ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Lewis & Clark School Bus Route Optimization

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COURSE: **EMGT 540 - Operations Research in Engineering Management**
YEAR: **2009 FALL**
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Introduction

Abstract

First Student is responsible for school buses in Lewis and Clark County and they are not currently using any software tools for route planning. The literature is full of research on school bus route optimization. The challenge we address in this report is meeting the needs of First Student, with a powerful solution that won't impact their budget. Our solution is not for the entire district at once, but rather optimizes route segments. A route segment is a section of a route in which the bus stops are not fixed by timing due to transfers or other such restrictions. The model also overcomes the limited number of decision variables in standard excel by only entering the parts of the decision matrix that will have values. This is done by using a single decision variable for each house to stop assignment, and houses are only assigned to stops within a limited walking distance. The model uses goal programming to allow the user to give priority to reducing the number of stops, reducing walking distance for students, or a combination of the two. The user is also able to reduce the preference of a single stop to account for things like over crowding or construction. We show how the change in these preferences impacts the assignment of houses to bus stops. When reduction of walking distance is preferred, more stops are used. In contrast when reduction of stops has highest priority, the fewest possible stops are selected to service each house.

Proposal: Lewis and Clark Bus Route

The goal is to develop a model using a linear program that will review a an urban route for a single school and determine the best assignment of houses to bus stops to reduce the amount of time required to complete within defined constraints. The route being reviewed does not impact any other bus routes and does not require transfers. Data is available from First Student to include the route, house addresses, number of students in the home, distance to bus stop, number of stops, and duration.

The current route guidelines will be reviewed to determine the feasibility of combining bus stops to minimize the amount of time a student must spend on the bus. This is the longest part of the route and will allow the district to implement our results without having to do further investigation and optimization. Our goal is to present the findings to the district administration and influence the decision of changing this route.

Data Collection

Due to the sensitive nature of student data, it was very difficult to obtain all the data we needed in the time constraints of this project. Therefore, we used the subset of the data provided and used it in our example. The model will demonstrate the ability to add additional data and expand the model.

Bus Route Definition

School Bus:

Figure 1 - School Bus

A school bus is used to transport children from their homes to the assigned school. They normally make one trip in the morning to pick children up from their homes and take them to school. The evening route will pick the children up in school and

Route:

A route is a set of addresses (roads) that a bus must travel. School buses are given a defined itinerary with the number of stops, arrival time at the each stop and the expected number of children assigned to be picked up at the stop.

Segment:

A route segment is defined as a specific set of contiguous street addresses defined by house number, street direction, from node (or bus stop) and to node. Many segments make up a bus route.

Bus Route:

Figure 2 below illustrates the map layout route 16 and the segments defined within the rural route. The blue dots represent the homes serviced by this route (Actual data in Appendix A).

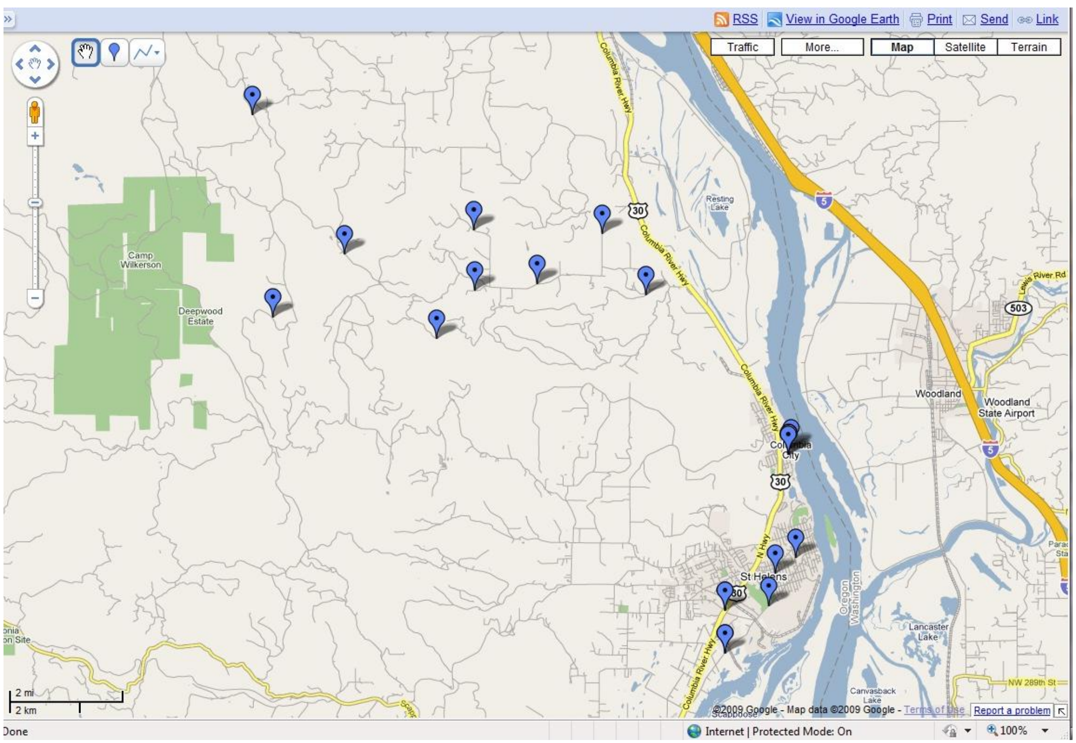

Figure 2 - Route 16 serving students with address in the area depicted in the Map

School District Profile

St. Helens is located 30 miles North of Portland, Oregon, on the Columbia River. The St. Helens School district provides educational services to the communities of St. Helens, Columbia City, Yankton, Deer Island and surrounding rural areas.

"The region has a number of industries that provide a stable economic base for the community and the school district. Small and large acreage home sites are available for families who choose the rural life but have easy access to the Portland Metro area. Many of our parents commute to work in the Portland Metro area on a daily basis, preferring the lifestyle of a smaller semi-rural area" [7]

The district is comprised of four schools consisting of one elementary school, an intermediate, middle and a high school. McBride Elementary is a school for Kindergartners, first graders and second graders. Lewis and Clark Intermediate School is a school for grades third thru fifth. Sixth graders attend Columbia City School. St. Helens Middle School is for seventh and eighth graders. The High School is for grades nine thru twelve.

Problem Statement

Current State

Currently, the person responsible for scheduling the bus stops on the route does not have a tool for scheduling. Scheduling is done manually and route and student information is maintained on Excel spreadsheets. The student's name, address and bus route information is updated manually as necessary. Currently multiple students are assigned to one bus stop, this is done by the scheduler who looks at a map and determines which stop to assign a student to. In an urban route, the student is assumed and expected to walk to a bus stop from their homes and take a bus.

Desired State

A software solution for optimizing route segments in rural bus routes is desired. The solution should enable the user to schedule and manage student and bus routing information electronically. When a child is enrolled or transfers out of the district, the tool would re-evaluate the route and would recommend the optimal recommendations to the scheduled route. The tool should be flexible and easy to use. Given the size and budget of the district, the cost of the solution must be kept to a minimum. Volunteer efforts towards implementing this solution would be ideal.

