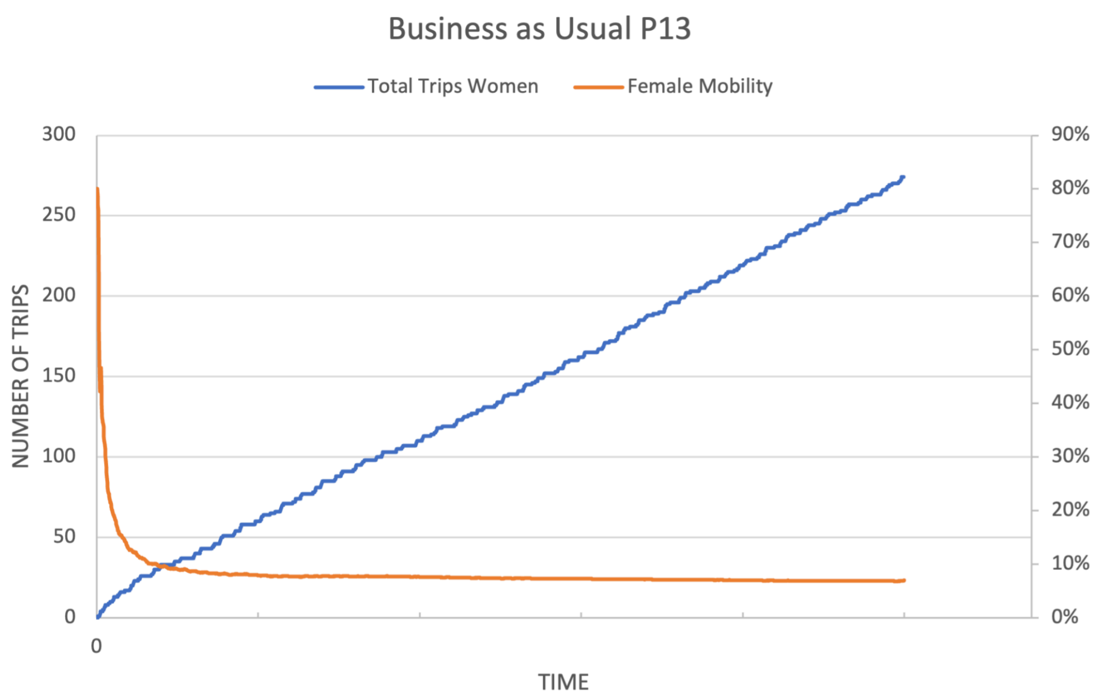

Fig. 15 Business-as-Usual Case with P13

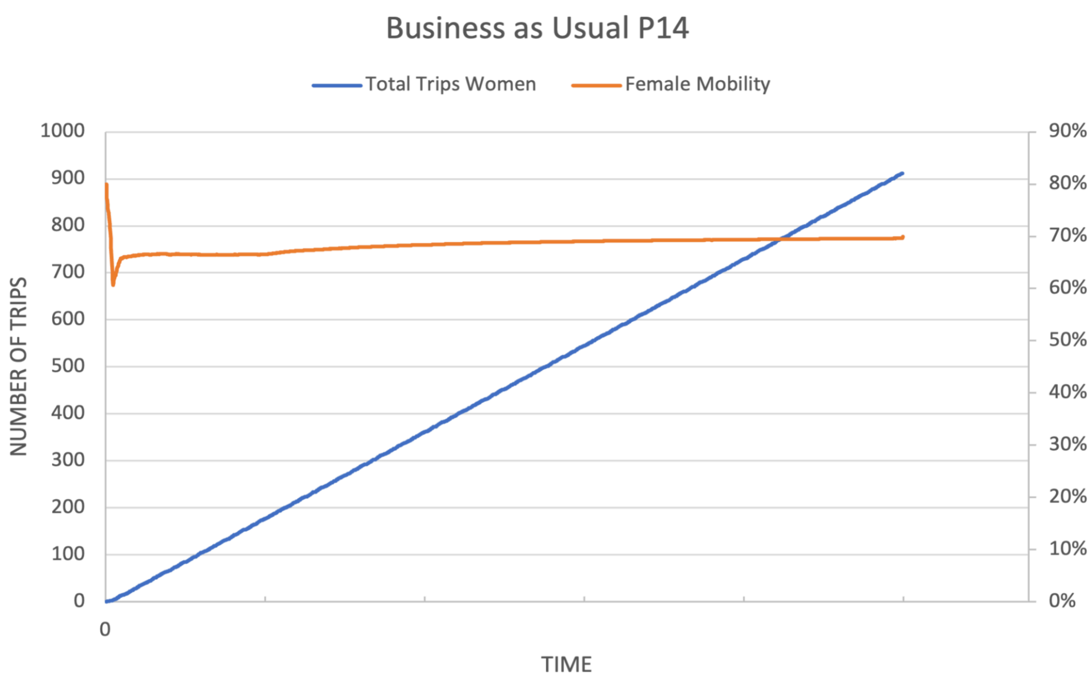

Fig. 16 Business-as-Usual Case with P14

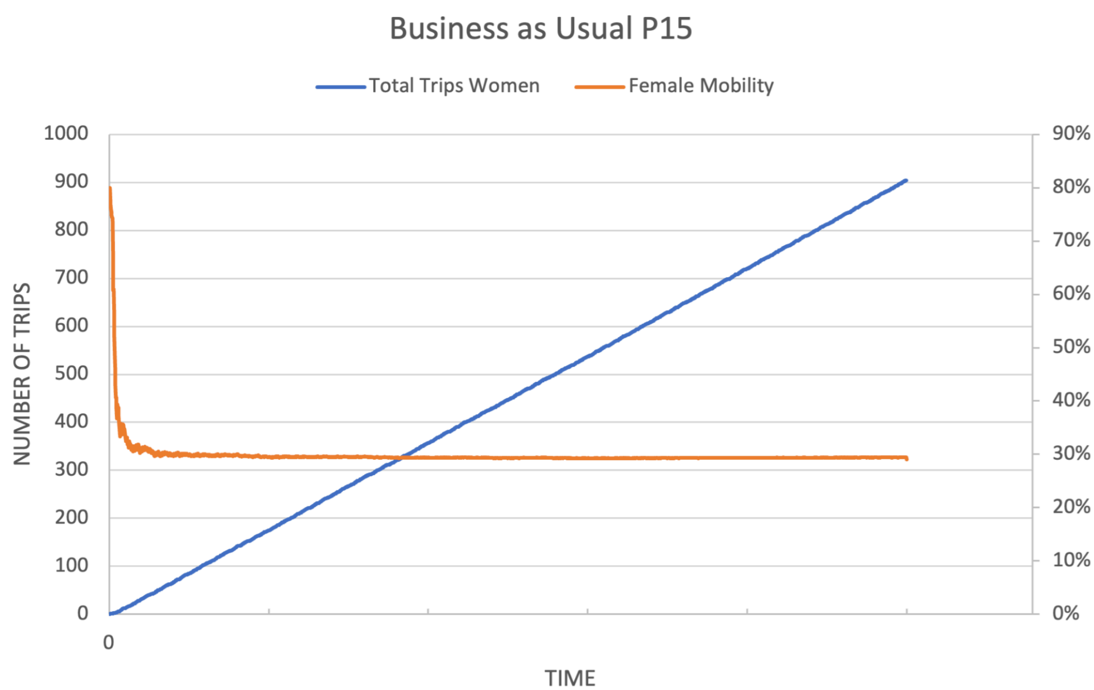

Fig. 17 Business-as-Usual Case with P15

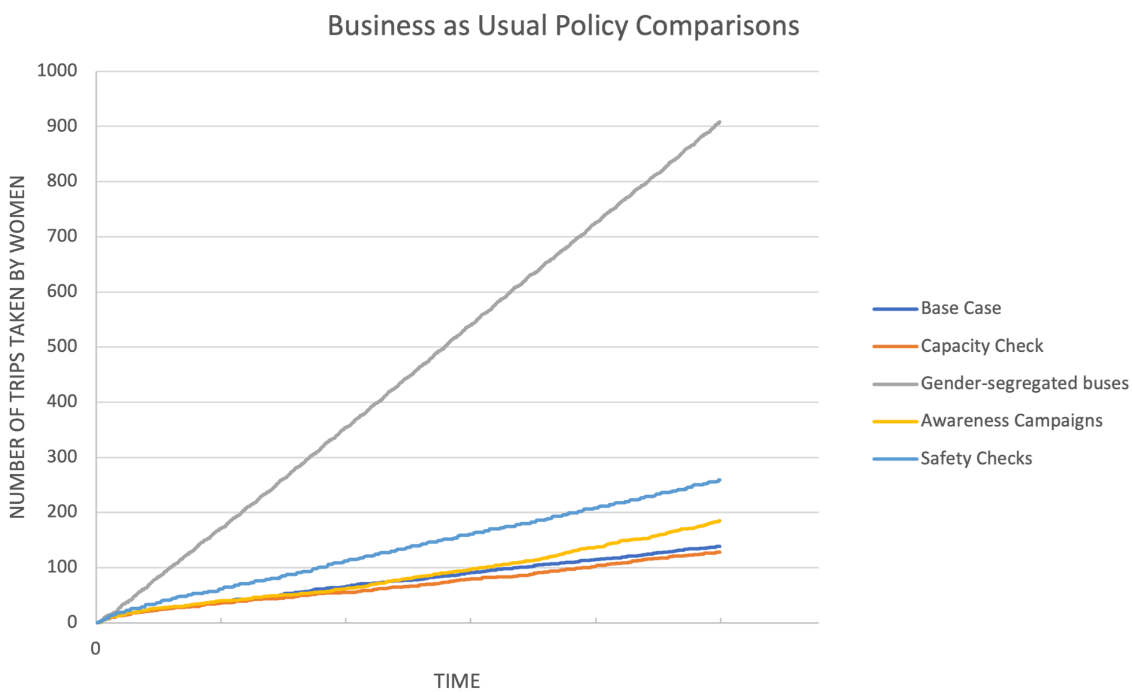

