BOX1

A Reusable Geospatial Information Management System for Sustainable Financial Reporting and Efficient Maintenance of the Road Infrastructure In Boxborough, Massachusetts

An Interdisciplinary Qualifying Project

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Abstract

This project created a reusable database and GIS map layers for roads and road-related assets in the town of Boxborough. Team members used a GPS unit to locate and evaluate the condition of all roads and road-related assets that had not already been inventoried and evaluated by the town. The information for each asset was entered into tables in the database and reports were created that calculate the values of the roads and assets so that a financial statement could be produced to satisfy the GASB Statement 34 reporting requirements. Our project also demonstrates the flexibility and reusability of the database for future use by the town for preventative maintenance, snow plowing, and budgeting predictions.

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1 Introduction

It is a government's duty to govern its constituents efficiently and waste as little as possible. The only way to ensure this is through good accounting and management, and public reporting of the finances of the government. United States municipalities have approximately 4 million miles[1] of public roads, which is a lot to account for and maintain. More than $167 billion was spent on public roads in the US in 2000[2]. With inefficient accounting and management, the US road infrastructure could waste large amounts of tax payers' money. To make financial reporting reliable and consistent, in 1984, the Governmental Accounting Standards Board (GASB) was established to set and improve standards for state and local accounting and reporting[3]. The consistent reporting created by the GASB standards is the only way users of financial statements, such as auditors, can assess the financial condition of one government compared to another. GASB statement 34 was issued on June 30, 1999[4] to require towns to report on their cost of delivering services to citizens and to estimate the value of public infrastructure such as roads, sewer, and water systems in a comprehensive manner. If a town's reporting of its assets is incomplete, it may receive less reimbursement from the state than it deserves.

Massachusetts has over 35 thousand miles of roads[1] located within its borders. Roughly one third of these roads require federal funding for maintenance. The state of Massachusetts spent $450 million on roads and bridge infrastructure in fiscal year 2004[2], much of it as aid to cities and towns. Local governments take care of roughly 24 thousand miles of roads in Massachusetts[1].

All Infrastructure Capital Assets must be valued and reported by the deadline. As a result of GASB 34, numerous solutions to help a town perform its reporting have arisen. Some towns contract with an accountant to do the reporting. Software packages are also available to help a town create its reports, but they can run upwards of $3,000[4] and you still have to train a person to use the software. Unfortunately, both of these are

[1] Bureau of Transportation Statistics Website
[2] National Transportation Library Website
[3] The GASB Organization Website
4 The GASB Organization Website: *The website contained links to accounting software companies, this reflects an average cost*

rather costly methods and require constant funding for overhead costs for contracted work, or for updating software and training/employing personnel to use the software.

Boxborough's Infrastructure Capital Assets were not all documented in the GIS layers that the town had. Most of the town's records were still in paper form, which slowed down the process of evaluating the assets. Boxborough's records needed to be kept up to date if the town wanted to receive the aid it deserved.

The plan of this project was to improve the efficiency and accountability of Boxborough's infrastructure assets. We planned to make it easier to retrieve pertinent data when needed by taking old records and updating them into GIS layers. We planned to make the town more accountable by going out into the town and recording data about Infrastructure Capital Assets. This data would also be incorporated into GIS layers. Our intension was to take information about the roads and their respective Capital Assets and break it down into an atomic level: road segments between intersections. This would allow the data to be reused in the future for continued GASB reporting as well as road maintenance, traffic analysis, budget, snow plowing, material planning and school bus route planning. Our project planned to reduce data gathering and streamline asset inventory tracking. It would also assist the DPW in task assignment. We predicted that there would be significant savings by the town by not having to pay for contracted work or for new software since we would integrated asset information into their pre-existing GIS software and database system.

2 Background

2.1 Boxborough, Massachusetts

The town of Boxborough was established on February 25, 1783, out of the need for centralized worship meeting place for the three surrounding towns[5]. The town was named such, because it was originally going to be formed in the shape of a box, but the south bordering town, Stow, would not relinquish part of their land to the development of Boxborough[8]. Because of this the south eastern corner of the "box" is still part of Stow (Figure 1). Boxborough was built of a foundation of agriculture, which included orchards and grazing for milk production. The center of the town is placed on a hill top, so the entire watershed flows out of the town (Figure 2). Boxborough was the fastest growing town in Massachusetts from the years 1990-2000, going from a population of 3,343 to 4,868, an increase of 45.6%[6]. Today Boxborough is a town of over five thousand with new and large businesses moving in. As of January 1, 2003 the population was 5,147, spread out over a total area of 10.39 square miles[8]. The location of Boxborough is in Middlesex County in the northeastern part of Massachusetts (Figure 3). It is bordered by Littleton on the north, Acton on the east, Stow to the south, and Harvard on the west. Boxborough is 25 miles northeast of Worcester, 28 miles west of Boston, and 198 miles from New York City. Both Interstate 495 and Route 111 pass through the town[7].

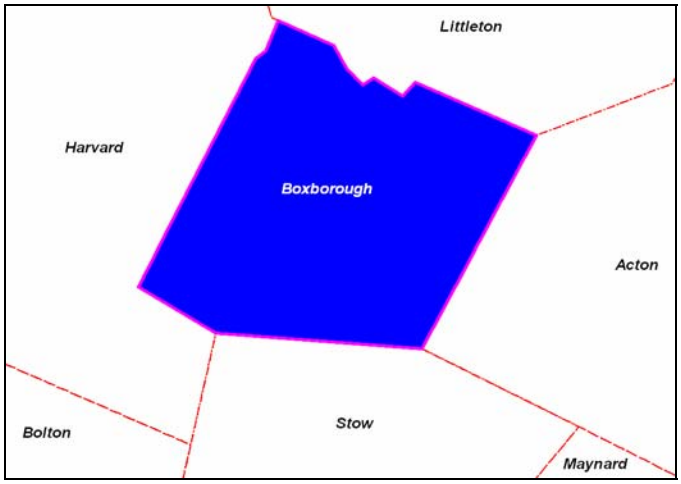

Figure 1 Towns Surrounding Boxborough

[5] The Town of Boxborough Website
[6] The Massachusetts Website
[7] The Town of Boxborough Website

2.2 GASB 34

The Government Accounting Standards Board (GASB) was established by the Financial Accounting Foundation to establish standards for state and local government accounting[8]. These standards are meant to guide the production of any external financial reports such as a town's annual report. The GASB mission is to create and improve accounting standards that will result in useful information for users of financial reports and guide and educate the public about the information presented in government financial reports[7].

GASB Statement 34 was issued in June 1999[7]. It has been heralded as a major change in the way governments are required to present financial information. Statement 34 requires a government to report each fund it manages separately, include a copy of the original budget and the final amended budget, and for the first time include information on long-term capital assets and liabilities. Also, a Management's Decision and Analysis section is required before the body of the report where the financial managers will give their insights into the current year's performance. These requirements will help users of government financial reports to assess the finances of a government in its entirety, including yearly operating results; determine whether a government's financial position has improved or not; evaluate whether or not the government's revenues were sufficient to cover its costs for the past period; see the governments' cost of providing services to its citizens; see how the government finances its programs; understand the extent to which the government has invested in capital assets; and make better comparisons between governments. The result is a much more comprehensive and understandable financial report

Figure 2 Orthographic Photo of Boxborough, MA

[8] The GASB Organization Website

The government of Boxborough is a Board of Selectmen with Open Town Meeting and a Town Administrator[9]. In Boxborough, it is the duty of the Department of Public Works to maintain the roads and replace the road related assets. This department receives a portion of the town budget to fund its repairs and maintenance. The town is financed by a few sources; approximately 69% tax levies, 15% State Aid, 9% local receipts, and 7% from other available sources[10]. In Fiscal Year 2004 the total town budget was $14,967,120 and actual spending was $14,522,947[11]. The budget for Fiscal Year 2005 is $15,588,869[11]. The town's Moody's bond rating is AAA[11]. A municipality's bond rating is determined by a few criteria: municipal debt, financial performance, local economy and tax base and municipal management. If a town does not follow the GASB statement guidelines, their bond rating may be lowered based on the criteria of municipal management. Municipal debt includes: debt per capita, debt as a percentage of equalized valuation and rate of debt amortization. Financial performance is based on operating surpluses or deficits, free cash as a percent of revenue, state aid reliance, property tax collection rates, and unfunded pension liability. Property values, personal income levels, tax base growth, tax and economic base diversity, unemployment rates and population growth are considered when the local economy is considered. Finally, the municipal management criteria is based on governmental structure, the existence of a capital improvement plan, the quality of accounting and financial reporting, etc. If a town's financial reports vary significantly from the generally accepted accounting procedures then an independent auditor may issue a qualified