Literature Review

The Oregonian Stage One problem statement for year 2010 on Transportation Development, the IM-10-07: "Finding a place for the new modes of transportation", is a potential research project to be sponsored by State Government during 2010 – 2011 Financial Year and seeks to generate social benefits in improved safety, reduced fuel wasted and reduced Green House Gas (GHG) emissions through improved transportation practice [1]. Operational Research in school bus systems is one of the many areas that undertakings in optimization has resulted in significant improvement in U.S and other developed countries such as in Europe. Any increased efficiency, effectiveness and cost saving in an existing school bus routing system contribute toward these national objectives. Where and when parents adopt school transportation for their school children, there is always likelihood that a few of the parents may shift to using public transportation, hence more reductions in traffic congestion and carbon emissions.

The significance of vehicle routing and scheduling problem is described in details in optimization literature [2]. Some authors further assert that reducing the number of schools bus stops results in less vehicle delays, less fuel consumption and fewer vehicle clashes. These multiple reductions translate to substantial savings in operating costs. Some authors further argue that an improvement in transportation quality is another additional benefit. Here, quality is the total amount of time spent by students on a ride.

According to Park and Kim [2], there are five components that form the school bus routing problem (SBRP). These subsystems are the Data Preparation, Bus Stop Selection, Bus Route Generation, School Bell Time Adjustment, and the Route Scheduling. Although these subsystems seem sequential, they are usually studied separately. In this research, the focus is on the Stop Selection subsystem with minimal prior work on data preparation. The optimization model maximizes the number of students' residential houses assigned to each bus stop by favoring stops with more houses.

The data preparation involved specifying a route segment, in an urban area for a single school using only the morning route and excluding the complication of a transfer stop. The model determines a set of bus stops for a given route segment and assigns students to these stops.

This model is based on known bus capacity, number of students, students' houses, and using a single route segment, therefore, it cannot result in excessive routes unlike when the bus capacities were not known in advance or if multiple routes existed as at transfer stops. This model also uses data from a single school but it is, for all intents and purposes, theoretically a home-based approach. A home-based approach is student centered [3,4]. Most researchers using home-based models opt for cost minimization but there are a few research papers that use optimization to improve the quality level of school bus service. This quality aspect is defined by the total travel time spent by all children [5]. This model provides the sum total time spent by all students in each ride, and a morning ride is considered. This makes the model a lot simpler since it reduces the heuristics that are typically used in solving more sophisticated models. The model is further simplified by excluding other time considerations such as waiting times at stops and at school like coming late to school [5,6].

Therefore, the extent to which this model is going to be effective in reducing cost is marginal given its sample size but it is certainly going to improve the time a student takes on each ride (by making it shorter), hence improving service quality and to some extent, less time on a road will imply lower probability of an accident on a road while a student in on a ride.

Proposed Model

Objective

Provide a Microsoft Excel interface for optimizing bus route segments. Currently bus stops are chosen by someone familiar with the area. Our project will provide a way for users to enter a route segment, add a route, add a house (with number of kids to ride the bus), add a bus stop, assign a house to a bus stop (ideally a house would be assigned to multiple bus stops), and then the Excel interface will allow the user to run the solver to select the minimum number of stops to service each house assigned to the route.

Proposed Solution

The proposed strategy to arrive at an efficient solution is to gather information to understand the existing requirements and provide a compelling reason to change the existing operating procedures to include the use of the Excel model. With the use the methods and best practices learned in the operations research and literature reviews to design and implement a model to enhance the route and bus assignments to students. The user of the model will be required to will physically look at the route or a map of the route to assign house addresses to bus stops in the Excel model. The more possible bus stops identified by the user, the more useful the tool will be. Since we are dealing with the safety of children, the model will provide a recommendation, but the critical review of a human is required.

The events that will require adding or removing an address to stop assignment(s) are:

- A student leaves town or moves to town.
- A student stops/starts riding the bus at some point during the year.
- A student gets older and can walk further to a bus stop.
- A sidewalk is added to a street, allowing a student to walk to a new bus stop.

Upon the trigger of these events and the modification of the data, the model will identify the needed bus size for the route. The user may want to show the number of student on the route as well as the number of open seats.

Implementation

The first implementation phase of the model will be implemented thru an Excel spreadsheet placed on the school bus route administrator’s desktop. The first phase of the implementation of this will be simple but usable. We will suggest future improvements, but our focus is to create something they can use today using the time and information we have.

Model Notation

Objective Function

Objective: Maximize the number of Houses assigned to each stop (by favoring stops with more houses) as well as accounting for the Total Distance Not Walked (aka minimize walking distance). Walking distance is not as important as minimizing stops. (The importance of Walking or Stops is controlled by User Entered Constants)

Decision Variables

X_{ij} = House *i* to be assigned to stop *j* $\begin{cases} 1, \mathit{If\ house\ is\ assigned} \\ 0, \mathit{Otherwise} \\ i, \mathit{is\ binary} \end{cases}$

Data

N_i = Number of students at house *i*. Each house can have a different number of students.

D_{ij} = Distance from house *i* to stop *j*

SM = Stop multiplier or Priority of stop (user entered Constant goal). Increase value to prefer fewer number of stops.

WM = Priority of walking distance (user entered Constant goal). Lower values mean shorter walking distances are preferred.

SPj = Stop penalty. Some bus stops may not be preferable by the user due to security or some other issues. By assigning penalty data to each bus stop user can affect the optimum solution by assigning no or as less student as possible to undesired bus stop.

M_{ij} = An i by j Matrix where all values are 9998. This matrix is used in calculation of K_{ij} matrix which uses 1 to show house i has possibility to be assigned to bus stop j and uses 0 otherwise. K_{ij} matrix is used to calculate RWS_j (relative weight of each bus stop) by looking at how much percentage of the houses are assigned to each bus stop. The more a bus stop is preferred the more likely the rest of the houses are to be assigned to that specific bus stop.

Other Notations Used in the Model

K_{ij} = Is a binary variable $\begin{cases} 1, \mathit{If\ house\ is\ walking\ distance} \\ 0, \mathit{Otherwise} \\ \mathit{Kij, is\ binary} \end{cases}$

As mentioned above K_{ij} matrix is created by using M_{ij} matrix. It helps us to identify the possible assignments by putting 1 and impossible assignments by putting 0 by looking at the distances between each house and each bus stop.

TSW = Total stop weight is a single value that represents the weighted and penalized values of all the stops.

WW = Walking weight is a single value that represents the weighted value of all distances not walked.

RWSj = Relative weight of each stop. As we mentioned above, the likelihood of assigning houses to a bus stop increases as the number of houses assigned to that specific bus stop increases. There is also penalty involved in each bus stop due to different reasons. This variable helps us to incorporate these two different values in one value.

NHASj = Number of houses assigned to each stop is multiplied with RWS_j (relative weight of each stop) to calculate TSW (total stop weight) which is directly affecting our objective value.