Fig. 18 Number of Trips Taken: Policy Comparison for Business-as-Usual Case

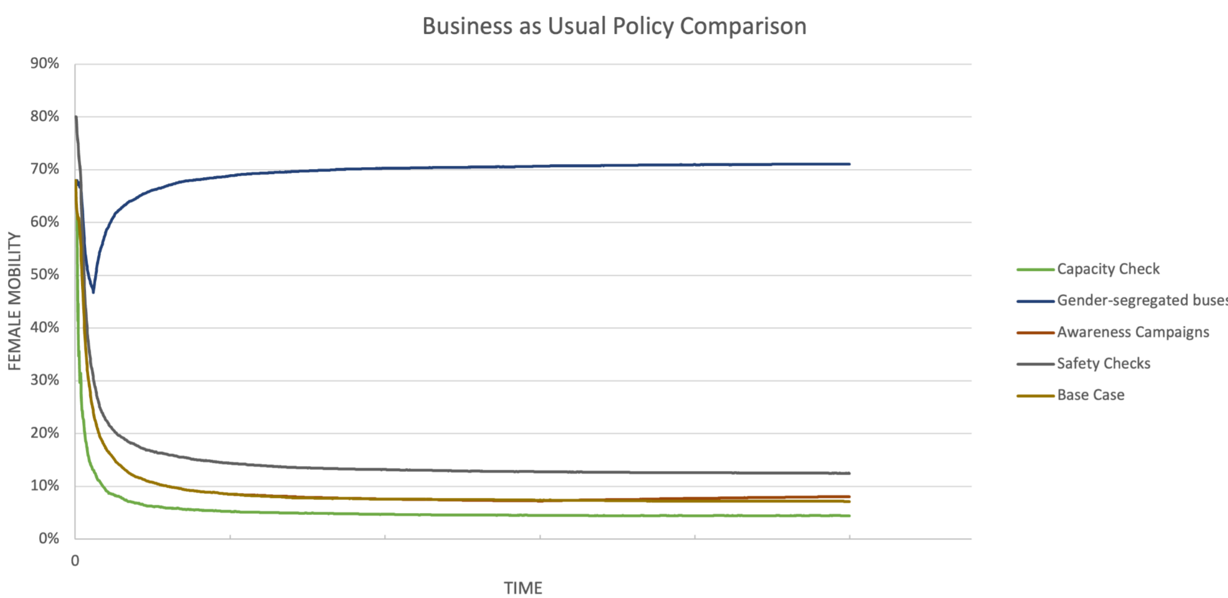

Fig. 19 Female Mobility: Policy Comparison for Business-as-Usual Case

HIGH AWARENESS, LOW CRIME SCENARIO RESULTS

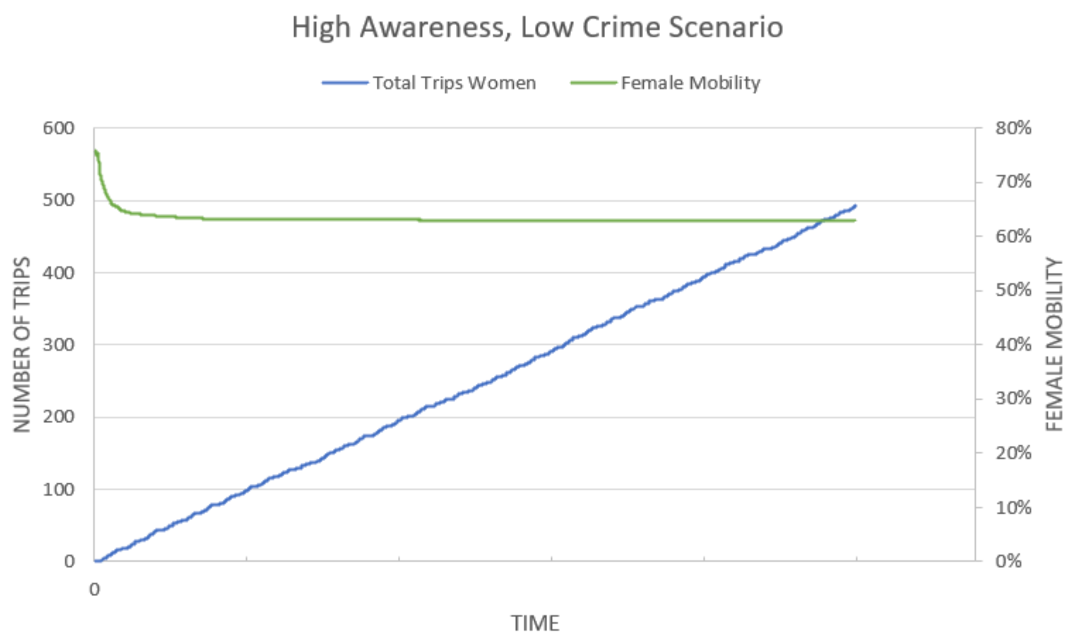