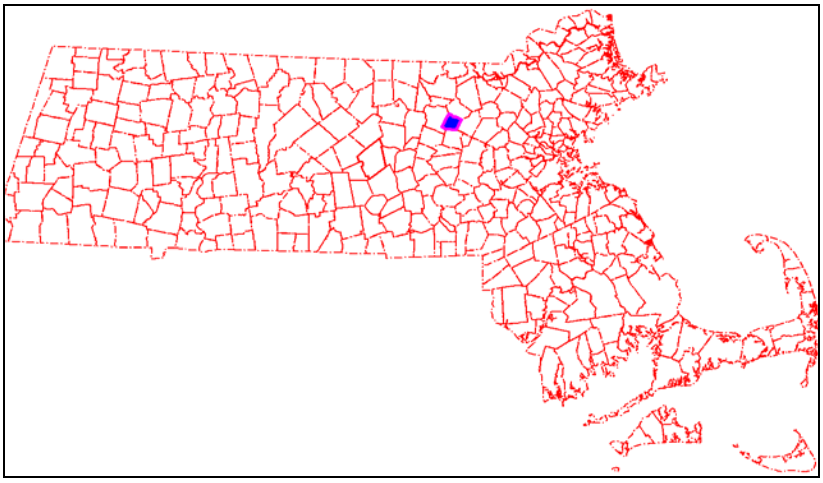

Figure 3 Boxborough Location in Mass

[9] The Town of Boxborough Website: *This information was either given to use or found on the website*
[10] The Massachusetts Website

opinion or disclaimer that may negatively affect a town's bond rating[11]. The town would then have a difficult time borrowing money, straining already tight small town budgets. The Town of Boxborough, MA falls into Phase 3 for GASB 34 compliance. Phase 3 requires that the town had an operating budget of less than $10 Million in the first fiscal year ending after June 15, 1999. The town must comply with GASB 34 for all financial statements for periods beginning after June 15, 2002[11],[12].

[11] The Moody Website
[12] The GASB Organization Website

3 Methodology

Our Project is designed to assist the town of Boxborough in complying with GASB 34 requirements by creating a reusable data infrastructure for road maintenance.

The objectives of our project are to inventory all of the roads and road related assets, to assess the condition of roads and road related assets, to create a system to estimate the value of the roads and road related assets, and to demonstrate reusability of data infrastructure for other purposes.

In order to achieve these objectives, we had to perform several tasks. Each task will be explained as to how it was performed, and its relevance to the objective identified.

The scope of our project includes all the town accepted roads of Boxborough, MA and their related road side assets. The first asset to be evaluated was the road itself. The road side assets that needed to be evaluated consisted of: street signs, guard rails, sidewalks, and storm drains. For each asset, a form was made to help aid in the data collection and condition assessment of the asset.

Each of the roads in Boxborough were previously evaluated, except the state roads and private ways, by the town of Boxborough. State roads belong to the state and the private roads to their owners, and thus are not assets of Boxborough and did not need to be evaluated. The information on their condition and length were given to us from the Boxborough Department of Public Works.

Road related assets includes the street signs on these roads owned by the town of Boxborough. Street signs include stops, speed limits, directional arrows, intersection signs, street names, cautionary signs. However, they do not include small reflectors and town line markers. All of the information that was collected represents the roads and road related assets in Boxborough as of July 2005.

Boxborough has three types of guard rails: all metal, concrete posts with steel cable, and wooden guard rails. There are not many in town, but anywhere the roadside conditions have the potential danger, guardrails are installed.

All manhole covers on all town accepted roads were evaluated and located. All sidewalks in town were also evaluated, including sidewalks along State roads as they are an asset of the town and not of the state.

3.1 Inventorying Roads and Road Related Assets

To inventory the road assets in the town, Boxborough has supplied the team with a Trimble ProXR GPS backpack unit. The unit uses a backpack that holds batteries and a receiver with a hand controller. The unit triangulates the position of the receiver using user entered offsets and satellites in the sky. Team members drove around town stopping at all of the road related assets and recorded the point in the GPS unit, with a short description of the asset.

3.2 Assessing the Condition of Roads and Road Related Assets

How the conditions of roads and road related assets are determined is explained in this section. While the assets were being inventoried, a notebook was kept to record the condition of each individual asset. Other pertinent information was recorded as well: type of sign, material of guardrail, type of pole, etc. Pictures were taken of the assets and their respective picture number was recorded in the notebook.

The Boxborough Department of Public works used the following scale to evaluate the condition of the roads:

1. **Poor:** Major cracking, major potholes, ruts, heaves, unpaved
2. **Fair:** Serious cracking, minor potholes
3. **Good:** No problems, slight-moderate cracking in some areas
4. **Excellent:** New

The following table contains examples of defects in a road that lowers its condition.

Unpaved, gravel road	 Figure 4 Unpaved gravel road
Collapsed Edges	 Figure 5 Collapsed edges
Slight-Moderate cracking	 Figure 6 Slight-moderate cracking
Overgrowth	 Figure 7 Overgrowth

To inventory street signs we recorded the type of sign, the type of post it is on, the physical condition of each, and the sign's visibility. The condition of the sign depends on its reflectivity, if there are any dents or bends in the sign, and if the sign is still readable. Anything on the sign that is not supposed to be on it would lower its condition on our

scale. The condition of the pole depends on the amount of rust that has formed on it, if the pole will stand upright, and if it is straight. This table contains examples of signs in each of the conditions:

1. **Poor**: Faded, chipped paint, rust, damaged, graffiti, unreadable	 Figure 8 Poor Street sign
2. **Fair**: Sign is faded or damaged	 Figure 9 Fair Street sign
3. **Good**: Sign is easily readable	 Figure 10 Good Street Sign
4. **Excellent**: New	 Figure 11 Excellent Street sign

Guard rails were judged on three categories: worst rating on overall, the percentage of the rail that receives that rating, and the condition of the remainder of the

road. Using that system, the guard rails were then placed in one of the following categories:

1. **Poor**: severe damage, parts missing	 Figure 12 Poor Guard Rail
2. **Fair**: moderate damage, several poles misaligned	 Figure 13 Fair Guard Rail
3. **Good**: cosmetic damage, nearly all poles vertical	 Figure 14 Good Guard Rail
4. **Excellent**: all poles are vertical, no damage	 Figure 15 Excellent Guard Rail

Sidewalks were evaluated similarly to how the road conditions were evaluated. Cracks, holes, ruts, and heaves all lower the condition of the road. To determine a sidewalk's rating, the worst portion of the sidewalk was rated, and that portion's percentage of the whole sidewalk was considered along with the rating of the rest of the sidewalk. From that information the condition was discussed and agreed upon. The overall ratings are:

1. **Poor**: Major cracking, ruts, heaves, holes, heavy growth in the sidewalk	No Picture Available
2. **Fair**: Minor cracking, minor growth, small ruts and dips	No Picture Available
3. **Good**: Cosmetic cracking/damage, little or no growth,	 Figure 16 Good Sidewalk
4. **Excellent**: New, no cracking, no growth	 Figure 17 Excellent Sidewalk

Storm drains were evaluated on rustiness, condition of pavement around the drain, amount of debris clogging the drain, and damage to the drain cover. They were categorized as:

1. **Poor**: Major rust flaking, missing pavement, serious damage or debris, poor or no drainage	 Figure 18 Poor Storm Drain
2. **Fair**: Minor rusting/damage, cracked pavement, constricted drainage	 Figure 19 Fair Storm Drain
3. **Good**: Cosmetic rusting/damage, little or no debris,	 Figure 20 Good Storm Drain
4. **Excellent**: New, no rust, little debris	 Figure 21 Excellent Storm Drain

3.3 Creating a System to Estimate Road and Road Related Asset Values

We decided to use Microsoft Access to generate a database to enter all of our information into. We chose this program because of its versatility and availability. The Town of Boxborough also uses this program. Forms would be needed to ease data entry into each of the tables. The forms would fill in all important information about the road or road related asset onto its designated table, while making the process more user-friendly. Summary Reports would also be needed to display all of the values and their totals at the end of the report.

