**Developing a Travel Demand Management (TDM) Assessment Tool for Office-Based TDM Strategies**

## 1. Introduction

Traffic congestion is one of the most common challenges for every city in the present world. Because, traffic congestion is an optimization problem, there is no direct or simple solution for the problem. If new infrastructure is built (i.e. expressway, overpass, rapid transit) congestion may be temporarily alleviated. Unfortunately, the addition of transportation infrastructures increases latent demand for travel, ultimately resulting in a return to the congested state of the transportation network. The phenomenon of latent demand is generated by the increase in development surrounding the newly-built infrastructure, which creates further demand for travel within the region. Therefore, providing additional road capacity is only effective for a limited time. It is imperative to find an alternative solution to provide long term congestion mitigation. That alternative solution is transportation demand management (TDM) strategies. By implementing TDM strategies, we encourage people to move away from single occupant vehicles (SOV) and provide incentives/disincentives for choosing sustainable modes of travel. Beyond the advantage of reducing congestion, TDM policies have other implications, including increased safety and emission reduction (Litman, 2003).

According to the TDM study report of Transport Canada (2011), a number of Canadian municipalities have been testing various TDM policies for the past decade. However, the evaluation of the effectiveness of these policies is still unclear. In order to assess the performance of a TDM policy it is necessary to do a "before and after" survey; whereby the state of the transportation system is compared before and after the implementation of the TDM policies. Once the assessment has been completed it is possible to estimate the overall effectiveness of a policy. Various regional and local surveys have been conducted by both government and private sector organizations to measure TDM policies. For example, Metrolinx, the regional transportation authority for the Greater Toronto and Hamilton Area (GTHA), has conducted baseline and follow-up surveys in GTHA to determine the return on investment and the impact of the Smart Commute program at a worksite (Transport Canada, 2011). Metrolinx has also conducted household level surveys to measure the performance of school based TDM programs. In 2002, the City of Ottawa conducted a survey to understand the travel behavior of commuters;

this survey identified triggering factors that encourage respondents to choose non-auto-centric transportation modes (public transportation, biking, walking) instead of single occupant vehicle. Similarly, the Central Okanagan Region and the Vélo Québec Association developed surveys to measure TDM policies in 2004 and 2005 respectively (Transport Canada, 2011). In the light of above discussion it is evident that surveys are essential to evaluate and understand the effectiveness of TDM policies. Majority of these surveys are done both before and after the TDM policy implementation to assess the change in travel behaviour. This approach is not cost effective as it is necessary to implement the policy initially and then maintain the particular TDM policy for an extended period prior to undertaking the performance measurement. This means that the policy selected for implementation may not be appropriate or optimal for the specific context of the region where it is being implemented. Furthermore, other land use or transportation network changes may skew the results of the evaluation. Finally, extrapolating the results of the performance measurements from a regional level to a more local level can be challenging using the existing "before and after" survey approach. There is an obvious lack of tools or techniques that can accurately measure the performance of various TDM policies prior to implementation.

In light of the limitation discussed above, the main objective of this project is to develop a tool that will aid planners and decision makers in assessing TDM policies prior to implementation. The tool prototype has been developed and tested for employer based TDM policies in the Region of Peel, Ontario. The development of this prototype was a joint effort between the Travel Demand Modelling Group at the University of Toronto and Staff Members at the Region of Peel. The tool will help to choose the most effective employer based TDM policies at multiple institutional levels ranging from the region as a whole down to large individual employers who operate within the region.

## 2. Objectives

To overcome the limitations and to implement a feasible method for assessment of TDM policies prior to implementation it was essential to define a set of major objectives. These objectives were established with a one-year time frame to be completed sequentially:

1. To develop a comprehensive individual specific Revealed Preference (RP) and Stated Preference (SP) web-based survey tool that will incorporate detailed household and socio-economic information, all hypothetical TDM policies and corresponding scenarios, and the revealed travel mode choice of a commuter working in the region in question;
2. To use the results of the aforementioned survey to test several mathematical specifications for a microscopic commuting mode choice model. The model will be based on random utility maximization (RUM) theory. Alternative specifications will be tested to identify the policy sensitivity and statistically significant model;
3. To develop a stand-alone assessment tool that will implement the final mode choice model specification, showing the base case modal share and changed mode share based on the execution of various hypothetical TDM policies. This tool will have a user-friendly interface, will be accessible to a broad range of users, and will provide both numerical and graphical outputs, which will be used to forecast the mode switching behaviour of commuters in response to various TDM policies.