Fig. 20 High Awareness, Low Crime Case with No Policies

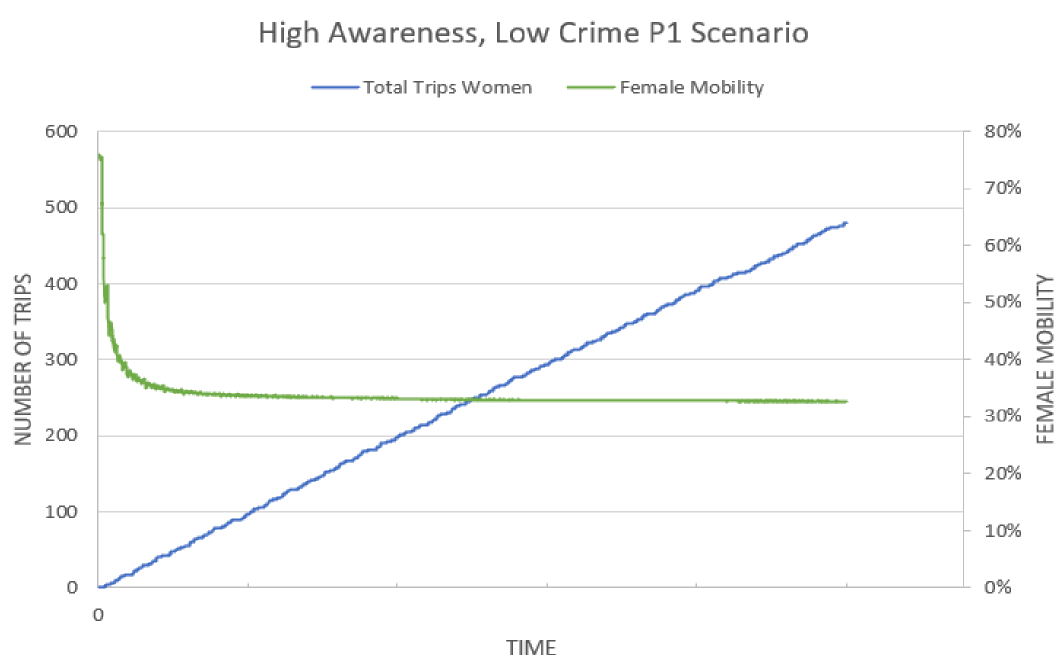

Fig. 21 High Awareness, Low Crime Case with P1

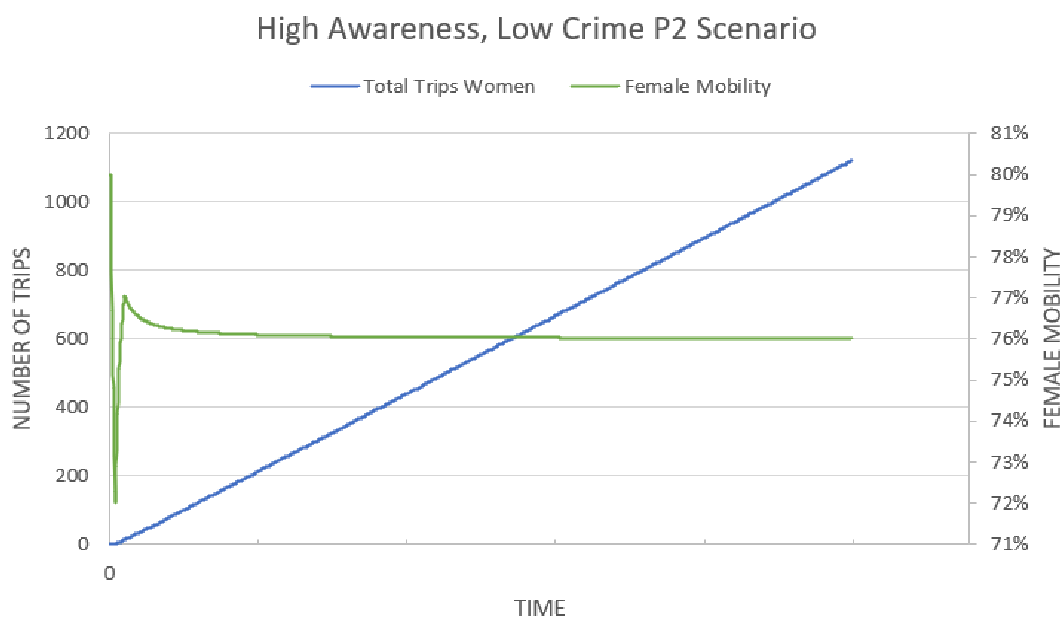

Fig. 22 High Awareness, Low Crime Case with P2

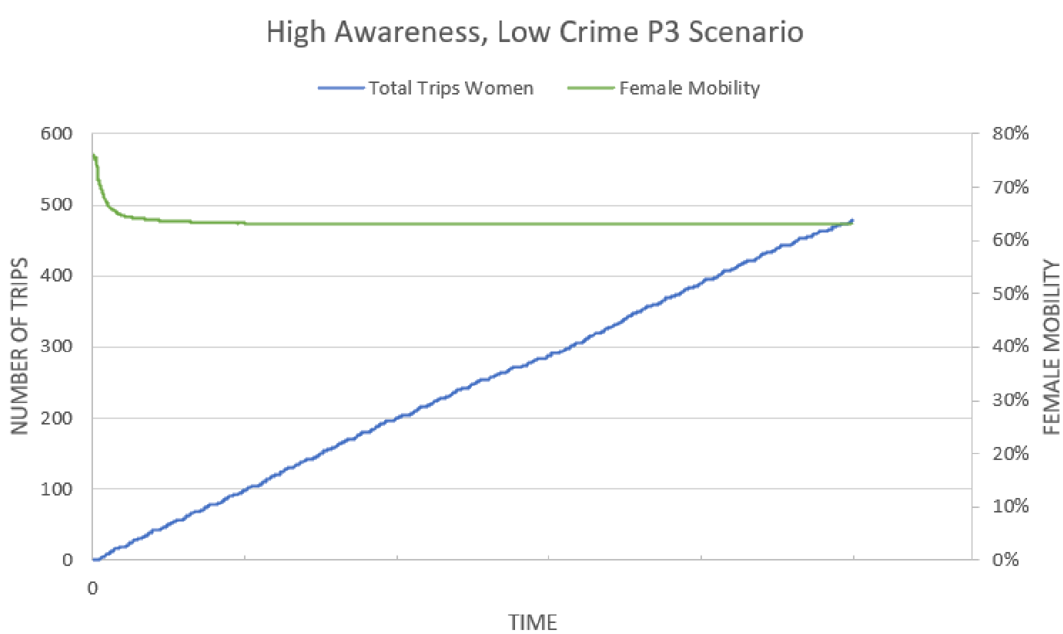