To evaluate the value of each asset, a linear depreciation method is recommended by GASB. To determine how much of an asset's value is retained the age of the asset, the current date minus the date of installation, is divided by the life expectancy of the asset and subtracted from one:

$$\% \text{ Original Value Retained} = 1 - \frac{(\text{Current Date} - \text{Date of Installation})}{(\text{Life Expectancy})}$$

This percent is multiplied by the original value of the asset to estimate its current value. This depreciation method can be used for all roads and road related assets.

3.4 Demonstrating the Reusability of the Data Infrastructure

The data infrastructure for this report must also be able to be expanded and used for other possible purposes. One possible use of the database can be to estimate the cost of plowing roads in Boxborough. By using road length data with other information from the town entered into the database, a report can be created in Microsoft Access to estimate the cost of plowing the roads in Boxborough once.

4 Results

The following information was collected from the town of Boxborough, Massachusetts from March through June 2005. The location data was collected and entered into a Trimble GPS unit. Using the GPS software provided by Boxborough, the data was transferred from the GPS unit into the Boxborough network. The information was exported from the GPS software into layers (maps) that can be viewed in GIS programs.

4.1 Roads

The town of Boxborough has a total of 65 roads, which can be seen in Figure 23, totaling nearly 30 miles, less than 1% of which received a poor rating. As you can see in Figure 22, the largest portion of the roads received a fair rating (47.51%) while 12.07% were found to be in good condition. There was still a large portion that received an excellent rating, 39.51% (Figure 22).

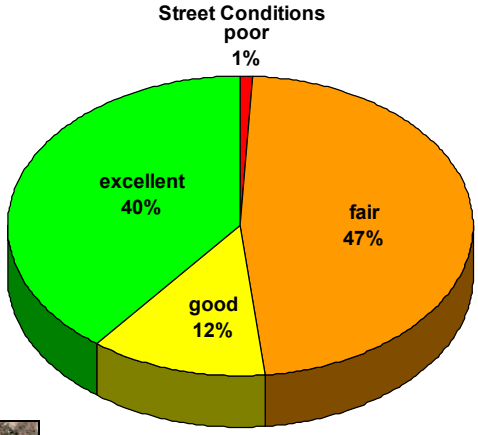

Figure 22 Road condition Pie Chart

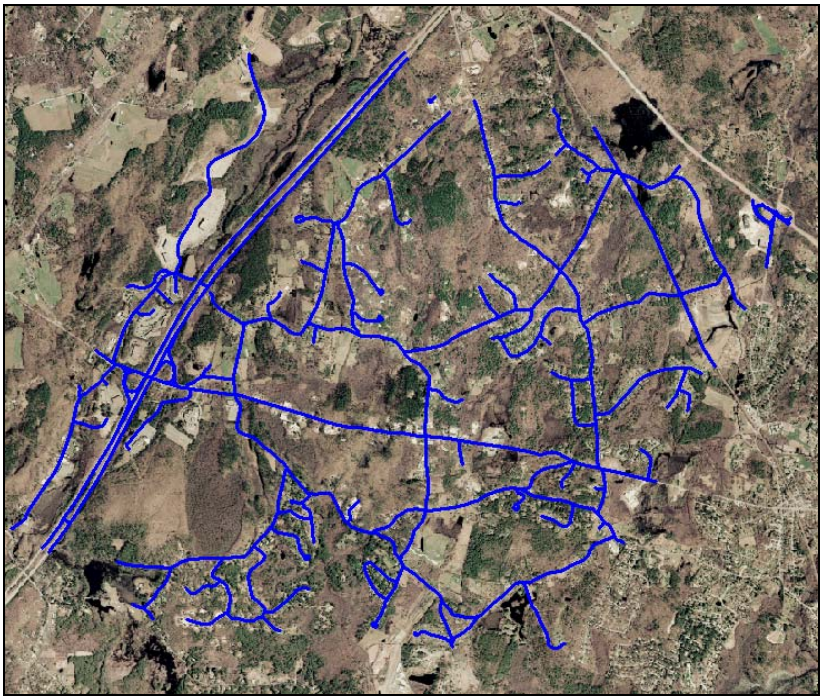

Figure 23 Roads in Boxborough

4.2 Street Signs

There are a total of 303 street signs in Boxborough (Figure 24) of 35 different types. Of those signs, 0.99% are in poor condition; 8.91% in fair condition; 36.96% are in good condition; and 53.14% were in excellent condition, Figure 25 depicts this. Appendix A contains a tabulated form of the statistical results for street signs and all other assets. Table 1 lists the total number of each type of signs in town, and the number that fell under each condition.

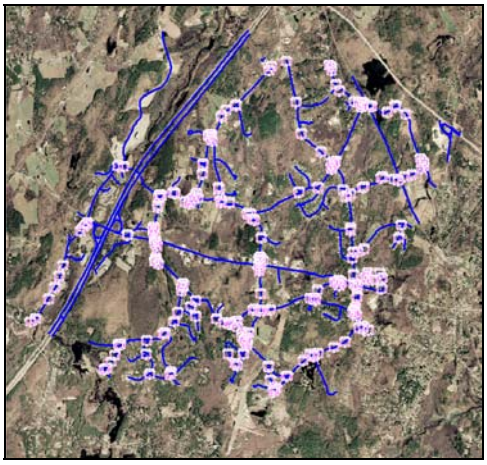

Figure 24 Street Signs in Boxborough

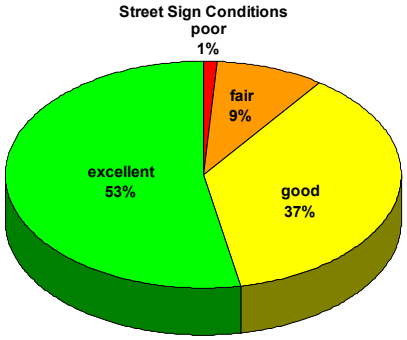

Figure 25 Street Sign Conditions

Type of Sign	Total #	#of Poor	#of Fair	#of Good	#of Excellent
Street Name	64		4	19	41
stop	55		4	20	31
arrow	28	2	3	8	15
30 MPH	24		5	15	4
25 MPH	18			5	13
go slow children	17		3	3	11
stop ahead	12			6	6
blind drive	9		2	4	3
35 MPH	7		1	5	1
one way	7				7
dead end	6	1		2	3
slow	6			3	3
RR x-ing	5			3	2
4way intersection	4		1	3	
20 MPH	3			3	
cattle crossing	3		1		2
dangerous intersection	3		1	1	1
right lane turn right	3				3
right turn	3			2	1
15 MPH	2				2
deaf children	2			2	
do not enter	2				2
hidden drive	2			1	1
horse crossing	2				2
island	2				2
left turn	2			1	1
no parking	2				2
reduce speed children	2			1	1
Trucks Entering	2		1	1	
bus stop ahead	1			1	
dangerous curve	1				1
merging traffic	1			1	
s curve	1			1	
T-intersection	1		1		
Town line	1			1	