Mathematical Model

Objective Function

Maximize WW+TSW

$$WW = \frac{\sum_{j=1}^{n} \sum_{i=1}^{m} D_{ij} - D_{ij}.N_i.X_{ij}}{WM}$$

$$TSW = \sum_{j=1}^{n} NHAS_j.RWS_j$$

Constraints

Every house has to be assigned to a bus stop

$$\sum_{j=1}^{n} X_{ij} = 1 \quad \forall i$$

K_{ij} matrix is needed for the calculation of RWS_j matrix which gives us relative weight of each bus stop which increases by the number of the houses assigned to that specific stop.

$$D_{ij} \le \mu_{ij}.K_{ij} \quad \forall i \text{ and } \forall j$$

$$RWS_j = \sum_{i=1}^{m} K_{ij}.SM - SP_j \quad \forall j$$

$$NHAS_j = \sum_{i=1}^{m} X_{ij} \quad \forall j$$

Excel Implementation

The model was created in Microsoft Excel so the user would be able to access and use the solution. A major boundary in working with the standard Excel Solver, is the limit of 250 decision variables. The natural way of setting up a problem like House to Stop assignments, would be to use a matrix of Houses by Stops. The difficulty with this is how quickly 250 decision variables are reached. For example 21 Houses and 12 stops = 252 decision variables. Some busses can hold 85 students. It is clear this solution would not work with the standard Excel Solver. To resolve this issue we helped the solver by removing the decision variables that would never be used, for example the Houses that were too far from a Stop. We are then left with something that could be easily visualized and worked with by a user. If a House is close enough to a Stop, then add a row into the model for the pair.

Once we minimized the matrix to only the decision variables that were feasible, we formatted as shown in Figure 3.

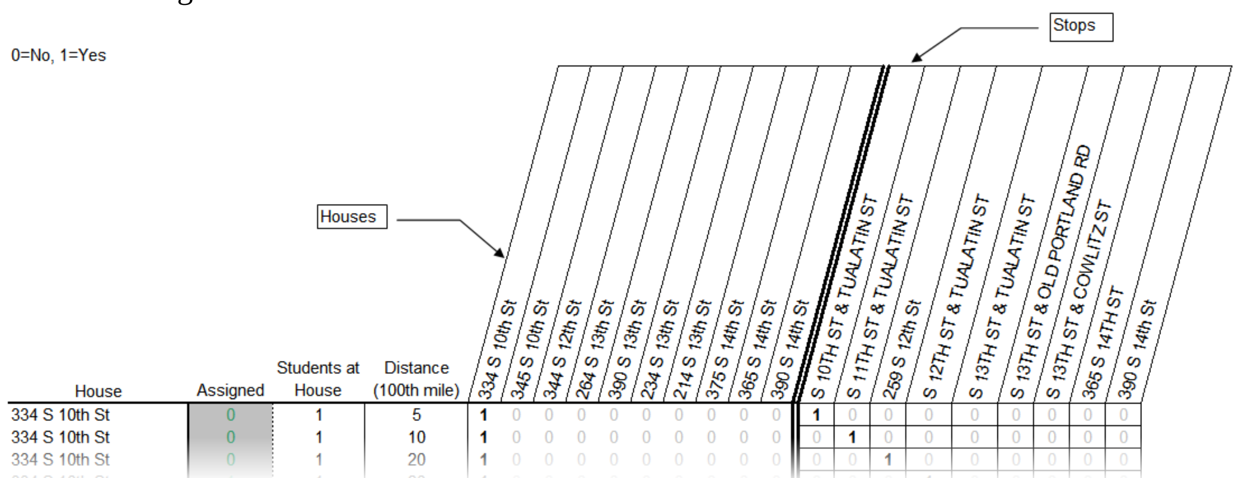

Figure 3 - Model Structure

The first column contains the Houses for each assignment (in retrospect this could state House Address to Stop Address, to be used for calculating distance). The second column contains the decision variables indicating if the pair is assigned, 1=Yes and 0=No. Column 3 indicates the number of students who live at the House. This is used for calculating the total walking distance and identifying how many students need to be picked up. The fourth column indicates the distance between the House and Stop pair, and is used for calculating walking distance. There are two more sets of columns. The first set is a column for each unique house address from the House to Stop pairings. The second set of columns is the unique set of Stops. For each of these sets of columns, each row will identify its House to Stop mapping by placing a 1 under the House and Stop for that row, the other cells will contain 0 for not assigned.

The power of this configuration is shown in Figure 4 where the calculations are implemented.

Constraints - Here you can see a row of 1s under the House columns. These are the constraints that require each House to be assigned to at most one Stop. This is done through a sumproduct of each House column and the decision variables column.

House Count - The set of cells to the right of these constraints show the number of Houses assigned to the Stop after the model is run. This is done through a sumproduct of each Stop column and the decision variables column.

Stop_Penalty – These cells are user entered constants used for the Stop related goal programming. Stop_Penalty allows the user to reduce a Stops preference by adding a penalty to a single Stop. For example, an over crowded Stop would be preferred when minimizing stops but may not be safe, or construction may impact the usefulness of a stop. Stop_Penalty allows a user to minimize Stops while accounting for specific Stop issues.

SM – Stop multiplier is another component to Stop related goal programming. This constant is entered by the user to increase the importance of selecting stops that have more Houses that can be assigned to them.

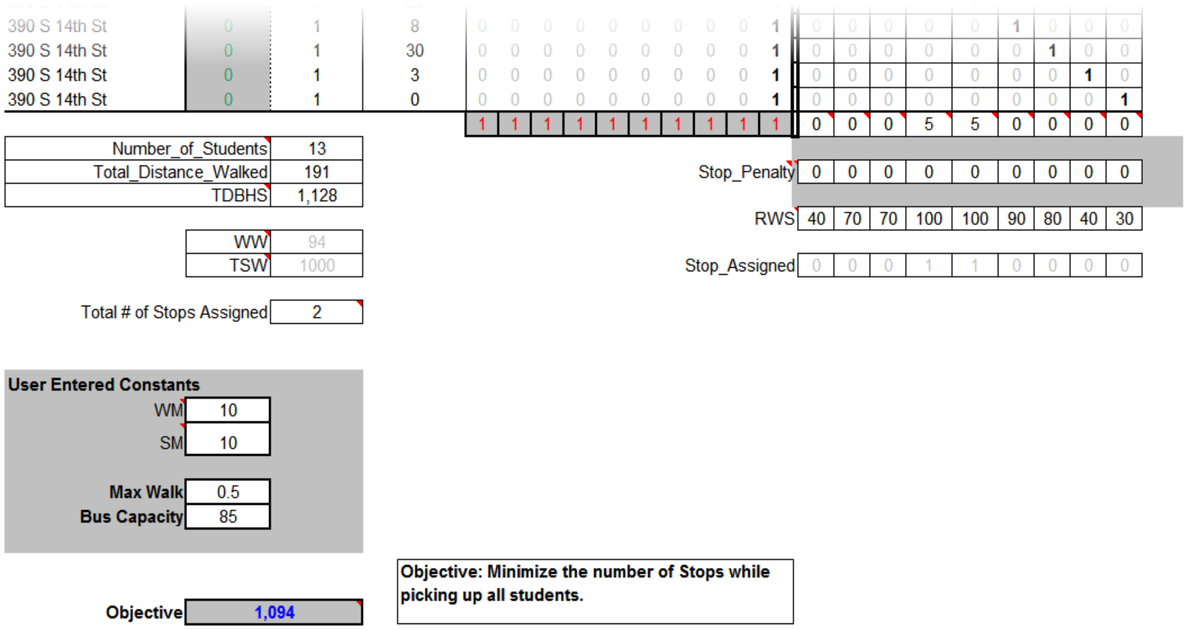

Figure 4 - Model Calculations

RWS - The relative weight per Stop cells bring WM and Stop_Penalty together, by multiplying the total possible number of houses that could be assigned to a Stop with WM and subtracting any Stop_Penalty, to produce the RWS.