Fig. 23 High Awareness, Low Crime Case with P3

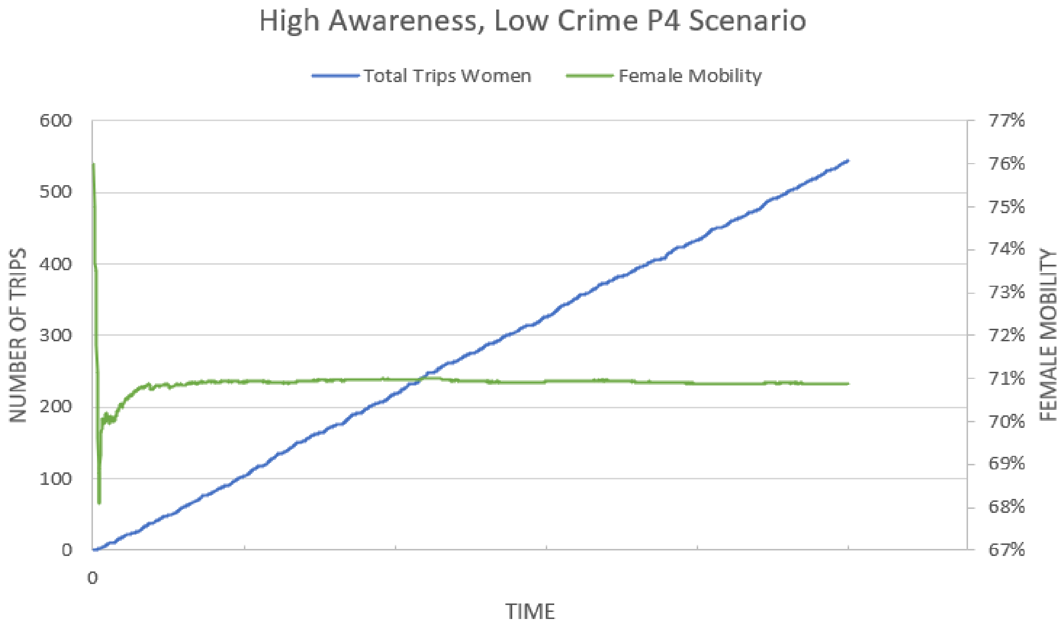

Fig. 24 High Awareness, Low Crime Case with P4

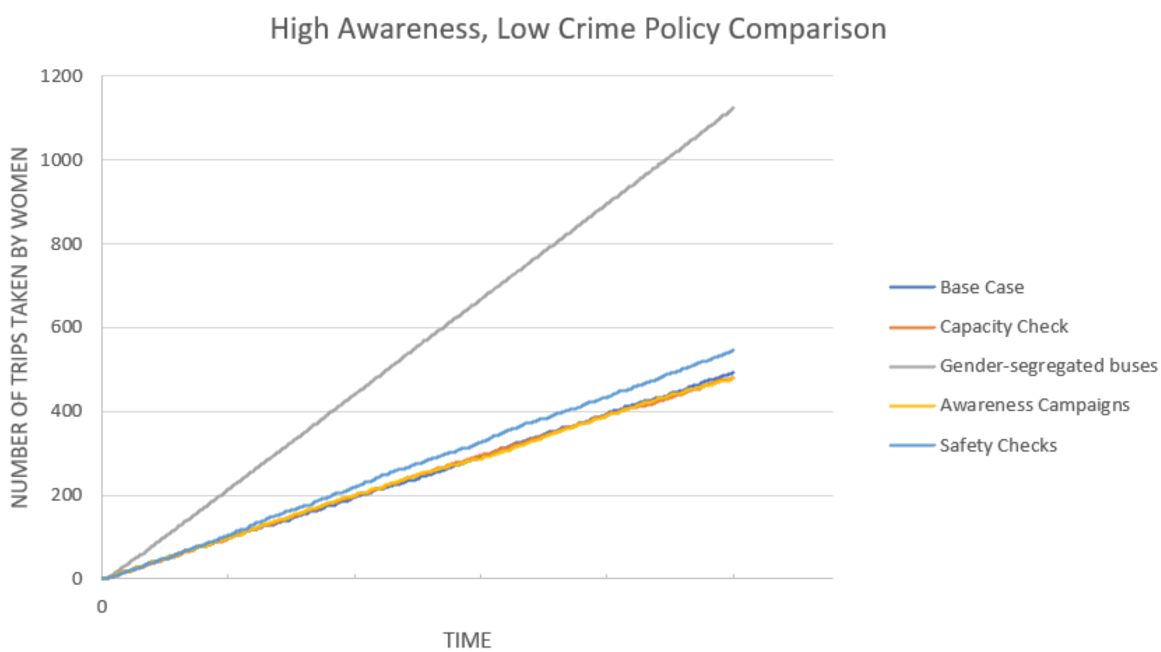

Fig. 25 Number of Trips Taken: Policy Comparison for High Awareness, Low Crime Case