Table 1.Types of Street Signs, Totals, Conditions

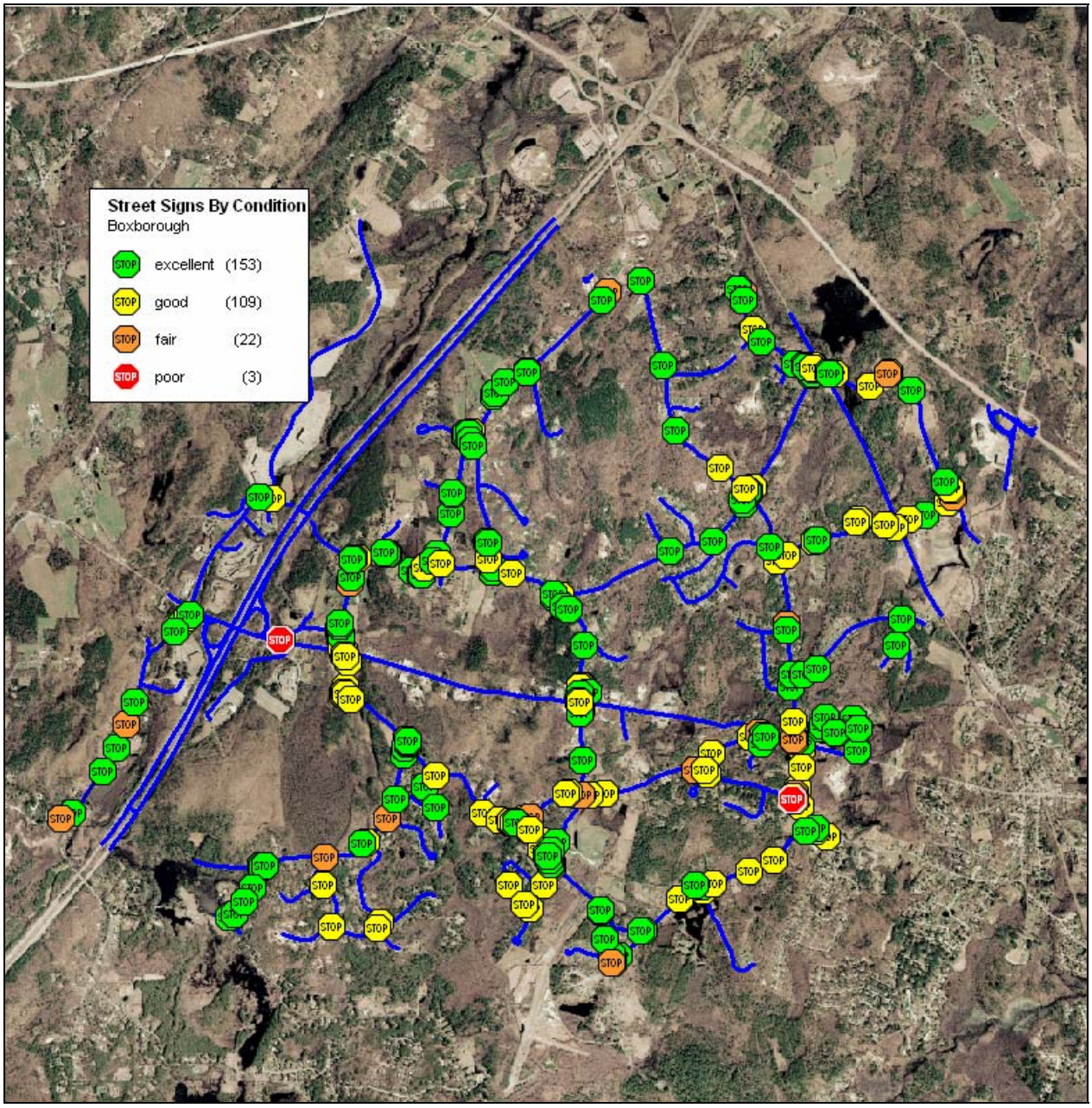

Figure 26 Distribution of Sign Conditions

Figure 26 shows the location of the street signs, and the present condition that each sign is in.

4.3 Guard Rails

There were a total of 27 guard rails in town, the location of which are shown in Figure 28, made of steel, concrete and steel cable, or wood. There were two wooden guardrails, and most of the concrete and cable guard rails were in fair or poor condition.

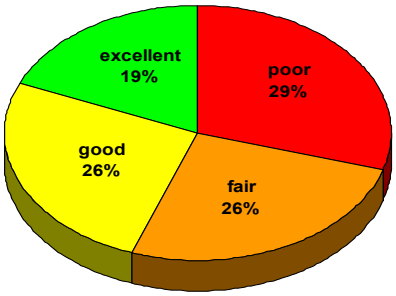

Figure 27 Guard Rail Conditions

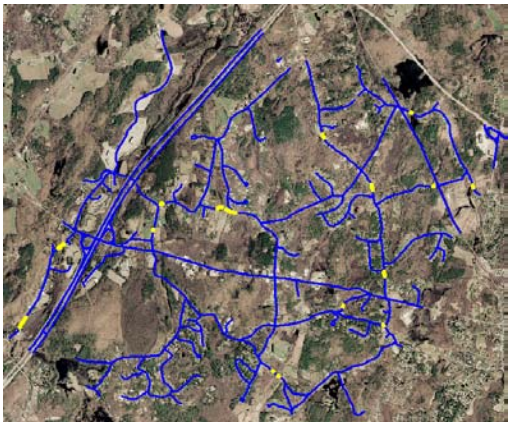

Figure 28 Guard Rails in Boxborough

The guard rails were relatively evenly distributed when it came to their conditions, as seen in Figure 27: The location of the guardrails by condition can be seen in Figure 29.

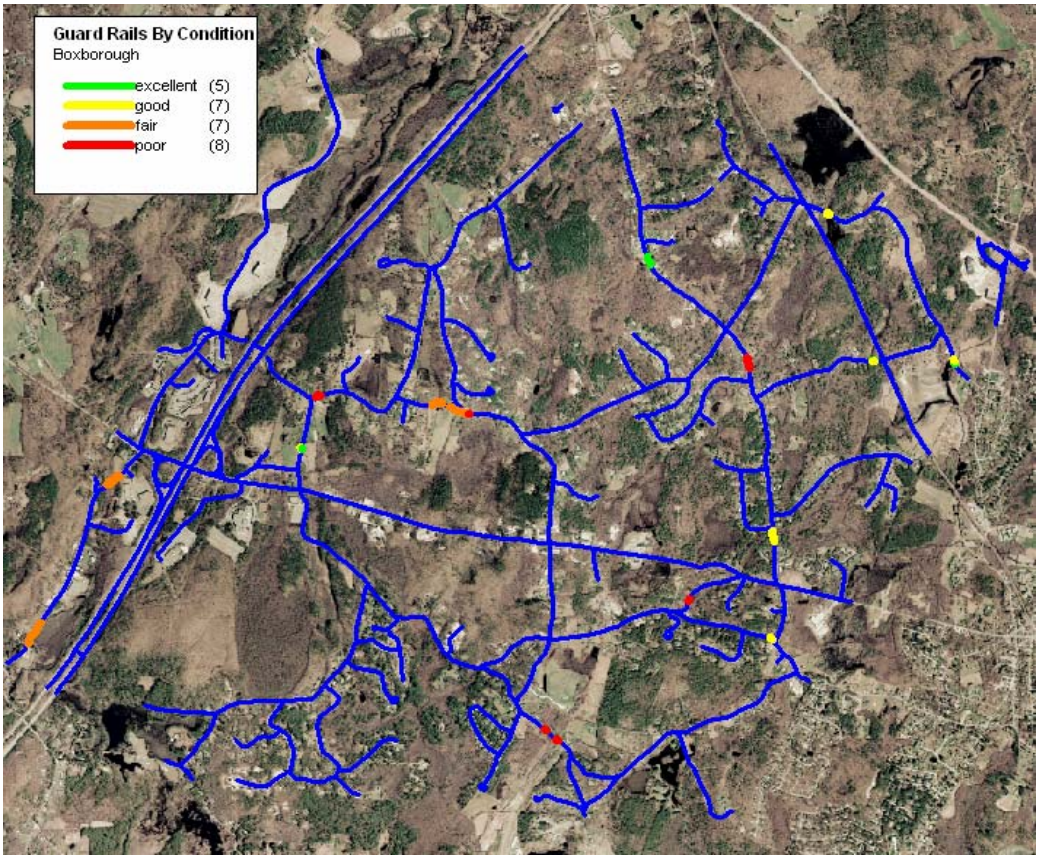

Figure 29 Distribution of Guard Rail Conditions

4.4 Sidewalks

There are a total of 22 different sidewalks in Boxborough (Figure 31), totaling a length of 71,042 feet. As seen in Figure 30, 66.2% are in good condition and 33.8% in excellent condition. This means that none of the sidewalks in Boxborough received a rating below 'good'. You can see the locations of the sidewalk conditions in Figure 32.