TSW – The total Stop weighting is a single value that represents the weighted and penalized value of all of the Stops. This is calculated with a sumproduct of House Count and RWS.

Number_of_Students – A sum of all of the students at each house.

Total_Distance_Walked – The total distance all of the students on the buss walked. This is implemented with a sumproduct of decision variables column, Students at House column, and Distance column.

TDBHS – Total distance between Houses and possible Stops. This is a sum of the Distance column and is used to calculate the distance not walked.

WM – Walking priority is a user entered constant to show preference of student walking distance. Lower values mean shorter walking distances are preferred.

WW – Walking weight calculates the total distance not walked and divides by WM. Distance not walked is needed, because the model is maximizing TSW and to account for walking distance the model needs something to maximize for walking. If you wan the students to walk less, then maximize the distance they don't walk.

Max Walk – For future use with automated distance calculation.

Bus Capacity – Currently used to warn the user when the number of students exceeds the capacity of the bus assigned for the route.

Total # of Stops Assigned – A quick reference to the user to evaluate the solution.

Stop_Assigned – Simple set of quick reference cells for the user to see what Stops have been selected in the current solution.

Figure 5 shows the model with an example of 10 houses and 9 stops. This is the set of data that will be used in the analysis. As you look down the House columns, you see multiple rows with a 1 for each House. As you look across the rows for each House, you will notice the Stop columns do not duplicate for a single House. These constant mapping values are the pathways for the model to make decisions. As the decision variables are changed, the Constraints force each House to be selected exactly once, the goal programming for the Stops favors Stop assignments where a Stop services the most number of Houses, and then the objective function adds in the goal programming for walking distance preferences. This provides a simple easy to read interface for modeling a route segment.

0=No, 1=Yes

Houses

Stops

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	0	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	1	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	1	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	1	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
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264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	1	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
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390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
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214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
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214 S 13th St	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
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375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
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365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	1	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	0	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	0	0	0	5	5	0	0	0	0
Stop_Penalty														0	0	0	0	0	0	0	0	0
RWS														40	70	70	100	100	90	80	40	30
Stop_Assigned														0	0	0	1	1	0	0	0	0

Number_of_Students	13
Total_Distance_Walked	191
TDBHS	1,128
WW	94
TSW	1000
Total # of Stops Assigned	2

User Entered Constants

WM	10
SM	10
Max Walk	0.5
Bus Capacity	85

Objective: Minimize the number of Stops while picking up all students.

Objective	1,094

Figure 5 - Initial Excel Model

User Interface

One goal of our project was to provide a solution using tools to which the customer already has access. Our focus was on implementing a solution using MS Excel/Solver. Because the size of the service area could change, in terms of a new house or an additional stop, a user interface was developed to provide flexibility and accommodate for variations. The interface prompts the user to add a new address, the number of students at the house, and the distance to the stop (Figure 6). Based on this data, a new row is added with the information (Figure 7). The user has to complete the row entries by finishing the house identity matrix and identifying valid stops. Once complete the user must rerun the model to identify the new optimal solution.