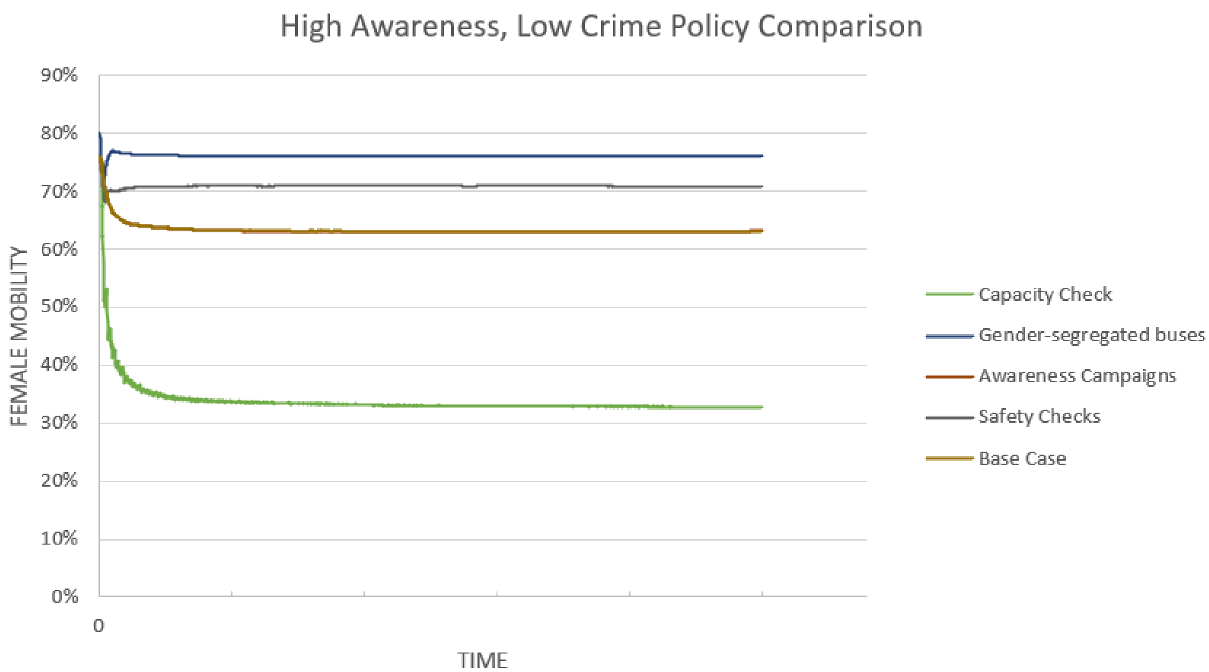

Fig. 26 Female Mobility: Policy Comparison for High Awareness, Low Crime Case

INCREASED GENDER PARITY, LOW SOCIAL STIGMA SCENARIO RESULTS

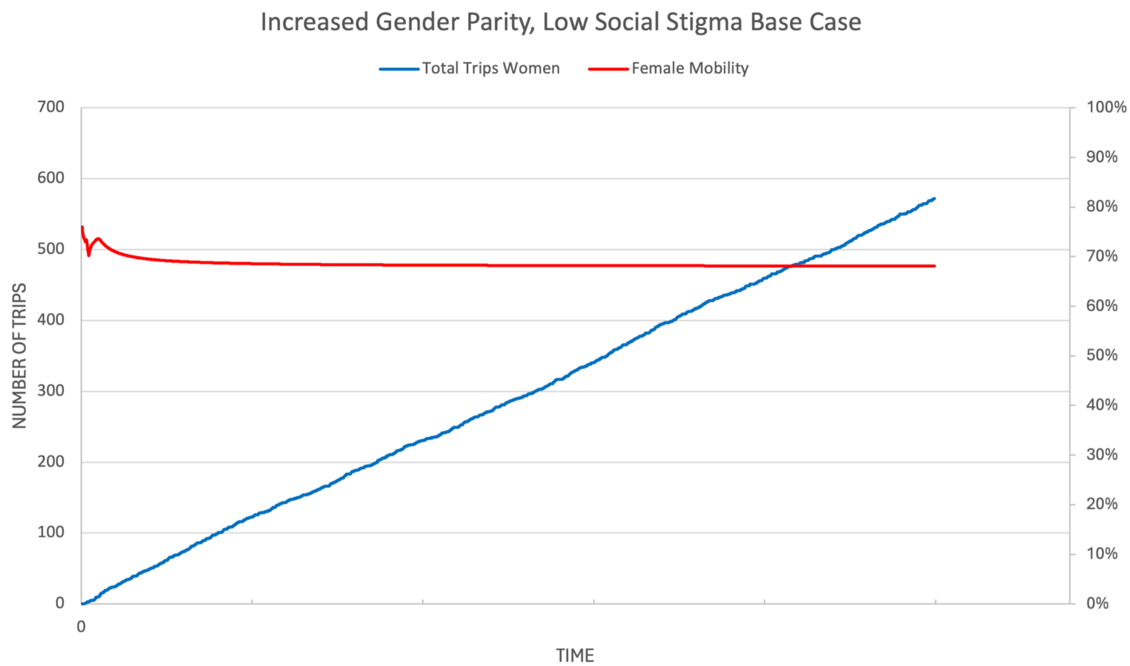

Fig. 27 High Gender Parity, Low Social Stigma Case with No Policies

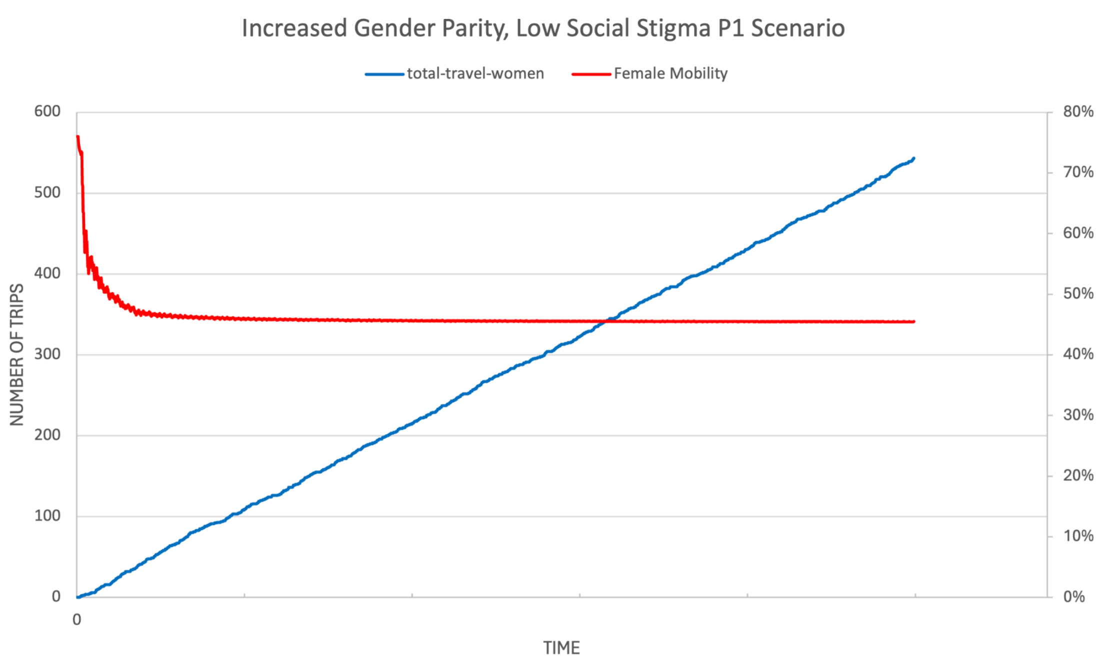

Fig. 28 High Gender Parity, Low Social Stigma with P1

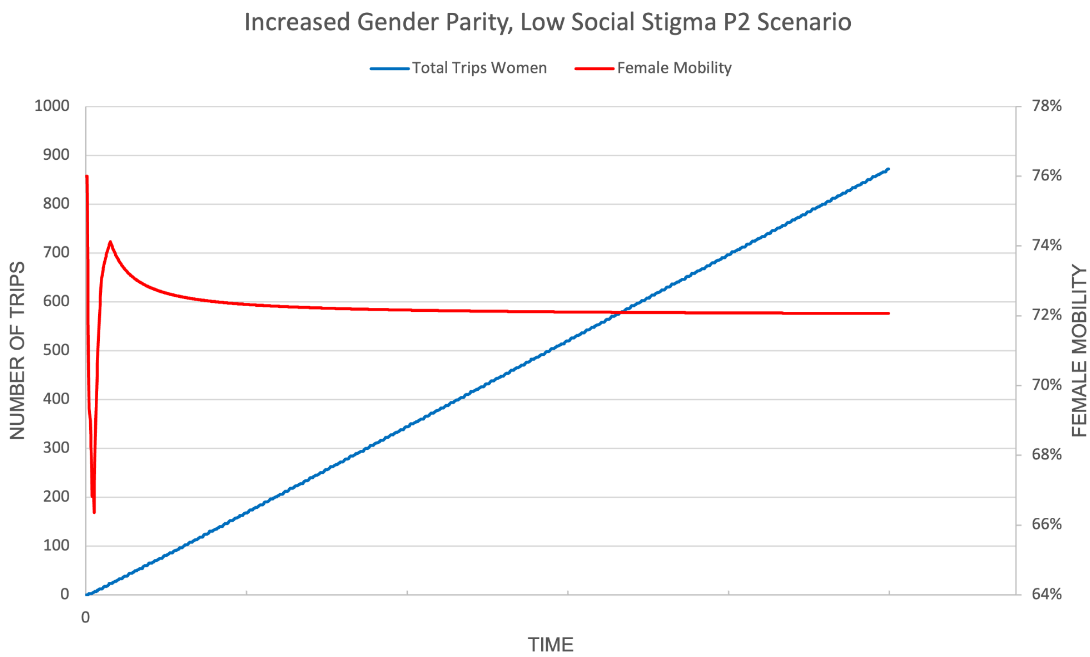

Fig. 29 High Gender Parity, Low Social Stigma with P2

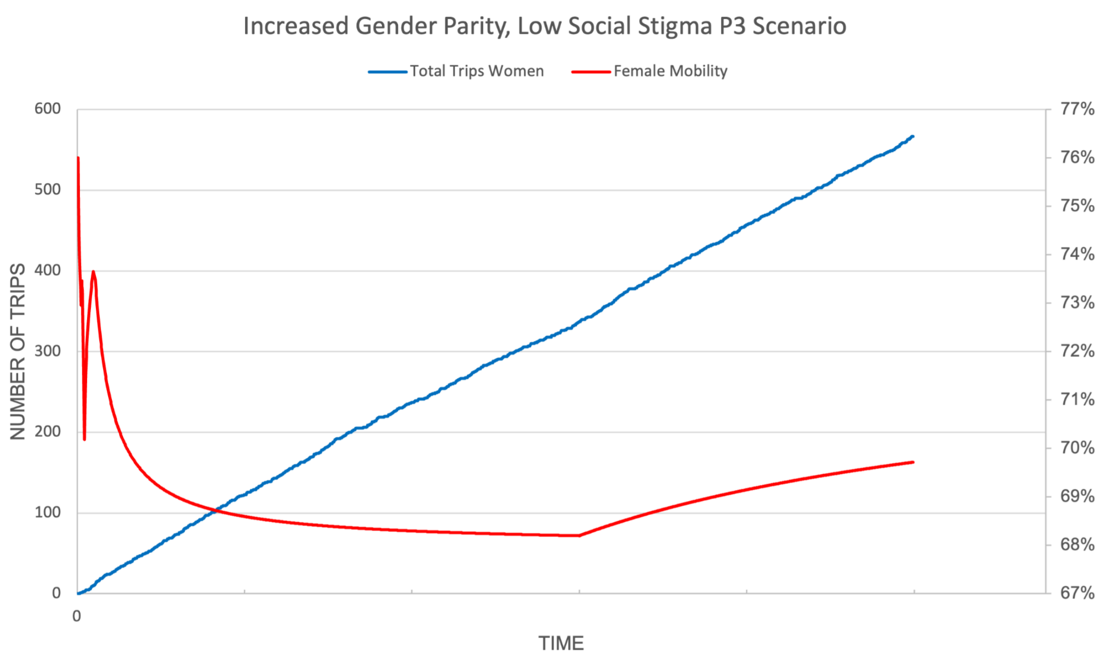

Fig. 30 High Gender Parity, Low Social Stigma with P3

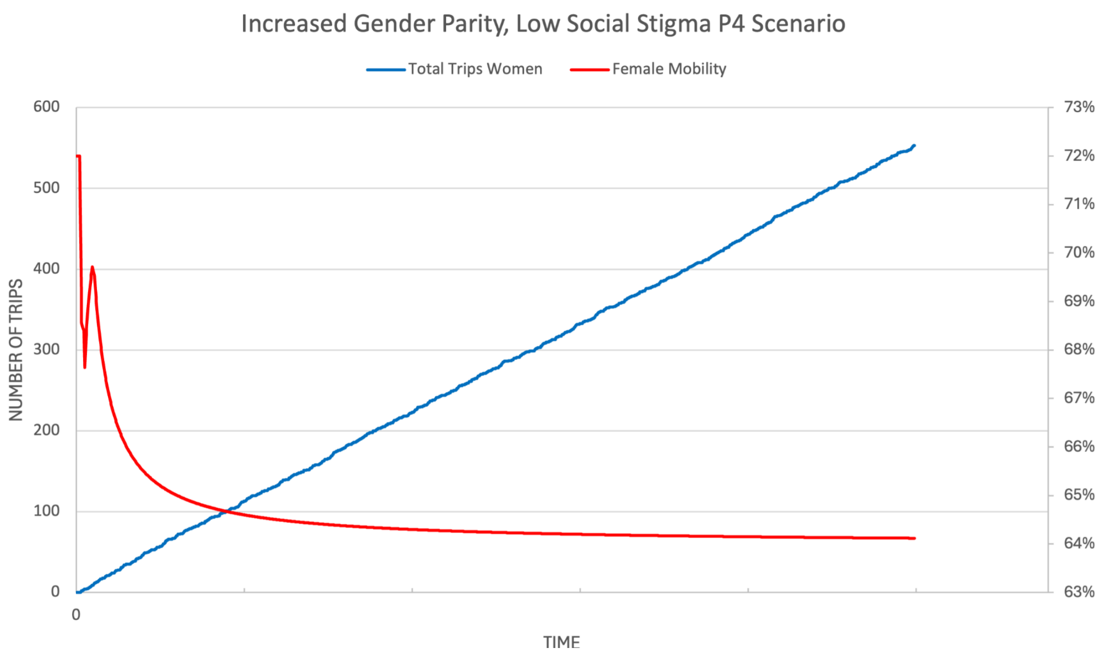