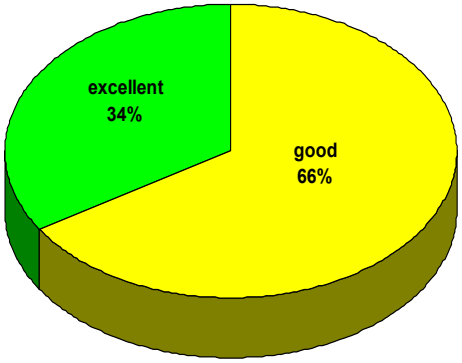

Figure 30 Sidewalk Conditions

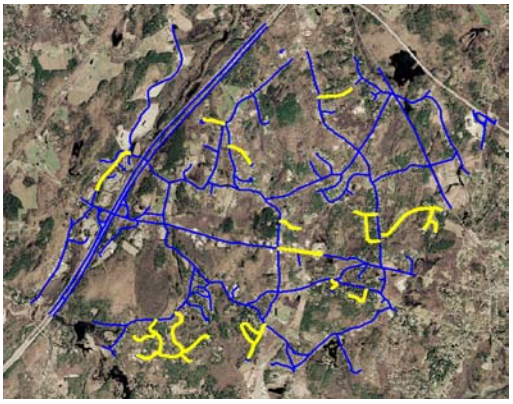

Figure 31 Sidewalks in Boxborough

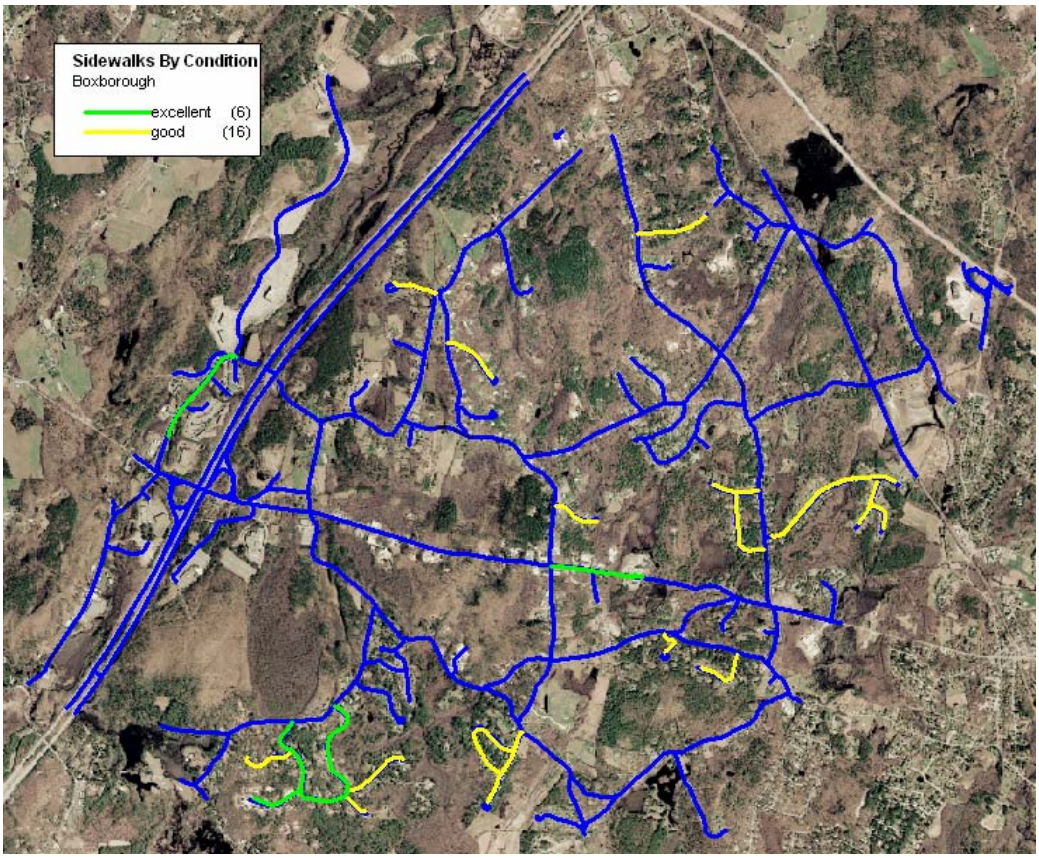

Figure 32 Distribution of Sidewalk Conditions

4.5 Storm Drains

There were a total of 292 storm drains in Boxborough, mostly in Good condition (Figure 33). The storm drains are located in areas that need drainage. Usually hilly roads have no storm drains, except if there was a valley where the water could collect, and then there would be a storm drain in the low lying areas. Most of the roads in Boxborough are located on hills. The condition and location of the storms drains can be seen in Figure 34.

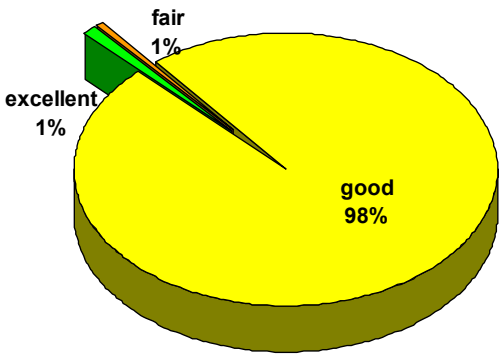

Figure 33 Storm Drain Conditions

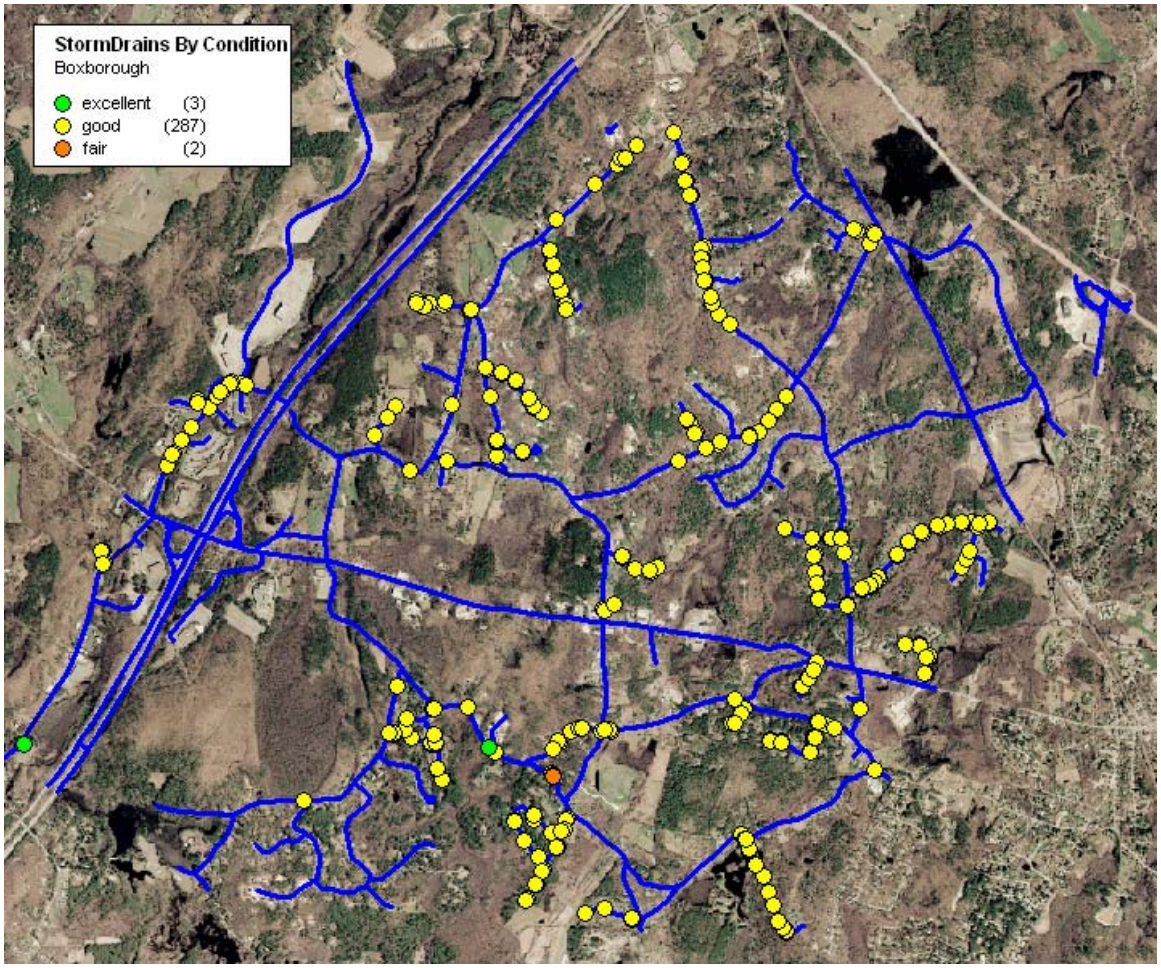

Figure 34 Distribution of Storm Drain Conditions

5 Analysis

The database created in this project was intended to determine the current values of all the roads and road assets in the town of Boxborough in order to create GASB 34 financial statements. These reports will guarantee that the town receives the maximum amount of reimbursement from the state for its expenditures. The database that was created can also be used for purposes other than creating reports for valuing roads and road related assets. Budgets for the maintenance of roads can be produced using the databases supplied. Another consideration would be to use this information to best route emergency vehicles to increase overall safety in the town. Many other possibilities exist for the re-use of our data and data infrastructure, but the afore mentioned will be discussed to illustrate how they re-use the database.