## 3. Methods

The methodology of this project can be divided into four stages:

1. Develop an individual specific, customized RP and SP web-based survey tool;
2. Conduct the survey;
3. Develop mathematical specifications for the microscopic policy sensitive commuting mode choice model;
4. Develop a TDM assessment tool.

The first stage is to design an RP-SP survey (Figure 1 and 2). A web based survey tool was coded by using JavaScript and jQuery. The survey tool generates hypothetical scenarios for each respondent regarding their hypothetical trip to work given the implementation of various TDM policies. These scenarios are customized based on each individual's home and work locations, bike and car ownerships information and other household attributes. The RP portion of the survey consists of three parts: detailed personal information, detailed household information, activity schedule (household travel diary). All three sections are based on the most recent Transportation Tomorrow Survey (TTS) data. This allows for potential data fusion with the much larger dataset. For the SP section of the survey an experimental design approach was followed. An efficient design technique was used in order to minimize the number of responses needed for statistically significant models. The Ngene software package was used to design the experimental design component (Choice Metrics Pty Ltd, 2014). In total, six scenarios were provided to each respondent to evaluate their mode choice behavior in response to various TDM policies.

The second stage is conducting the survey. The respondents were selected using a probability-sampling method. This method collects an unbiased sample, as the collection method is completely random. The survey mode is web based and invitations to participate were sent through email. The survey respondents were randomly chosen from the panel of a market research company and through telephone recruitment. In total over 800 responses were collected.

The third stage is to develop the mathematical specification for the microscopic policy sensitive commuting mode choice model. The model was developed using a joint RP-SP specification to account for the systematic bias associated with SP data. This bias is the result of the potential lack of consistency within the responses to the hypothetical scenarios.

The fourth and final stage involves incorporating the mathematical model developed in stage three into a comprehensive TDM assessment tool. The tool prototype was established as a spreadsheet based software package that provides the user with detailed information regarding changes to modal share based on the implementation of various TDM policies. The tool utilizes simulation-based approaches to predict the impact of different policy penetration levels.

## 4. Software Interface

The tool interface can be developed using a number of different techniques and approaches. The two most notable approaches include a spreadsheet based tool and a web-based tool. Each approach has its own strengths and weaknesses. The spreadsheet-based tool is a stand-alone tool that requires minimal maintenance and upkeep once developed. However, issues related to the distribution of the tool may be complex.  There are also some privacy concerns related to sensitive micro data contained within the spreadsheet. Conversely, a web-based tool requires some minor maintenance and upkeep associated with maintaining a server to host the tool.  This approach may allow for the tool to reach a much larger audience and has fewer privacy concerns associated with sensitive personal data.

Irrespective of the interface, the tool itself has three main components:

1. In the start-up page of the tool there are the definitions of the available modes (Table 1).
2. The next section contains the input interface for the tool (Table 2).
   a. The first column provides a list of the possible TDM policies to be tested;
   b. In the second column, there is an "input type and instruction" section for the policies;
   c. In the third column, users have to input the policies they would like to test. The inputs are either binary (zero and one) or continuous numbers. For daily or monthly parking "one" means monthly parking and "zero" means daily parking. For other cases, "zero" means this policy will not be implemented, whereas "one" means this policy will be implemented. Users can input and test any kind of dollar amount for daily parking cost for driving and carpooling.
   d. Sometimes, policies may not be implemented across the entire region. In these cases, a percentage of employers will chose to implement a policy. This percentage is defined as the penetration rate. The penetration rate is incorporated within the tool using a simulation technique, where an equivalent percentage of commuters in the region will be affected by the TDM policy. Since the daily parking cost penetration rate can be directly captured by the average dollar value, no cell is provided for the under penetration rate column.