Fig. 31 High Gender Parity, Low Social Stigma with P4

Fig. 32 Number of Trips Taken: Policy Comparison for High Gender Parity, Low Social Stigma Case

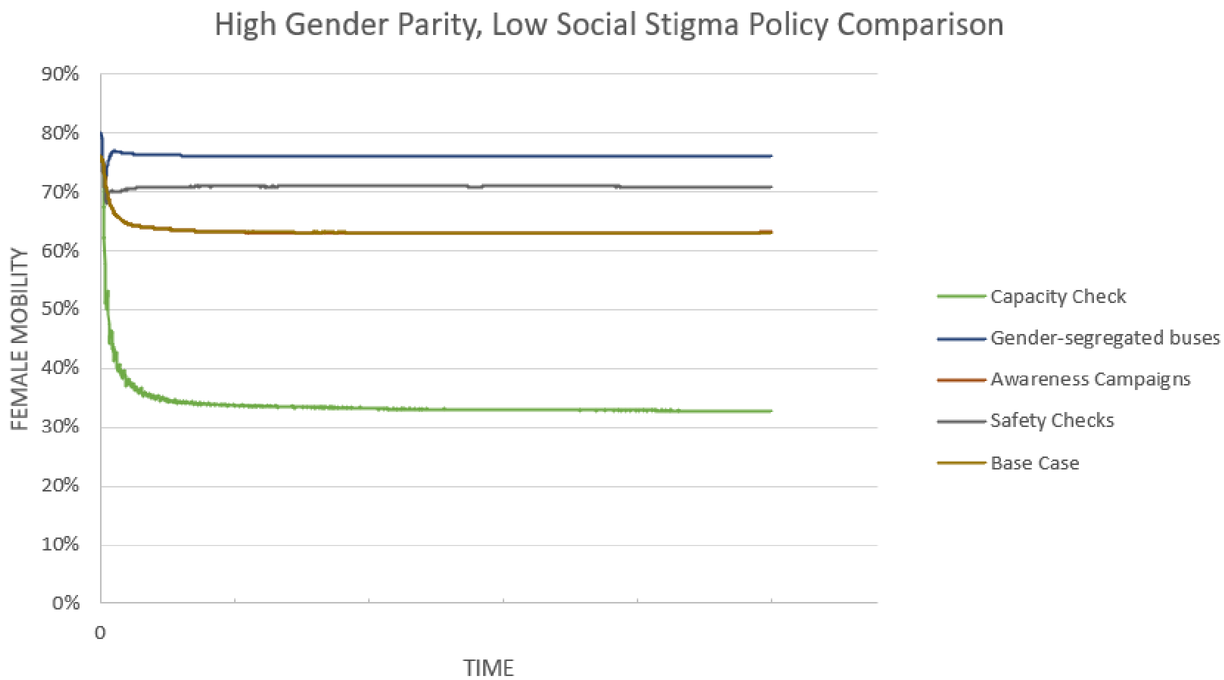

Fig. 33 Female Mobility: Policy Comparison for High Gender Parity, Low Social Stigma Case

RESULT ANALYSIS AND OUTLOOK

BUSINESS AS USUAL SCENARIO RESULT ANALYSIS

The results for the Business-as-Usual base case and policy scenarios are plotted and shown in figures 2-19. The plots show that P2 (gender-segregated buses) is the most successful policy for increasing female mobility and the total number of trips taken by women.