5.1 GASB 34 Valuations

In order to derive the values of the sidewalks and roads for the town we created a database in the program Microsoft Excel. We entered the GPS length and width for each sidewalk and road into the data base. We then got the year of the last repair, from the town, and entered that into the data base. Using the current year and expected life we were able to calculate the depreciation of each asset like so:

Depreciation = (Expected Life – (Current Year – Year Last Repaired)) / Expected Life

Then using the cost to replace per square foot, length, and width we were able to calculate the cost to replace each asset like so:

Cost To Replace = Length * Width * Cost To Replace per. Square Foot

We then entered the cost to replace into an inflation calculator to get the Historical Cost. With the historical cost and the depreciation we were able to calculate the worth of each asset by simply multiplying the two together. The value that we derived for the total worth of the sidewalks in the town is $59,582.35, and the total worth of the roads is $2,592,125.10, this is shown in Table 2.

Asset	Total Worth
Roads	$2,592,125.10
Sidewalks	$59,582.35

Table 2 Total Worth of Roads and Assets

5.2 Plowing

New England can have large snowfall amounts in the winter, and plowing information and costs become concerns for the city's and towns in this area. In 2003, the Massachusetts snow plowing budget was set at $16 million. In just one blizzard that February, the cost of removing the snow cost the state between $7 million and $8 million. The total cost of snow removal that year for Massachusetts was $62 million. In Fairfield, Connecticut the snow removal budget was set at $200,000 for 2003. Before that same blizzard struck, it had already spent $500,000 on snow removal. In the town of Boxborough, where the total snow and ice budget for Fiscal Year 2003 was about $65,000, the town ended spending over $91,000 to take care of snow and ice that year. Planning for such events could save the town money, as well as provide better response. Better budget planning could be achieved by using the information in the database with other information from the town of Boxborough.

To calculate the approximate cost of plowing the entire town once, information on pay rates, average plowing speed, fuel economy, and fuel price will be needed. A table can be created to contain all information on the plowing staff, including pay rate. To evaluate the cost of plowing, this information would need to be in the following expression in the report:

Cost = (Road Length / Average MPH)* Average Salary + Road Length * Cost per Gallon of fuel / Truck Fuel Efficiency

This equation would be calculated for each road, so at the end of the report a summation of all of these costs would report the approximate total cost of plowing the town of Boxborough once. Using this calculated number, the town can compare the cost of the DPW plowing against private contractors in an effort to save money. In the appendix there is a how-to guide on how to make these changes to the Microsoft Access database and generate a report that yields the total plowing cost for each road and a total for the whole town. A walk through for this process can be found in Appendix B.

5.3 Sanding and Salting

The database can also be used to evaluate other essential information for the town for winter related purposes. In addition to plowing roads, to prevent ice from forming on roads and creating slippery conditions sand and salt is spread over the road surface. The database can be used to calculate the amount of salt the town needs. The database contains information on road lengths and widths, which can be used to calculate the area of each road. With the area calculated, the amount of sand needed for each road can be determined using a constant volume of sand per area of road surface. This evaluation can also help determine if the DPW is using too much sand or salt, and adjust their equipment accordingly.

5.4 Maintenance

Schedules for preventative maintenance can also be assembled by using the town's guidelines for preventative road maintenance and the information in our database. The database already contains information on the condition of each road and road related asset; it also contains fields for dates of installation. Using this information, a report could be created that follows the guidelines for maintenance scheduling to recommend when a road or asset should go under maintenance. Maintenance scheduling can extend beyond just roads and road related assets as well. Using the lengths of roads included in the database and the paths the utility vehicles take around town, a record of the mileage on the tires could be created. Using that record, the town would know when to expect to change or rotate the tires on each of the utility vehicles. Proper maintenance for tires can extend their lives significantly, which could in turn save the town money by reducing how often they need to buy new tires. Using the speed limits and road segment lengths a report of engine runtime can be estimated. The engine runtime is used to determine when to do maintenance on the engine. Proper maintenance of the engines ensures a longer lifetime as well as better fuel economy to make sure the town gets the most out of its investments.

5.5 Emergencies

Another great use for the database could be emergency vehicle route planning, which can be directed along the shortest path or the fastest path and possibly directed around high traffic areas. The town of Boxborough has for a couple of years been considering development of a regional dispatch system for emergency services with surrounding towns, and a system like this could decrease response time and ensure that the proper resources are called in to handle the emergency, such as making sure that a ladder truck is part of the first response when one is needed.

6 Conclusions and Recommendations

The database and preliminary copy of this report was given to the town of Boxborough. They were both presented and explained to the Board of Selectmen. The Board of Selectmen was very pleased with how our project will help the town report on its roads and road related assets. The future use that was designed into the database was also praised as it will aid the town in future projects and budgeting. The town accountant, Michael Guzzo, estimated that our project had saved the town approximately $15,000. This also added to the delight of the Board of Selectman. Our project was a success as it supplied a way for the town of Boxborough to report for GASB Statement 34, a platform for future use of the database, and saved the town a good deal of money. From the data that we collected for this project, we were able to distinguish what roads and road related assets were in what kind of condition.

From that information, we can give recommendations to the town as to what needs to be replaced or what road may need maintenance. There was only one road in Boxborough that was not completely paved, East Whitcomb Rd. It was the only road that received a poor rating as it was partially gravel and heavily overgrown. This is a small road that leads to a gravel road out of town. It is not necessary to replace the road immediately since there is only one house on it and very low traffic. We think that in a few years it might need some maintenance work. A good portion of the roads received a fair condition, but we think that most maintenance needed on these roads would be cosmetic.

There were seven guardrails that received a rating of poor and seven that received a rating of fair, as you can see in Figure 35. We would recommend that these guardrails that are in poor condition be replaced as soon as possible, and the guardrails that are in

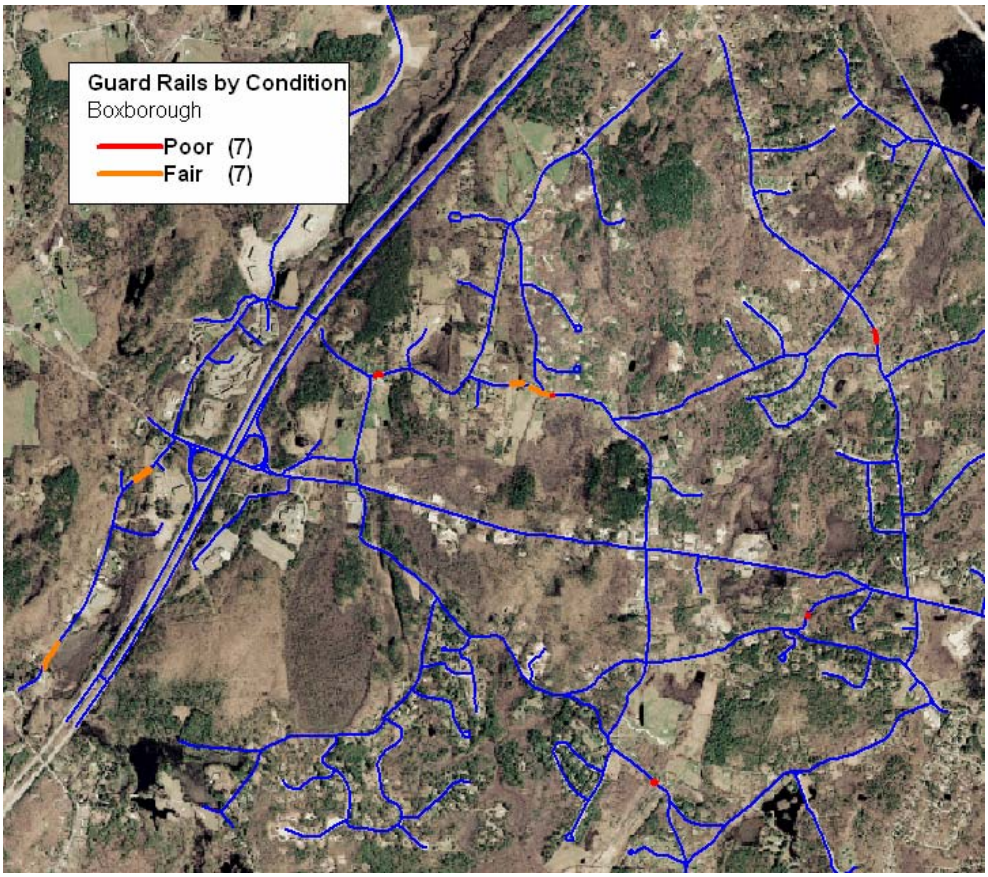

Figure 35 Guardrails in Fair and Poor Condition

fair condition have maintenance done to them to keep them from becoming unsafe. We also recommend that the town use the layers to check if guardrails are in place where they should be with respect to waterways. Roads that pass over a waterway should have a guardrail on both sides of the street to prevent cars from going off the road into these waterways.