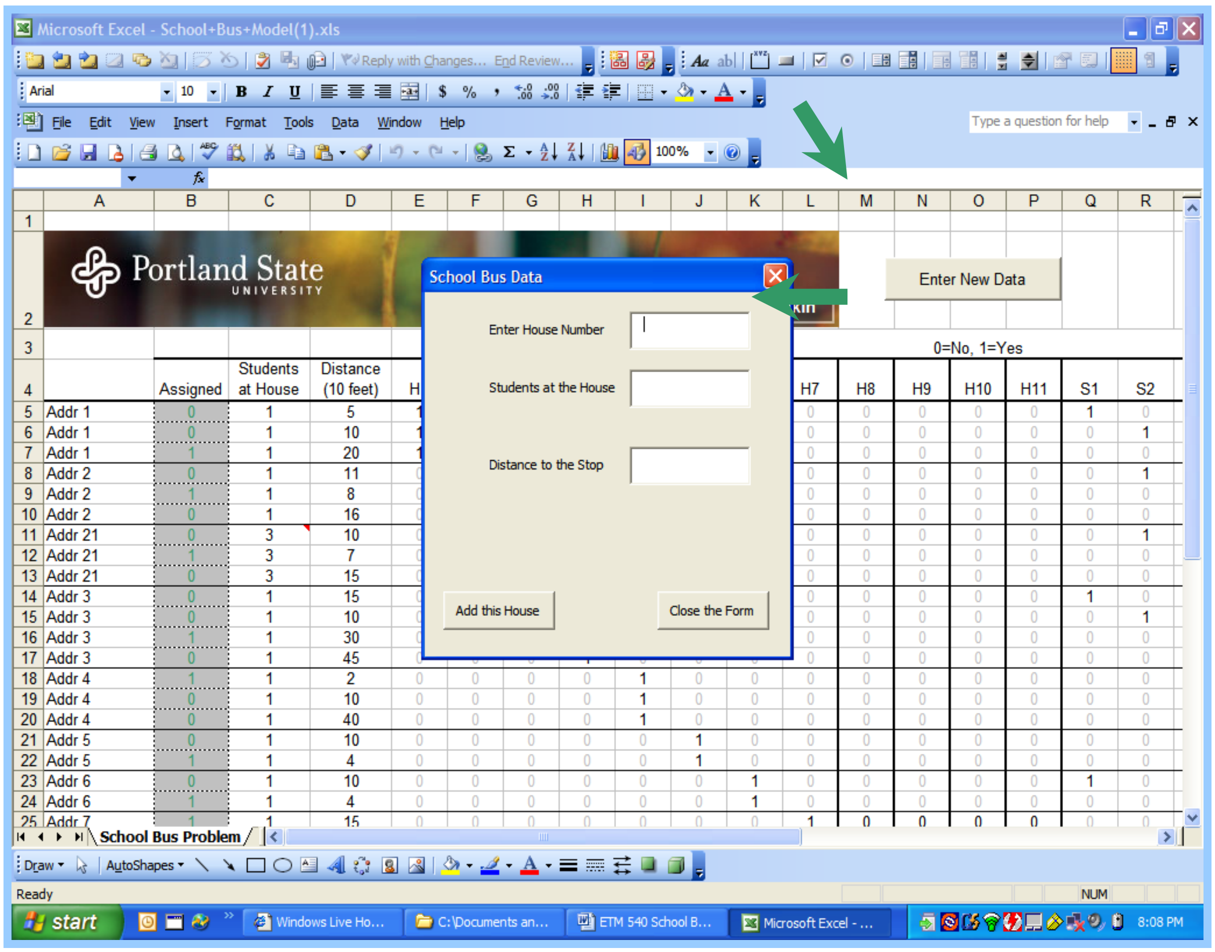


Figure 6 – Excel user interface

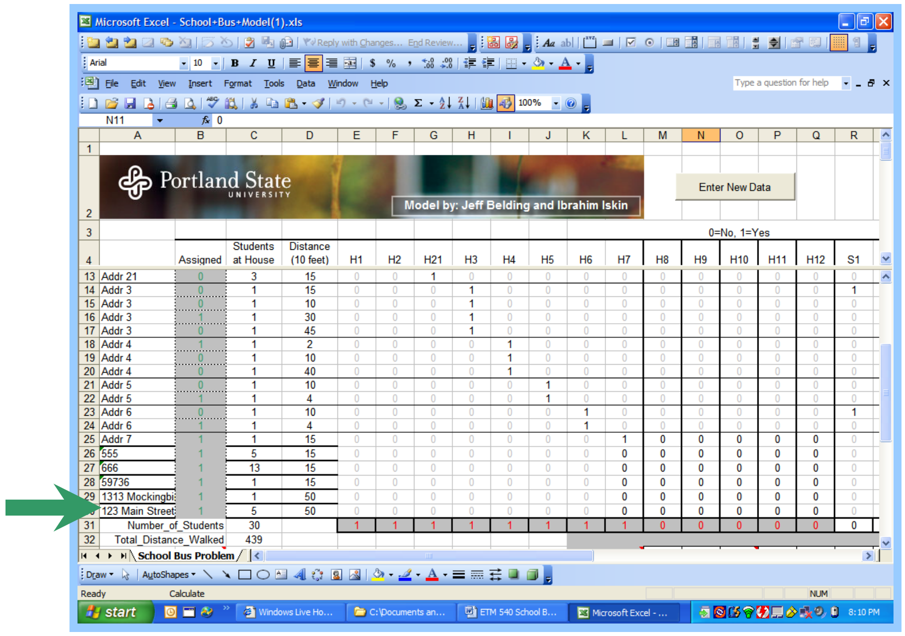


Figure 7 – New house row is added

Suggested Improvements to the User Interface

In general, the suggested improvements would make the interface and model more automated – requiring minimal user interaction (with the model). After a new address, number of students, and the stop distance is entered, the user must update the house and stop matrices. This requires the user to be aware of how the model is working, understand the impact of putting data in the incorrect cells, and then how to rerun the solver to find the new optimal solution. Due to the amount of manual input there is the potential for errors. A more automated solution would minimize this risk.

An interface could be developed where the user inputs a new address, the number of students at the address, and distances to the nearest stops. This input would trigger the model to rerun and find the subsequent optimal solution. The optimal solution could be provided on a separate excel worksheet.

Results/Analysis

To illustrate the diversity of the model, we have chosen 5 scenarios.
Note: There are **Multiple Optimal Solutions** depending on the way the data is set up.

Scenarios:

1. Minimize walking distance
2. Minimize Stops with minimal consideration of walking distance
3. Minimize Stops with a Stop Penalty
4. Minimize Stops accounting for walking preferences
5. Minimize Stops with Stop Penalty and accounting for walking preferences

Figure 8 shows Scenario 1 –Minimize walking distance. You can see for each House to Stop pair that the row with the shortest path is selected by a decision variable. This shows the preference minimizing walking distances for students.

0=No, 1=Yes

Houses

Stops

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	1	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	1	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	0	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
264 S 13th St	0	1	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
390 S 13th St	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
234 S 13th St	1	2	20	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
234 S 13th St	0	2	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
214 S 13th St	0	1	20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
214 S 13th St	0	1	40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	1	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
375 S 14th St	1	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
375 S 14th St	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	0	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	2	0	1	1	2	1	1	1	1

Number_of_Students	13
Total_Distance_Walked	68
TDBHS	1,128
WW	10,600
TSW	690
Total # of Stops Assigned	9

Stop_Penalty	0	0	0	0	0	0	0	0	0
RWS	40	70	70	100	100	90	80	40	30
Stop_Assigned	1	1	1	1	1	1	1	1	1

User Entered Constants

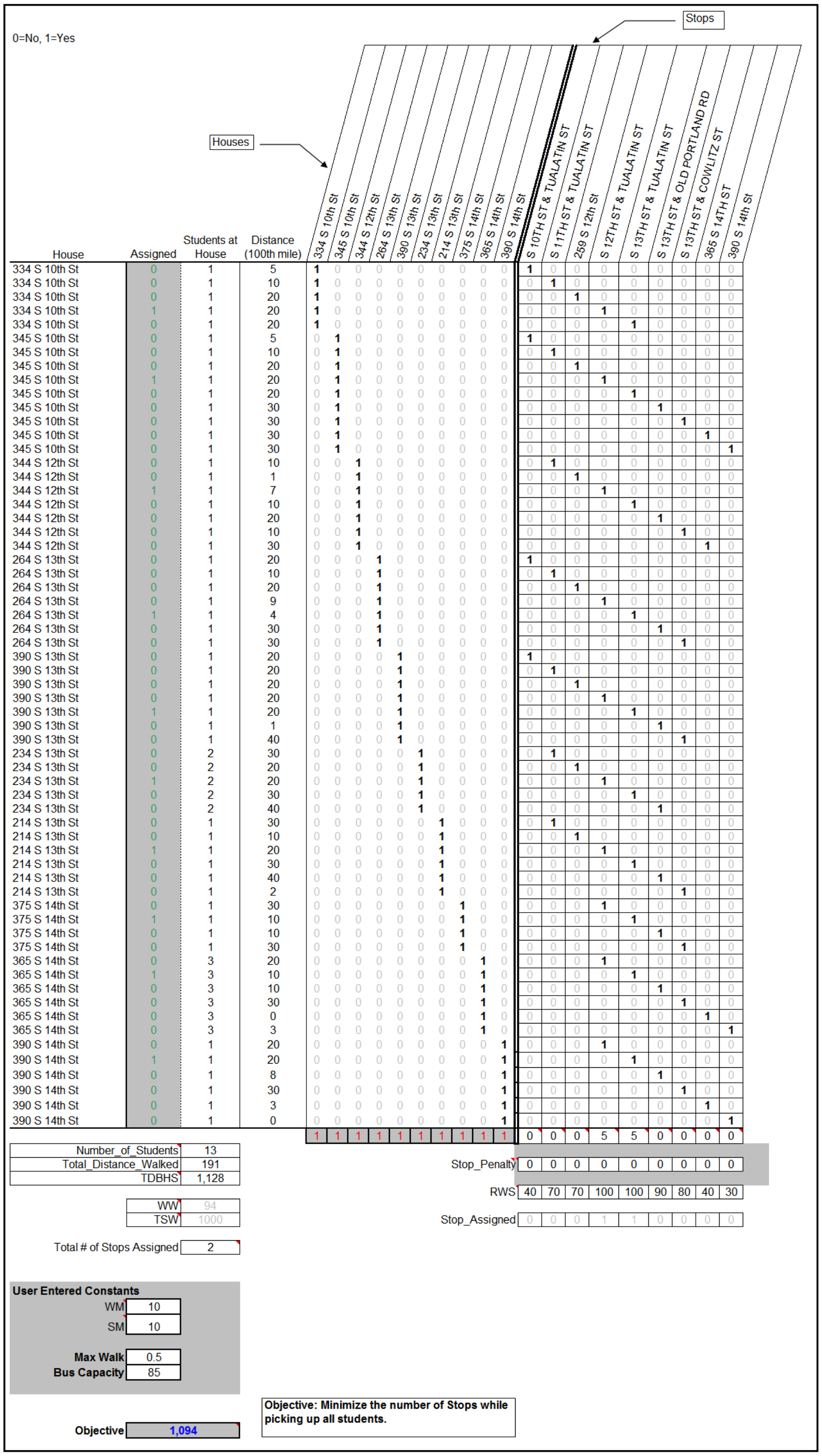
WM	0.1
SM	10
Max Walk	0.5
Bus Capacity	85