   Table 3 presents an example of how the table is used, with both continuous, binary and penetration rates being selected.

3. Figure 3, Figure 4 and Table 4 provide the mode share, before and after implementation of the policies in question. It is also possible to determine the reduction in vehicle kilometers travelled and emissions relative to the base case.

## 5. Project Evaluation Criteria

The employer based TDM assessment tool for the Region of Peel and the methods undertaken during the development of the tool are both strong contributions to promoting sustainable urban transportation in Canada. In addition to assisting the Region of Peel to implement TDM policies that encourage sustainable travel behaviour and a healthy lifestyle, this tool can set a benchmark for the evaluation of TDM policies across Canada.

### 5.1. Development and Enhancement of Sustainable Urban Transportation

This section discusses how the TDM assessment tool addresses the three main pillars of sustainability, namely the social, economic and environmental aspects.

#### 5.1.1. Social

The social component of the tool stems from the ability of the Region of Peel, as well as local municipalities and employers in the region to make evidence based decisions regarding the most appropriate TDM tools to implement. This form of evidence based planning provides both rational and transparency to the decision making process. From a more general standpoint, the decision to the implementation of employer based TDM policies provides a number of social benefits associated with congestion reduction, including reduced commute times for employees, promotion of a healthy and active lifestyle, and the promotion of vibrant and healthy multimodal communities for both current and future generations to enjoy.

#### 5.1.2. Economic

The tool itself provides a cost effective alternative to conventional TDM assessment approaches for determining the effectiveness of a set of TDM policies. As the conventional method for TDM evaluation requires both a “before and after” survey, as well as the implementation of the policies in question in order to determine their effectiveness, the cost of conducting a single survey before any implementation is significantly low. Decision makers can then use the tool to support evidence based planning, selecting the combination of TDM policies that will most cost effectively address their needs. The generic nature of the tool allows multiple users within the region to apply the tool, rather than conducting their own potentially expensive study. More generally, the implementation of TDM employment based policies may reduce the need for employers to provide and pay for employee parking. Other potential economic implications include carbon tax/trading credits.

#### 5.1.3. Environmental

This tool can be easily extended to measure the reduction of the vehicle kilometer traveled (VKT) and emissions associated with reduced SOV trips associated with TDM implementation. As alluded to above, this measure can be used to justify employer carbon reduction targets associated with employer carbon taxes, trading or quotas/regulations. More generally, TDM policies encourage the use of sustainable modes, which may encourage commuters to make changes to other aspects of their daily travel (for example, if a commuter rides their bike to work, they may be more inclined to use their bike for non-work based trips). These changes may ultimately result in a shift towards more sustainable land use travel interaction.

### 5.2. Degree of Innovation

The innovation associated with this project is derived from two main components. The first is the partnership between the Region of Peel and the University of Toronto Travel Modeling Group (TMG). This partnership allowed for the application of state of the art research practices in the development of the tool while providing a source of research revenue/funding as well as data for the TMG to conduct their research. The second innovative aspect of this project stems from the use of a joint RP-SP mode choice model. This type of model formulation is very innovative for TDM evaluation within the Canadian context. The execution of this technique required a customized RP-SP survey and the use of efficient survey design techniques, which are relatively well represented in the international research community (Rose et al. 2008) (Cherchi & Ortúzar, 2011), but lack representation in practice.

### 5.3. Transferability to Other Canadian Communities and Organizations

While the tool itself has been designed for employment based TDM within the Region of Peel, there is a huge amount of potential for the development of similar tools across the country. Because the data collection process was designed specifically for the Region of Peel and employer based TDM policies, any other application would require a modification or redevelopment of the data collection tool. These modifications could include alternative TDM policies (land use, home based etc.) or alternative modes for the specific regional context. Once the data has been collected, a new mathematical mode choice model must be estimated and integrated within the tool interface. This allows the tool interface to remain consistent while modifying the data and model structure to fit a specific region and policy context of interest.