Most of the storm drains were in excellent or good condition, but there were two drains that are in fair condition on Chester Road, as is depicted in Figure 36. We do not recommend that these drains be replaced, but we do recommend that the condition of them be monitored to prevent poor drainage of this road.

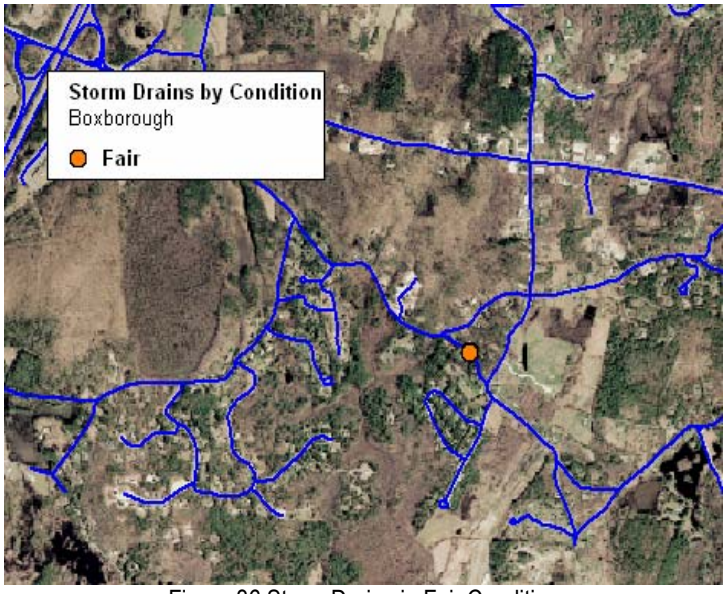

Figure 36 Storm Drains in Fair Condition

There are three signs in Boxborough that received a poor rating, two arrow signs and a dead end sign. These signs, as shown in Figure 37, could not be easily read by a passing driver. We recommend that they be replaced as soon as possible. Most of the signs that received a fair rating are just fading with little damage but are still readable. Their conditions should be checked in a year and replaced accordingly. Several signs also received less than perfect visibility ratings. Some signs in town were not overly visible because of bushes or tree branches growing in front of them. The DPW should use our information on sign visibility to go out and fix the visibility problem with the signs that did not receive a visibility rating of four. The same should be done for replacing sign poles that received a rating of one. We feel that these signs are in a much weakened condition and need to be replaced soon.

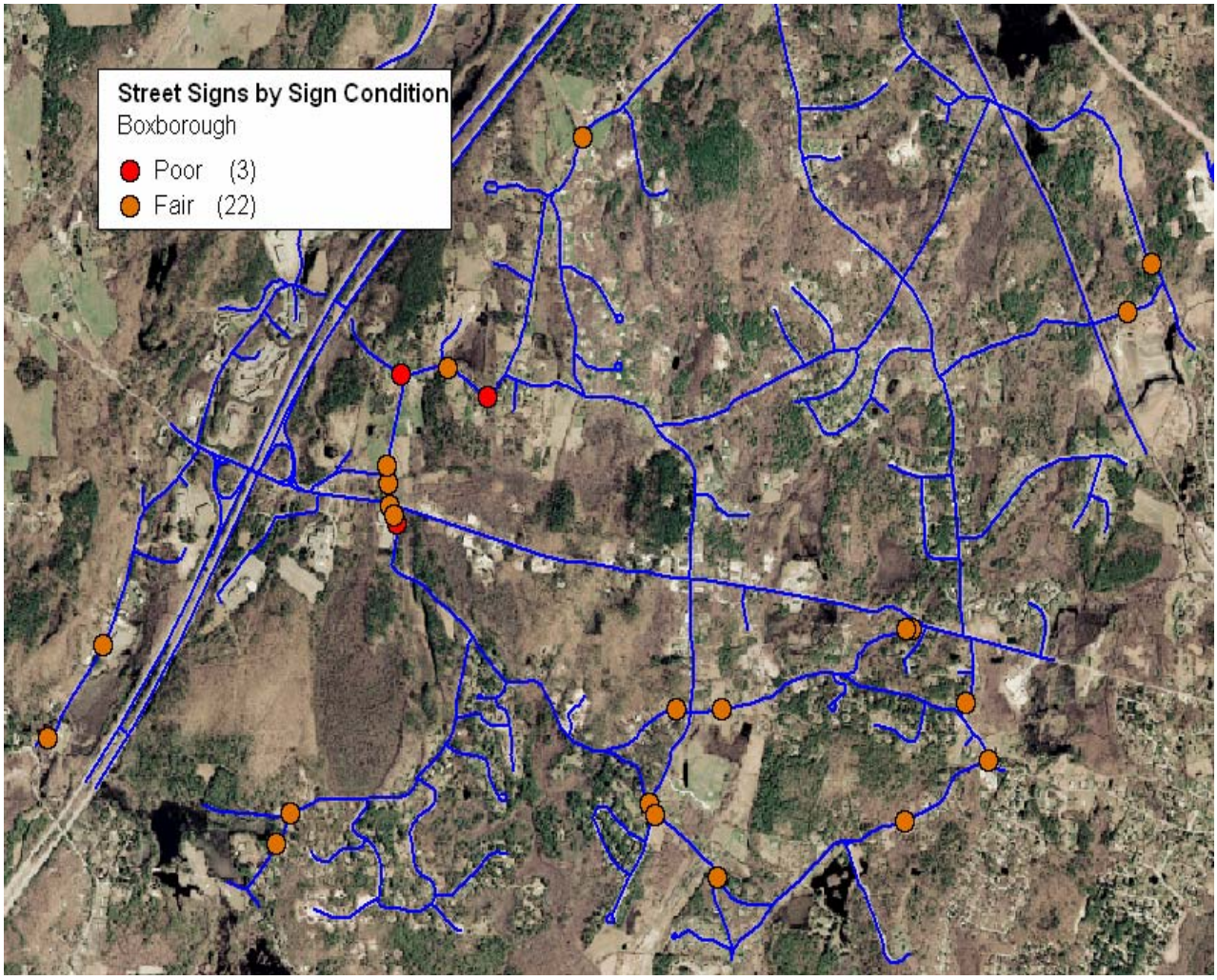

Figure 37 Street Signs in Fair and Poor Condition

7 Bibliography

- **National Transportation Library Website**, http://ntl.bts.gov/
- **Bureau of Transportation Statistics Website**, http://www.bts.gov/
- **The Town of Boxborough Website**, http://town.boxborough.ma.us/
- **The Massachusetts Website,** http://www.mass.gov/
- **The Moody Website,** http://www.moodys.com/
- **The GASB Organization Website**, http://www.gasb.org/

Appendix A Raw Data

This is the tabulated form of the information collected for the roads and road related assets in the Town of Boxborough from March through July 2005. The information for dates of installation was not collected by the town in time for the writing of this report.