Objective: Minimize the distance students must walk.

Objective 11,290

Figure 8 - Scenario 1 Minimize walking distance

Figure 9 Error! Reference source not found. shows Scenario 2 – Minimize stops with minimal consideration of walking distance. You can see that there are only 2 stops assigned and from looking at the data shown, you can see these 2 Stops are assigned to every House. The data also shows that only in some cases was an assignment made for a shorter distance, but it was enough to prevent the model from minimizing to a single Stop.



0=No, 1=Yes

Houses

Stops

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	0	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	1	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	1	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	1	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
264 S 13th St	0	1	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	1	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
390 S 13th St	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
234 S 13th St	1	2	20	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
234 S 13th St	0	2	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
214 S 13th St	1	1	20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
214 S 13th St	0	1	40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
375 S 14th St	1	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
375 S 14th St	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
365 S 14th St	1	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	1	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	0	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	0	0	0	5	5	0	0	0	0
Stop_Penalty														0	0	0	0	0	0	0	0	0
RWS														40	70	70	100	100	90	80	40	30
Stop_Assigned														0	0	0	1	1	0	0	0	0

Number_of_Students	13
Total_Distance_Walked	191
TDBHS	1,128
WW	94
TSW	1000
Total # of Stops Assigned	2

User Entered Constants

WM	10
SM	10
Max Walk	0.5
Bus Capacity	85

Objective: Minimize the number of Stops while picking up all students.

Objective 1,094

Figure 9 - Scenario 2 minimize Stops

Figure 10 Error! Reference source not found. shows Scenario 3 – Minimize Stops with Stop Penalty. Comparing this result with Scenario 2, now only one stop is selected. This is due to one of the two stops having a penalty assigned to make it less appealing.

0=No, 1=Yes

Stops

Houses

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	0	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	1	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	1	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	0	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	1	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
264 S 13th St	0	1	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	1	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
390 S 13th St	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
234 S 13th St	1	2	30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
234 S 13th St	0	2	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
214 S 13th St	0	1	20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
214 S 13th St	1	1	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
214 S 13th St	0	1	40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
375 S 14th St	1	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
375 S 14th St	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
365 S 14th St	1	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	1	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	0	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	0	0	0	0	10	0	0	0	0
			Stop_Penalty											0	0	0	10	0	0	0	0	0
			RWS											40	70	70	90	100	90	80	40	30
			Stop_Assigned											0	0	0	0	1	0	0	0	0

Number_of_Students	13
Total_Distance_Walked	224
TDBHS	1,128
WW	90
TSW	1000
Total # of Stops Assigned	1

User Entered Constants

WM	10
SM	10
Max Walk	0.5
Bus Capacity	85
Objective	1,090

Objective: Minimize number of Stops but use a Stop Penalty to reduce the importance of a preferred stop.

Figure 10 - Scenario 3 Minimize Stops with Stop Penalty

Error! Reference source not found.Error! Reference source not found. shows Scenario 4 – Minimize stops accounting for walking preferences. You can see that the 2 stops that were preferred when focusing on minimizing Stops, is now dispersed due to the user preferring that students walk shorter distances. The number of Stops is now 3. (Note: For some reason excel is showing 4, when the count should be 3.)

0=No, 1=Yes

Houses

Stops

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	0	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	1	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	1	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	1	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
264 S 13th St	0	1	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
390 S 13th St	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
234 S 13th St	1	2	20	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
234 S 13th St	0	2	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
214 S 13th St	1	1	20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
214 S 13th St	0	1	40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
375 S 14th St	1	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
375 S 14th St	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
365 S 14th St	1	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	1	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	0	0	0	5	3	2	0	0	0

Number_of_Students	13
Total_Distance_Walked	160
TDBHS	1,128
WW	968
TSW	980
Total # of Stops Assigned	4

Stop_Penalty	0	0	0	0	0	0	0	0	0
RWS	40	70	70	100	100	90	80	40	30
Stop_Assigned	0	0	0	1	1	1	1	0	0

User Entered Constants

WM	1
SM	10
Max Walk	0.5
Bus Capacity	85

Objective 1,948

Objective: Minimize number of Stops while accountin for walking distance preferences.

Figure 11 - Scenario 4 – Minimize stops accounting for walking preferences

Figure 12 Error! Reference source not found. shows Scenario 5 – Minimize Stops with Stop Penalty and accounting for walking preferences. Finally the mix comes together and you can see all of the pieces still play a role. Stop Penalty pushes assignments away from the 4th Stop, the walking distance is choosing shortest distances except when a Stop is preferred enough to force an increase in walking distance. For example 344 S 12th St is pulled away from a walking distance of 1 because of Stop preference, pulled away from a walking distance of 7 because of a Stop Penalty, and settles at a walking distance of 10. Not the best walking distance, but not the worst either.

This scenario is a good example of the flexibility of our model.