## 6. Conclusion

This tool captures the impact of implementing TDM policies in a comprehensive and effective way. The methodology that is used to develop the tool is very unique, innovative and it is an example of advanced experimental design and microscopic, policy sensitive, joint RP-SP modelling. This tool is a benchmark from where a planner can start looking into the comprehensive effects of TDM policies and the methodology that was used to develop this tool is a guideline for our researchers.

## Appendix - I

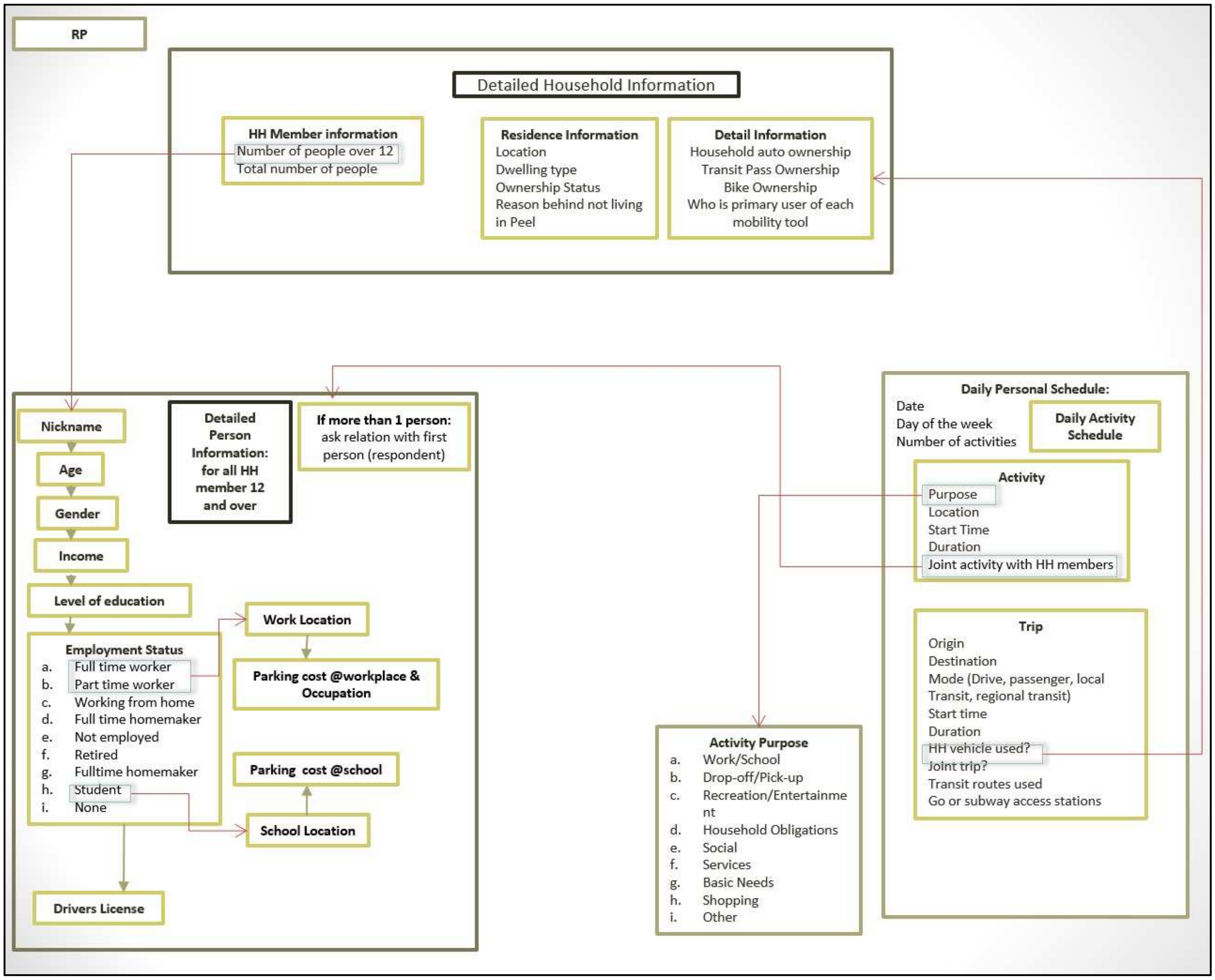


**Figure 1. Data Model for RP Survey**

| Attribute /Travel mode to work | Drive | Dropped off by household member | Carpool with fellow employee | Public Transit | Transit Bike Access(bring your bike on board) |
|---|---|---|---|---|---|
| **Level of service values (travel time, travel cost, etc.). These remain consistent between scenarios.** | | | | | |
| Total Drive Time (minutes) | 20 | 20 | 23 | ---- | ---- |
| Transit Walk/ Bike Time | ---- | ---- | ---- | 25 | 8 |
| Transit Wait Time (minutes) | ---- | ---- | ---- | 12 | 12 |
| Total Time Traveling in the Transit Vehicle | ---- | ---- | ---- | 57 | 57 |
| Travel Cost (Dollars) | $4.23 | $4.23 | $2.12 | $2.8 | $2.8 |
| **Employer based TDM polices. These change between scenarios.** | | | | | |
| Daily or Monthly Parking Cost at Your Workplace (charged at a per day basis, or a monthly parking pass is offered at a discounted rate) | monthly | ---- | monthly | ---- | ---- |
| Employer pays for region of Peel (Miway or Brampton Transit) transit passes | ---- | ---- | ---- | no | no |
| Parking Cost (Daily and Monthly Rates) at Your Workplace | Monthly $36.00 (Daily rate: $1.80) | ---- | Monthly $0.00 (Daily rate: $0.00) | ---- | ---- |
| Indoor Car Parking at Your Workplace | yes | ---- | yes | ---- | ---- |
| Sheltered Bike Parking at Your Workplace | ---- | ---- | ---- | ---- | no |
| Showers and Changing Rooms at Your Workplace | ---- | ---- | ---- | ---- | yes |
| Employer Owned Bikes Available to Rent (For Going Out to Lunch) | ---- | no | no | no | no |
| Bike Friendly Building Access (Ramps) at Your Workplace | ---- | ---- | ---- | ---- | yes |
| Likelihood of Finding a Parking Spot Within 5 minutes walk to your Work Place (due to parking reductions) | 100% | ---- | 100% | ---- | ---- |
| Emergency Vehicle or Ride Home Program at Your Workplace | ---- | yes | yes | yes | yes |