Table 5 BUSINESS-AS-USUAL: STEADY STATE FEMALE MOBILITY

Policy/Scenario	Steady-State Female Mobility
Base Case	7%
P1	4%
P2	71%
P3	8%
P4	12%

Female mobility is around 8% for the base case. When P1 (capacity-check) is implemented, female mobility decreases to around 5% even though women's comfort levels improve (see figure 3). Similar patterns are observed for P5 (capacity-check and gender-segregated buses), P6 (capacity-check and awareness-campaigns), P11 (capacity-check, gender-segregated buses, and awareness-campaigns), P12 (capacity-check, gender-segregated buses, and safety-check), and P15 (all four policies). However, when capacity-check is implemented in combination with other policies, especially P2 (gender-segregated buses), the overall negative impact of capacity-check on female mobility is minimised (see figure 7).

The results for P2 show a significant increase in female mobility, with the steady-state value of female mobility increasing to around 71%. The graph initially shows a dip in mobility, followed by a rise (see figure 4). The fluctuation may have been caused by initial unfamiliarity and lack of trust in gender-segregated buses among women. As awareness and confidence levels improve over time, more and more women become open to the idea of using gender-segregated buses, leading to improved mobility rates. Similar trends are noted for policy combinations incorporating gender-segregated buses such as P8 (gender-segregated buses and awareness-campaigns) and P9 (gender-segregated buses and safety-check). However, in the case of policies P5, P11, P12, and P15, all of which incorporate capacity-check, an initial adjustment period consisting of oscillatory motion in female mobility is observed. When capacity limits are enforced, they disrupt usual travel patterns, causing confusion and inconvenience for passengers, leading to fluctuations in mobility as users adapt to the new changes. However, over time, passengers become accustomed to these changes, and the fluctuations diminish over time, leading to stabilisation of mobility patterns.

P3 (awareness-campaigns) alone does not significantly improve female mobility, showing only an increase of 1% from the base case (see figure 5). Similarly, when P3 is paired with other policies excluding P2, it again fails to significantly enhance female mobility. This is because awareness campaigns usually require a longer amount of time to influence behaviour and perceptions. However, when P3 is combined with P2 in P8, there is a noticeable increase in female mobility, from 71% to 73% – the maximum female mobility observed across all policy combinations (see figure 10). These results show that combining P3 with other supportive policies, such as gender-segregated buses, is more effective in enhancing female mobility.

P4 (safety-check) minimally improves female mobility, both when implemented alone and in combination with other policies. Compared to the base case, when P4 is run alone, there is a 5% increase in female mobility (see figure 6), and when combined with P3 in P10 (awareness-campaigns, safety-check), the increase is 6% (see figure 12). However, when P4 is combined with P2 in P9 (see figure 11), female mobility reduces from 71% to 66%. This decrease can be attributed to the fact that gender-segregated buses already significantly enhance safety and additional security checks might be seen as unnecessary or inconvenient.

The results indicate that P8 is the most successful policy, achieving a steady-state female mobility rate of 71% while combining all four policies results in a significantly lower female mobility rate of 29%. This outcome highlights that more is not always better. Excessive policy implementation can result in diminished effectiveness due to overlapping measures that complicate usage or minimise the positive effects of individual policies.

2.4.2: HIGH AWARENESS, LOW CRIME SCENARIO RESULT ANALYSIS

The results for the High Awareness, Low Crime base case and policy scenarios are plotted and shown in figures 20-26. The plots show that P2 (gender-segregated buses) is the most successful policy for increasing female mobility and the total number of trips taken by women.

Table 10 HIGH AWARENESS, LOW CRIME: STEADY STATE FEMALE MOBILITY

Policy/Scenario	Steady-State Female Mobility
Base Case	63%
P1	33%
P2	76%
P3	63%
P4	71%

Female mobility is 63% for the base case in the high awareness, low crime scenario. This is significantly higher than the steady-state value for the business-as-usual case, indicating just how impactful world parameters can be in influencing female mobility and respective policy implementation. All policy implementations yield a steady-state value of female mobility greater than 30% in this scenario.

When P1 (capacity checks) is implemented, female mobility steadily declines to 33% - a staggering loss of 30% from the base case (see figures 21 and 26). Similar to the business-as-usual scenario, P2 (gender-segregated buses) is the most effective policy, followed by P4 (safety checks) yielding steady-state values of 76% and 71% for female mobility respectively. Referring to figure 22, it can be seen that female mobility sharply dips to approximately 72% before rising back up to 77% and slowly decaying to a steady-state value of 76% when P2 is implemented. Implementation of P3 (awareness campaigns) does not result in any deviation in female mobility from the base case scenario for the high awareness, low crime scenario, as can be seen in figures 23 and 26. Figure 24 shows that when P4 is implemented on the high awareness, low crime scenario, the female mobility dips to about 68% before rising back to 71%.

It is interesting to note these results given the parameters that were set for this scenario. The weight for safety in the psychological model was decreased from 0.8 to 0.3 and the harasser percentage was decreased from 70% to 30% to show low crime in this scenario. The weight for awareness was increased to 0.9 to show high awareness. Given these changes, it was predicted that P3 would be more effective as awareness was given higher importance, however similar to the business-as-usual scenario, the female mobility with P3 implemented was similar to that as the base case. Even more interestingly, implementation of P4 yielded a significant increase in female mobility of about 8%, which was not expected as both the safety weight in the psychological model and harasser percentage was decreased. The results obtained from this scenario show that regardless of world parameters, policies targeting safety of women on public transport tend to yield better results as compared to other policies.

Capacity checks continue to hinder female mobility even though they result in higher values of comfort for women using the BRT. This effect is particularly prominent in this case, where the base case female mobility was already quite high. This shows that comfort - while an important part of the decision-making framework - does not take precedence when making modal choices. Attempts in improving female comfort through capacity checks actually limits the number of women that can use the BRT - and this number is quite significant given that the capacity was increased from 4 to 10 in the high awareness, low crime scenario - modelled after the Tokyo bus system.

2.4.3: INCREASED GENDER PARITY, LOW SOCIAL STIGMA SCENARIO RESULT ANALYSIS

The results for the base case and policy scenarios are plotted and shown in figures 27-33. The plots show that P2 (gender-segregated buses) is the most successful policy for increasing female mobility and the total number of trips taken by women. However, when compared to the base case, the increase (4%) is minimal. Surprisingly, policies P1, P3, and P4 decrease female mobility. These results demonstrate the importance of implementing policies only when necessary. As shown in table 6, poorly conceived or excessive policy measures can have the opposite of the intended effect.

Table 6 INCREASED GENDER PARITY: STEADY STATE FEMALE MOBILITY

Policy/Scenario	Steady-State Female Mobility
Base Case	68%
P1	45%
P2	72%
P3	-
P4	64%

Oscillatory motion in female mobility is seen across all five graphs, but is particularly significant for P2 and P3 due to the nature of these interventions.

For policy P3, oscillations in female mobility can be seen during the first two days (see figure 30). This occurs because it takes a lot of effort and time to change entrenched behaviours and attitudes. People often revert to familiar patterns unless they are continuously motivated or reminded of the new behaviours. The rise in female mobility after day 3 shows that awareness campaigns can create change once they have overcome initial resistance.