0=No, 1=Yes

Houses

Stops

House	Assigned	Students at House	Distance (100th mile)	334 S 10th St	345 S 10th St	344 S 12th St	264 S 13th St	390 S 13th St	234 S 13th St	214 S 13th St	375 S 14th St	365 S 14th St	390 S 14th St	S 10TH ST & TUALATIN ST	S 11TH ST & TUALATIN ST	259 S 12th St	S 12TH ST & TUALATIN ST	S 13TH ST & TUALATIN ST	S 13TH ST & OLD PORTLAND RD	S 13TH ST & COWLITZ ST	365 S 14TH ST	390 S 14th St
334 S 10th St	0	1	5	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
334 S 10th St	0	1	10	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
334 S 10th St	0	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
334 S 10th St	1	1	20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
345 S 10th St	0	1	10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
345 S 10th St	0	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
345 S 10th St	1	1	20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
345 S 10th St	0	1	30	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
344 S 12th St	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
344 S 12th St	0	1	7	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
344 S 12th St	1	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
344 S 12th St	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
344 S 12th St	0	1	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
344 S 12th St	0	1	30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
264 S 13th St	0	1	10	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
264 S 13th St	0	1	20	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
264 S 13th St	0	1	9	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
264 S 13th St	1	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
264 S 13th St	0	1	30	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
390 S 13th St	0	1	20	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
390 S 13th St	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
390 S 13th St	0	1	40	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0
234 S 13th St	0	2	20	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
234 S 13th St	1	2	20	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
234 S 13th St	0	2	30	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
234 S 13th St	0	2	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
214 S 13th St	0	1	10	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
214 S 13th St	0	1	20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
214 S 13th St	0	1	30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
214 S 13th St	0	1	40	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
214 S 13th St	1	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
375 S 14th St	1	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
375 S 14th St	0	1	10	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
375 S 14th St	0	1	30	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	20	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
365 S 14th St	1	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0
365 S 14th St	0	3	10	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
365 S 14th St	0	3	30	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
365 S 14th St	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
365 S 14th St	0	3	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
390 S 14th St	0	1	20	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
390 S 14th St	1	1	8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
390 S 14th St	0	1	30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
390 S 14th St	0	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
390 S 14th St	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
				1	1	1	1	1	1	1	1	1	1	0	0	0	1	6	2	1	0	0
													Stop_Penalty	0	0	0	10	0	0	0	0	0
													RWS	40	70	70	90	100	90	80	40	30
													Stop_Assigned	0	0	0	1	1	1	1	0	0

Number_of_Students	13
Total_Distance_Walked	145
TDBHS	1,128
WW	983
TSW	950
Total # of Stops Assigned	4

User Entered Constants

WM	1
SM	10
Max Walk	0.5
Bus Capacity	85

Objective: Minimize the number of Stops while accounting for Stop Penalties and walking distance preferences.

Objective	1,933

Figure 12 - Scenario 5 – Minimize Stops with Stop Penalty and walking preferences

Recommendations

The recommendation is that the St. Helen’s school districts modify the current procedure and implement and use this model to determine the assignment of students to bus routes. This will enable the district to ensure that the students are not required to walk more than the specified distance of half a mile. In addition, it will also reduce the amount that the student spends on the bus by ensuring that the closest addresses are serviced by the closest bus stops.

Training - First Student staff will require training on the use of the software solution. The training should cover an overview of the model, use cases and a thorough review of the expansion options available.

Future Enhancements - Increase the complexity of the model by adding additional constraints, transfer points and automate the user interface.

Examples of additional enhancements:

- Sidewalk constraint - children cannot walk on the street which does not have sidewalks. Or sidewalk is required constraint; otherwise the stop is assigned in front of the student’s house.
- Add transfer points
- Add rural routes – generally more stops due to lack of sidewalks
- User interface
  - Automate interface with www.googlemaps.com
  - Automate assignment of weight
  - Auto-populate assignment of stops to a house
- It is also very important to keep the track of the changes. By using our model we have decreased the number of distance walked and bus stops, but we are not aware of how much cost or time improvement has been achieved. One of the next steps should be to keep the track of these and making revisions on the model in the future.

Implementing this model will give the district a good starting point to increasing the efficiency of the transportation system for their school. It will also serve as an aid to increase the student safety by ensuring that students only walk a minimum distance in a safe walking environment such as sidewalks on streets. The district can partner with other districts to enhance this model and implement a more complex solution to avoid the limitations of Excel Solver.

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Appendix A – Route Data from First Student

Note: Stops that are blank represent stops at the House address.