| Employee Run Car Share Program at Your Workplace (for business related or short personal trips) | ---- | yes | yes | yes | yes |
| **Please select your preferred travel option** | | | | | |

**Figure 2. A Sample SP Scenario for a Respondent**

**Table 1. Start-up Page of the Tool**

| Mode Alternatives | Definition |
|---|---|
| Bike | The respondent will bike to work |
| Walk | The respondent will walk to work |
| Local Transit | The respondent will take the local transit to work |
| Car Pool | The respondent will share a car so that more than one person travels in the car to work |
| Auto Passenger | The respondent is sharing the car which is driven by someone else from the same household |
| Drive | One passenger driving alone all-way |

**Table 2. Input Interface of the Tool (before implementing TDM policies)**

| TDM Policy | Input type and instruction | Input Here | Penetration Rate |
|---|---|---|---|
| Daily Parking Cost Driving | Provide any Dollar amount | 0 | |
| Monthly or Daily Payment Structure for Parking (Driving) | For "Monthly" input 1 and for "Daily" input 0 | 0 | 100.00% |
| Daily Parking Cost for Carpool | Provide any Dollar amount | 0 | |
| Monthly or Daily Payment Structure for Parking (Carpool) | For "Monthly" input 1 and for "Daily" input 0 | 0 | 100.00% |
| Employer provides incentive for Region of Peel transit passes | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Driving: Likelihood of Finding a Parking Spot Within 5 minutes' walk to work place (due to parking reductions) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Carpooling: Likelihood of Finding a Parking Spot Within 5 minutes' walk to work place (due to parking reductions) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Driving: Indoor parking facilities at workplace | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Carpooling: Indoor parking facilities at workplace | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Car share program | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Emergency ride home program. | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Bike service (shower, locker, access) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Bike share | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides shower and change room at work place | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides indoor bike storage/lockers | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides bike friendly building access | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |

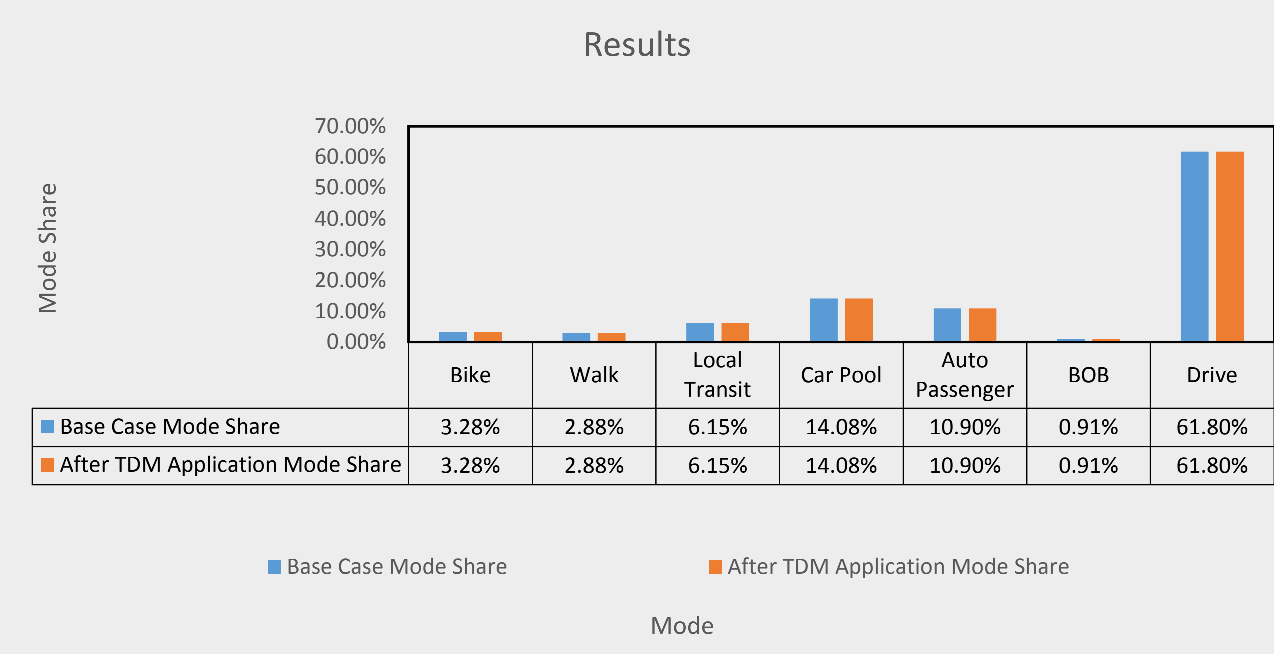


**Figure 3. Result Interface of the Tool (before implementing TDM policies)**

**Table 3. Input Interface of the Tool (after implementing TDM policies)**

| TDM Policy | Input type and instruction | Input Here | Penetration Rate |
|---|---|---|---|
| Daily Parking Cost Driving | Provide any Dollar amount | 4 | |
| Monthly or Daily Payment Structure for Parking (Driving) | For "Monthly" input 1 and for "Daily" input 0 | 1 | 100.00% |
| Daily Parking Cost for Carpool | Provide any Dollar amount | 0 | |
| Monthly or Daily Payment Structure for Parking (Carpool) | For "Monthly" input 1 and for "Daily" input 0 | 0 | 100.00% |
| Employer provides incentive for Region of Peel transit passes | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Driving: Likelihood of Finding a Parking Spot Within 5 minutes' walk to work place (due to parking reductions) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Carpooling: Likelihood of Finding a Parking Spot Within 5 minutes' walk to work place (due to parking reductions) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Driving: Indoor parking facilities at workplace | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Carpooling: Indoor parking facilities at workplace | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Car share program | For "Yes" input 1 and for "No" input 0 | 1 | 50.00% |
| Emergency ride home program. | For "Yes" input 1 and for "No" input 0 | 1 | 100.00% |
| Bike service (shower, locker, access) | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Bike share | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides shower and change room at work place | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides indoor bike storage/lockers | For "Yes" input 1 and for "No" input 0 | 0 | 100.00% |
| Employer provides bike friendly building access | For "Yes" input 1 and for "No" input 0 | 1 | 50.00% |