For policy P2, an initial dip in female mobility is observed (see figure 29). The simulation parameters for this scenario are based on the NYC Bus System, where gender segregation in public transport might be opposed due to cultural norms that emphasise inclusivity. Female mobility continues to rise and drop until steady-state is reached. These fluctuations in female mobility may result from periods where passengers perceive an increased sense of safety due to the segregation, contrasted with periods of backlash from others who view such policies as regressive.

OVERALL ANALYSIS

It is important to note that the simulation results of the scenarios inspired by the Tokyo and New York bus systems may not accurately reflect real-life outcomes. This is because the psychological model used to simulate decision-making is based on the assumptions and parameters of the Calicut model, which does not capture the characteristics of New York or Tokyo. The goal is to explore how female mobility in Lahore would change if the city were to adopt societal and cultural norms similar to those in Tokyo or New York.

From the results obtained, it can be seen that female mobility increased significantly in the high awareness, low crime and increased gender parity, low social stigma scenarios with no policy implementation as compared to the business-as-usual scenario. This indicates the importance of targeting societal issues in Pakistan - specifically those of decreasing crime rates, improving gender parity, and reducing social stigma surrounding the use of public transport. Initiatives to target these issues do not necessarily have to be in the public transport realm. Crime rates could be decreased by improving street lighting and surveillance in the city, police patrolling, etc. Gender parity can be improved through the implementation of equitable policies that promote inclusive education and awareness, as well as ensuring equal opportunities and representation for all genders in all sectors of the society. Social stigma can be decreased through public awareness campaigns, and the enactment of supportive legislation that both protects and promotes the rights of women.

It is interesting to note that across all three scenarios, P1 (capacity checks) actually hindered female mobility. This goes to show that implementing capacity checks in order to improve the feeling of comfort in women actually hinders them from using the BRT system to their needs -

showcasing that comfort does not play as vital a role in modal decision making. On the other hand, safety measures - be it through the introduction of gender-segregated initiatives or safety checks - leads to improved female mobility across all three scenarios, underscoring the importance of safety in female decision-making to use the BRT regardless of world parameters.

The business-as-usual scenario further sheds light on the negative consequences of excessive policy implementation, showing that a policy combination of gender-segregated buses with safety checks leads to the highest female mobility rate of 71%, whereas a combination of all four policies implemented together results in a female mobility rate of only 29%. These results indicate the importance of the systematic analysis of policy implementation in order to achieve the optimal result.

Referring to figure 34, a breakdown is given of the number of trips across all three scenarios for the base case and all four policy implementations separately. It can be seen that P2 yields the highest number of trips taken for all three scenarios, however it is important to note that real-world implementation of gender-segregated buses will not result in such a stark difference as compared to other policies. This is due to the implementation of gender-segregated buses in the simulation. As per the code, enactment of gender-segregated buses leads to only women being able to use the BRT system. This means that the entire fleet of buses in the BRT system are converted to women-only. This cannot be replicated in the real world, and normally the introduction of gender-segregated buses means that a certain percentage of the entire fleet of buses are converted to women-only. However, these results show the true demand of women's mobility needs that are currently not being met by the BRT system. This result actually refutes the common misconception that gender-segregated services are bound to fail due to the lack of demand by women.

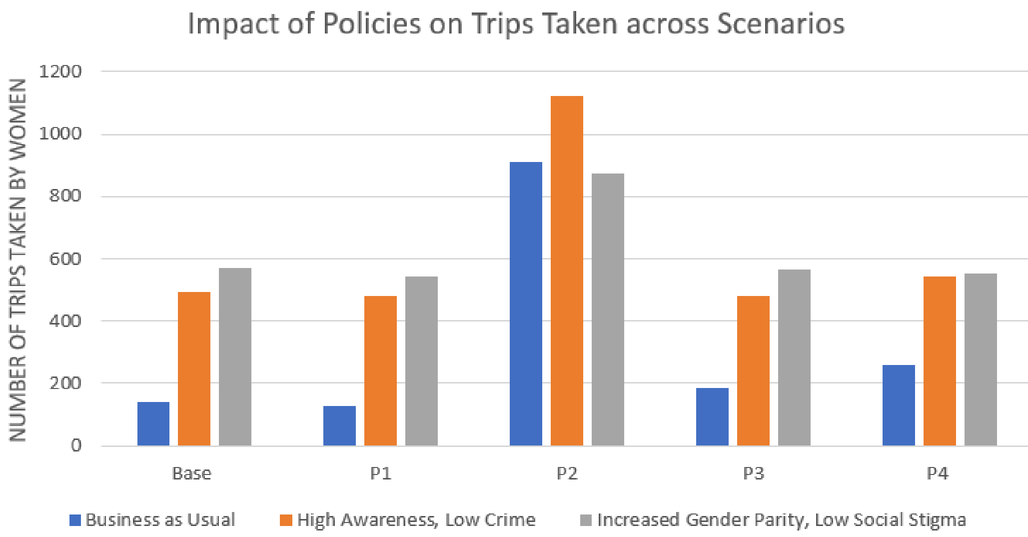

Fig. 34 Impact of Policies on Number of Trips Taken Across all Scenarios

The impact of world parameters on number of trips taken by women can also be seen through figure 34 - i.e. in the increased gender parity, low social stigma scenario, the number of trips taken is higher than the other two scenarios in the base case, P1 and P3 implementation, whereas it is lowest in P2 implementation and about equal to the high awareness, low crime scenario for P4. This shows that while P2 may be the most effective policy as compared to the other three policies for the increased gender parity, low social stigma scenario, the level of impact of P2 on the increased gender parity, low social stigma scenario is actually lower than on the other two scenarios. Therefore, analysis across all three scenarios provides further insights into policy behaviour.

SUMMARY

Our work highlights the need for policy changes that are targeted towards the local population to improve female mobility in the Lahore BRT system. The scenarios examined revealed that certain combinations of policy changes can dramatically improve mobility outcomes for women, thus empowering women and contributing to their social and economic development. Policymakers should consider the following recommendations to create a safe, accessible, and gender-inclusive public transit system that supports the mobility of all citizens, especially women.

- For the business-as-usual scenario, P2 (gender-segregated buses) is the most effective policy. It significantly increases female mobility from 8% to 71% by improving women's feeling of safety and comfort. P3 (awareness campaigns) are helpful when combined with other policies, but does not result in significant improvements as a standalone policy while P4 (safety checks) increases female mobility from 8% to 12%. The results show that combining multiple policies may not improve outcomes and can sometimes be counterproductive.
- For the high awareness, low crime scenario, P2 (gender-segregated buses) and P4 (safety checks) are the most effective policies for improving women's feeling of safety and increasing awareness while P1 (capacity checks) results in a reduction in mobility, suggesting that while it may increase comfort, it does not result in higher usage rates by women.
- For the high gender parity, low social stigma scenario, P2 (gender-segregated buses) is moderately effective with female mobility increasing to 72% from 68%. However, in this case, P1, P3, and P4 reduce mobility, indicating that in environments with high gender parity and low social stigma, restrictive measures may be counterproductive. Policies must be designed by considering the local social context, avoiding overregulation which might limit accessibility and acceptance.

Overall, our findings suggest that policymakers should prioritise safety and gender-segregated buses to improve female mobility in the Lahore BRT system. However, policymakers must consider the cultural and social context when designing these policies to maximise their acceptance and effectiveness without overwhelming the system or the users.

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