	A	B	C	D	E	F	G
1	A.M. ROUTE	TRANSFER	GRADE	HOUSE #	STREET NAME	STOP	
2	16		10	35158	Archer Dr		
3	16		10	35144	Archer Dr		
4	16		10	35097	Archer Dr	WESTSHIRE LN & SYKES RD	
5	16		7	35179	Archer Dr		
6	16		10	35179	Archer Dr		
7	16		8	35237	Aubuchon Dr		
8	16		8	35186	Aubuchon Dr		
9	16		7	35234	Aubuchon Dr	AUBUCHON DR & SYKES RD	
10	16		7	35234	Aubuchon Dr		
11	16		7	35234	Aubuchon Dr		
12	16		11	35234	Aubuchon Dr		
13	16		9	59283	Barr Ave		
14	16		9	59315	Barr Ave		
15	16		12	59315	Barr Ave		
16	16		8	59600	Barr Ave		
17	16		11	59600	Barr Ave		
18	16		9	59400	Barr Ave	BARR AVE & SYKES RD	
19	16		9	59400	Barr Ave		
20	16		11	59620	Barr Ave		
21	16		8	59640	Barr Ave		
22	16		7	59610	Barr Ave		
23	16		9	59610	Barr Ave		
24	16		11	59693	Blue Jay Ln		
25	16		11	59693	Blue Jay Ln	BLUE JAY LN & PITTSBURG RD	
26	16		9	59702	Blue Jay Ln		
27	16		8	34867	Burt Ct		
28	16		7	34855	Burt Ct		
29	16		8	34886	Burt Ct		
30	16		11	34999	Burt Ct		
31	16		7	35121	Burt Rd		
32	16		10	34940	Burt Rd		
33	16		12	34897	Burt Rd		
34	16		10	35140	Burt Rd	BARR AVE & PITTSBURG RD	
35	16		9	34920	Burt Rd		
36	16		7	35130	Burt Rd		
37	16		11	35130	Burt Rd		
38	16		7	35023	Burt Rd		
39	16		12	35101	Burt Rd		
40	16		10	34960	Burt Rd		
41	16		8	35099	Burt Rd		
42	16		12	35099	Burt Rd		
43	16		8	59391	Cade Dr	CADE DR & SYKES RD	
44	16		7	59381	Cade Dr		
45	16	15	6	1070	Cowlitz St	S 12TH ST & COWLITZ ST	
46	16		2	811	Cowlitz St	S 8TH ST & COWLITZ ST	
47	16		2	1221	Cowlitz St	S 12TH ST & COWLITZ ST	
48	16		11	27	Crescent Dr		
49	16		10	52	Crescent Dr	CRESCENT DR & SUNSET BLVD	
50	16		7	46	Crescent Dr		
51	16		10	34817	Edna Barr Ln		
52	16		12	34817	Edna Barr Ln		
53	16		7	34870	Edna Barr Ln	BARR AVE & PITTSBURG RD	
54	16		8	34870	Edna Barr Ln		
55	16		11	34870	Edna Barr Ln		
56	16		10	35141	Ha Ln		
57	16		12	35141	Ha Ln		
58	16		9	35162	Ha Ln		
59	16		12	59521	Ha Ln		
60	16		7	35142	Ha Ln	OAKRIDGE ST & PITTSBURG RD	
61	16		8	59511	Ha Ln		
62	16		9	59511	Ha Ln		
63	16		8	35126	Helens Way		
64	16		12	35126	Helens Way		
65	16		7	35347	Helens Way		
66	16		9	59671	Kimmell Ln		
67	16		11	59671	Kimmell Ln		
68	16		7	59715	Kimmell Ln		
69	16		12	59666	Kimmell Ln	KIMMEL LN & PITTSBURG RD	
70	16		8	59739	Kimmell Ln		
71	16		9	59742	Kimmell Ln		
72	16		12	59742	Kimmell Ln		
73	16		12	59351	Mountain View Dr		
74	16		8	59690	Oak Ridge St		
75	16		12	59465	Oak Ridge St		
76	16		7	59620	Oak Ridge St	MOUNTAIN VIEW DR & SYKES RD	
77	16		10	59663	Oak Ridge St		
78	16		8	59400	Oak Ridge St		
79	16		9	59633	Oak Ridge St		
80	16		8	59670	Oak Ridge St		
81	16		7	59525	Oak Ridge St		
82	16		12	59520	Oak Ridge St		
83	16		7	59660	Oak Ridge St		
84	16		10	59660	Oak Ridge St		
85	16		11	59613	Oak Ridge St		
86	16		8	59450	Oak Ridge St		
87	16		10	59450	Oak Ridge St		
88	16		12	59450	Oak Ridge St		
89	16		2	820	Old Portland Rd		
90	16		12	35064	Oliver Heights Ct		
91	16		11	35246	Pittsburg Rd		
92	16		12	34377	Pittsburg Rd		
93	16		10	34805	Pittsburg Rd		
94	16		10	34281	Pittsburg Rd		
95	16		7	35087	Pittsburg Rd		
96	16		7	34281	Pittsburg Rd		
97	16		10	35255	Pittsburg Rd	BATTLE MOUNTAIN RD & PITTSBURG RD	
98	16		12	34981	Pittsburg Rd		
99	16		7	59361	Ponderosa Dr		
100	16		7	59420	Ponderosa Dr		
101	16		7	28	Red Cedar St		
102	16		9	35024	Roberts Ln		
103	16		11	35120	Roberts Ln		
104	16		8	34969	Roberts Ln		
105	16		11	34969	Roberts Ln	RED CEDAR ST & SUNSET BLVD	
106	16		12	34959	Roberts Ln		
107	16		8	35083	Roberts Ln		
108	16		9	35084	Roberts Ln		
109	16		11	35084	Roberts Ln		
110	16		8	35121	Roberts Ln		
111	16		9	35069	Roberts Ln		
112	16		7	35150	Roberts Ln		
113	16		9	35140	Roberts Ln		
114	16		7	35170	Roberts Ln		
115	16		9	35170	Roberts Ln		
116	16		11	35002	Roberts Ln		
117	16		11	35002	Roberts Ln		
118	16		10	34997	Roberts Ln		
119	16		10	35064	Ruby Ct		
120	16		8	35012	Ruby Ct		
121	16		9	35069	Ruby Ct		
122	16		12	35069	Ruby Ct		
123	16		11	35045	Ruby Ct		
124	16		12	35045	Ruby Ct		
125	16		11	35057	Ruby Ct		
126	16		9	35076	Ruby Ct		
127	16		12	35076	Ruby Ct		
128	16	15	6	334	S 10th St		
129	16		2	345	S 10th St		
130	16		1	444	S 11th St		
131	16	15	6	259	S 12th St		
132	16	15	6	391	S 12th St		
133	16	15	6	324	S 12th St		
134	16		2	344	S 12th St		
135	16	15	6	264	S 13th St		
136	16	15	6	390	S 13th St		
137	16		1	234	S 13th St		
138	16		2	234	S 13th St		
139	16		2	214	S 13th St	S 13TH ST & OLD PORTLAND RD	
140	16	15	6	375	S 14th St		
141	16		1	365	S 14th St		
142	16		2	365	S 14th St		
143	16		2	365	S 14th St		
144	16		1	390	S 14th St		
145	16		2	306	S 14th St		
146	16	15	6	344	S 15th St		
147	16	15	6	374	S 15th St		
148	16		2	196	S 15th St		
149	16	15	6	275	S 15th St		
150	16		2	125	S 16th St		
151	16		1	355	S 17th St		
152	16		2	275	S 17th St		
153	16		6	397	S 17th St	S 16TH ST & TUALATIN ST	
154	16		2	155	S 7th St		
155	16		2	164	S 7th St		
156	16	15	6	157	S 7th St		
157	16	15	6	215	S 7th St		
158	16	15	6	215	S 7th St		
159	16	15	6	165	S 8th St		
160	16		2	288	S 8th St	215 S 7th St	
161	16	15	6	294	S 8th St		
162	16		1	126	S 8th St		
163	16		1	325	S 9th St		
164	16	15	6	315	S 9th St		
165	16	15	6	212	S 9th St		
166	16		8	27	Salal St		
167	16		8	68	Salal St		
168	16		7	67	Salal St		
169	16		8	78	Salmon St		
170	16		7	28	Salmon St		
171	16		8	18	Salmon St		
172	16		8	214	Shore Dr		
173	16		8	84	Shore Dr		
174	16		7	265	Shore Dr		
175	16		8	430	Sunset Blvd		
176	16		8	430	Sunset Blvd		
177	16		11	38	Sunset Pl		
178	16		10	48	Sunset Pl		
179	16		10	35196	Sykes Rd		
180	16		9	35290	Sykes Rd		
181	16		7	35144	Sykes Rd		
182	16		11	34875	Sykes Rd		
183	16		8	35056	Sykes Rd		
184	16		12	35088	Sykes Rd		
185	16		7	34928	Sykes Rd		
186	16		9	34928	Sykes Rd		
187	16		7	35244	Sykes Rd		
188	16		12	35129	Sykes Rd	34928 Sykes Rd	
189	16		7	265	Trillium St		
190	16		8	214	Trillium St		
191	16		2	1103	Tualatin St		
192	16	15	6	1320	Tualatin St		
193	16		9	59897	Twin Oaks Dr		
194	16		7	59656	Twin Oaks Dr		
195	16		10	59656	Twin Oaks Dr	S 13TH ST & TUALATIN ST	
196	16		9	59717	Twin Oaks Dr		
197	16		8	59707	Twin Oaks Dr		
198	16		7	59600	Twin Oaks Dr		
199	16		9	59600	Twin Oaks Dr		
200	16		11	55	Wagner Ave		
201	16		9	34815	Westboro Way		
202	16		8	59174	Whitetail Ave		
203	16		7	59165	Whitetail Ave		
204	16		11	34855	Willie Ln		
205	16		10	59980	Windy Ridge Dr		
206	16		9	59714	Woodland Terrace	WOODLAND TERRACE & PITTSBURG RD	