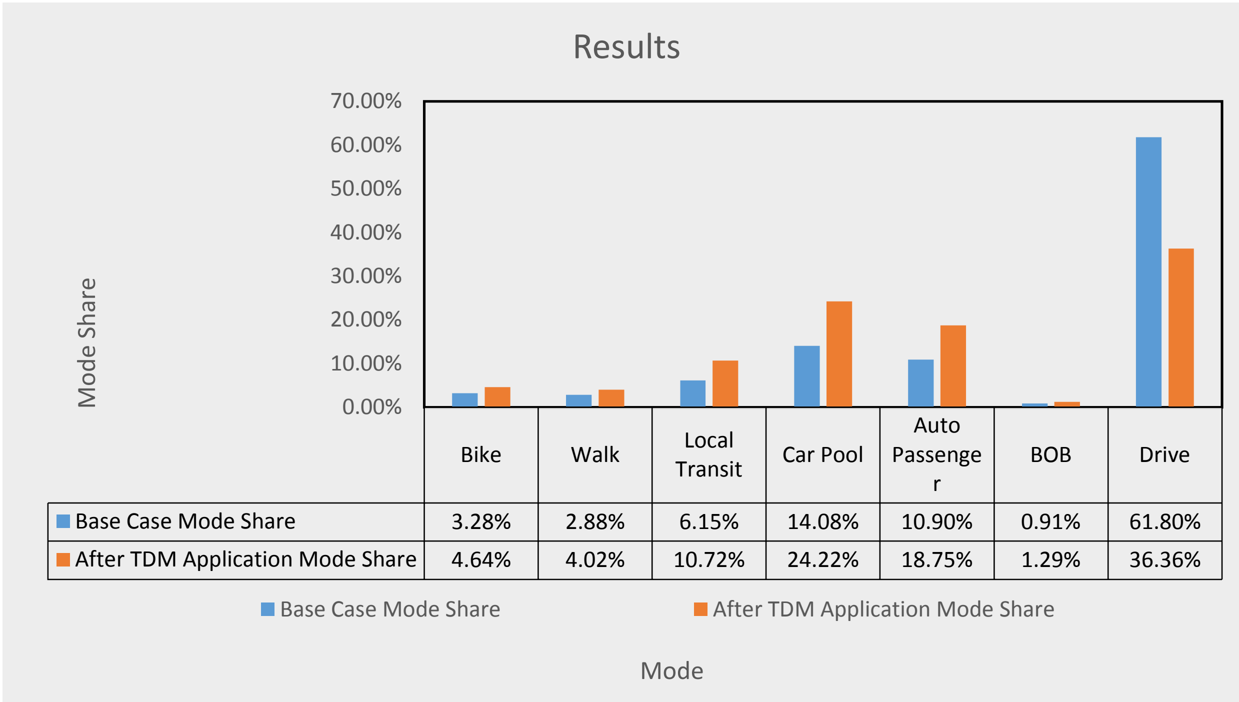


**Figure 4. Result Interface of the Tool (after implementing TDM policies)**

**Table 4. Final Result interface**

| Modes | Base Case | After TDM application | Difference |
|---|---|---|---|
| Bike | 3.28% | 4.64% | 1.36% |
| Walk | 2.88% | 4.02% | 1.14% |
| Local Transit | 6.15% | 10.72% | 4.57% |
| Car Pool | 14.08% | 24.22% | 10.14% |
| Auto Passenger | 10.90% | 18.75% | 7.85% |
| BOB | 0.91% | 1.29% | -0.38% |
| Drive | 61.80% | 36.36% | 25.44% |

**APPENDIX - II**

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