Appendix A.1 Roads

Street Name	Best rating	% worst	Worst rating	Length(Mi)	Length(Ft)	Width(avg)
Summer St	4	1.00	4	0.49	2,587.20	21
Liberty Square Rd	4	0.41	2	2.37	12,513.60	27
Kendall Rd	2	1.00	2	0.17	897.60	22
Burroughs Rd	3	1.00	3	2.53	13,358.40	18
Stow Rd	4	1.00	4	1.37	7,233.60	18
Middle Rd	2	1.00	2	1.16	6,124.80	20
Hill Rd	2	1.00	2	2.70	14,256.00	20
Codmann Hill Rd	4	1.00	4	1.17	6,177.60	22.5
Swanson Rd	4	1.00	4	0.62	3,273.60	25
Whitcomb West Rd	2	1.00	2	0.44	2,323.20	18
Whitcomb East Rd	1	1.00	1	0.27	1,425.60	13
Picnic St	2	1.00	2	0.67	3,537.60	14
Depot Rd	2	1.00	2	2.15	11,352.00	16
Old Harvard Rd	2	1.00	2	1.31	6,916.80	18
Chester Rd	3	1.00	3	0.25	1,320.00	22
Pine Hill Rd	2	1.00	2	0.45	2,376.00	16
Flagg Hill Rd	2	1.00	2	1.15	6,072.00	17
Sargent Rd	2	1.00	2	0.90	4,752.00	15
Littlefield Rd	2	1.00	2	0.91	4,804.80	17
Davidson Rd	2	1.00	2	0.55	2,904.00	21
Central St	2	1.00	2	0.34	1,795.20	30
Taylor Ln	3	1.00	3	0.23	1,214.40	
Prescott Ln	4	1.00	4	0.21	1,108.80	29
Osceola Dr	2	1.00	2	0.08	422.40	16
Old Orchard Rd	4	1.00	4	0.20	1,056.00	24
Richardson Rd	2	1.00	2	0.23	1,214.40	17
Barteau Ln	2	1.00	2	0.14	739.20	13
Weatherbee Ln	2	1.00	2	0.18	950.40	14
Robinson Rd	4	1.00	4	1.10	5,808.00	24
Hager Ln	4	1.00	4	0.30	1,584.00	24
Steele Ln	4	1.00	4	0.24	1,267.20	24
Morse Ln	4	1.00	4	0.14	739.20	24
Cunningham	2	1.00	2	0.30	1,584.00	15
Bicentennial Way	3	1.00	3	0.21	1,108.80	
Blanchard Rd	4	1.00	4	0.61	3,220.80	30
Cedarwood Rd	3	1.00	3	0.13	686.40	20
Cobleigh Rd	4	1.00	4	0.22	1,161.60	24
Coolidge Farm Rd	4	1.00	4	0.25	1,320.00	22

Fifers Ln	4	1.00	4	0.21	1,108.80	22
Houghton Ln	4	1.00	4	0.26	1,372.80	22
Howard Ln	3	1.00	3	0.08	422.40	
Inches Brook Ln	4	1.00	4	0.16	844.80	22
Littleton Rd	2	1.00	2	0.14	739.20	12
Mayfair Dr	4	1.00	4	0.28	1,478.40	22
Pierce Ln	4	1.00	4	0.21	1,108.80	22
Pine Pasture Run	4	1.00	4	0.06	316.80	22
Reed Farm Rd	4	1.00	4	0.71	3,748.80	30
Tokatowan Spring Ln	4	1.00	4	0.37	1,953.60	22
Whitney Ln	4	1.00	4	0.12	633.60	22
Windmere Rd	4	1.00	4	0.57	3,009.60	24
Woodward Ln	3	1.00	3	0.16	844.80	
Stonehedge Pl	4	1.00	4	0.29	1,531.20	24
Schoolhouse Ln	4	1.00	4	0.19	1,003.20	22

Appendix A.2 Street Signs

COMMENT	Sign Cond	Pole Type	Pole Cond	Visibility	Exp Life Time	Orig Value
stop	3	Square Galvenized	3	4	5	30
dead end	3	Square Galvenized	3	4	5	30
35 MPH	3	Painted U-channel	2	4	5	30
35 MPH	3	Painted U-channel	2	4	5	30
Trucks Entering	2	Painted U-channel	2	4	5	30
Stop/town line	3	Square Galvenized	3	4	5	30
35 MPH	2	Painted U-channel	2	4	5	30
Trucks Entering	3	Painted U-channel	2	4	5	30
35 MPH	3	Painted U-channel	3	4	5	30
right lane turn right	4	Square Galvenized	3	4	5	30
right lane turn right	4	Square Galvenized	3	4	5	30
right lane turn right	4	Square Galvenized	3	4	5	30
30 MPH	3	Painted U-channel	3	4	5	30
20 MPH and left turn	3	Painted U-channel	2	4	5	30
arrow	3	Round Galvenized	3	4	5	30
arrow	3	Round Galvenized	3	4	5	30
arrow	3	Round Galvenized	3	4	5	30
arrow	3	Round Galvenized	3	4	5	30
30 MPH	3	Painted U-channel	2	4	5	30
reduce speed children	3	Painted U-channel	2	4	5	30
stop ahead	3	Painted U-channel	3	4	5	30
stop	3	Painted U-channel	3	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
stop	3	Painted U-channel	3	4	5	30
Street name- Burroughs/Stow	3	Round Galvenized	3	4	5	30
30 MPH	2	Painted U-channel	2	4	5	30
T-intersection	2	Painted U-channel	2	4	5	30
stop	3	Painted U-channel	3	4	5	30

30 MPH	2	Painted U-channel	3	4	5	30
Street name- Burroughs Rd	3	Round Galvenized	2	4	5	30
s curve	3	Painted U-channel	2	4	5	30
stop ahead	3	Painted U-channel	2	4	5	30
stop	3	Painted U-channel	3	4	5	30
30 MPH	2	Painted U-channel	3	4	5	30
go slow children	4	Painted U-channel	3	4	5	30
stop ahead	4	Painted U-channel	4	4	5	30
stop	4	Painted U-channel	4	4	5	30
30 MPH	3	Painted U-channel	3	4	5	30
stop	3	Round Galvenized	2	4	5	30
30 MPH	3	Painted U-channel	1	4	5	30
20 MPH and right turn	3	Painted U-channel	2	4	5	30
arrow	1	Painted U-channel	1	4	5	30
4way intersection	2	Painted U-channel	2	4	5	30
stop	2	Square Galvenized	3	4	5	30
Street name- Burroughs Rd	3	Round Galvenized	1	4	5	30
Street name- Chester Rd	3	Painted U-channel	2	4	5	30
20 MPH	3	Painted U-channel	2	4	5	30
blind drive	3	Painted U-channel	2	4	5	30
stop ahead	3	Painted U-channel	3	4	5	30
Stop/2X arrows/Street Name- Chester	2	Round Galvenized	3	4	5	30
Street name- Chester Rd	2	Round Galvenized	3	4	5	30
Street name- Meadow ln	3	Painted Round	3	4	5	30
deaf children	3	Painted U-channel	2	4	5	30
Street name- Meadow ln	3	Painted Round	3	4	5	30
deaf children	3	Painted U-channel	2	4	5	30
25 MPH	3	Painted U-channel	2	4	5	30
stop ahead	4	Painted U-channel	4	4	5	30
stop	3	Painted U-channel	3	4	5	30
30 MPH	3	Painted U-channel	3	4	5	30
stop ahead	3	Painted U-channel	3	4	5	30
right turn	3	Painted U-channel	2	3	5	30
stop	3	Painted U-channel	3	4	5	30
blind drive	3	Painted U-channel	3	4	5	30
4way intersection	3	Painted U-channel	2	4	5	30
stop	3	Painted U-channel	3	4	5	30
30 MPH	3	U-channel Galvenized	2	4	5	30
stop ahead	3	Painted U-channel	3	4	5	30
leftturn/junction	3	Painted U-channel	2	4	5	30
stop	3	Painted U-channel	3	4	5	30
blind drive	3	U-channel Galvenized	3	4	5	30
Street Name- Stow rd	3	Round Galvenized	3	4	5	30
Street Name- Fifers ln	3	Round Galvenized	3	4	5	30
Street Name- Flagg hill	3	Painted Round	3	4	5	30
30 MPH	3	U-channel Galvenized	3	4	5	30
30 MPH	2	Painted U-channel	3	4	5	30
hidden drive	3	Painted U-channel	3	3	5	30

stop	3	Painted U-channel	3	4	5	30
Stop/st sign flagg hill/summer	2	Round Galvenized	3	4	5	30
30 MPH	3	U-channel Galvenized	3	4	5	30
Street Name- Richardson	3	Painted Round	2	4	5	30
stop	2	Painted U-channel	3	4	5	30
Street Name- Richardson	3	Painted Round	2	4	5	30
stop	3	Painted U-channel	3	4	5	30
stop	3	Painted U-channel	3	4	5	30
30 MPH	3	U-channel Galvenized	3	4	5	30
dangerous intersection	3	Painted U-channel	3	4	5	30
Street Name- Middle/hill	3	Round Galvenized	3	4	5	30
30 MPH	3	U-channel Galvenized	3	4	5	30
go slow children	3	Painted Round	2	4	5	30
blind drive	3	Painted Round	3	4	5	30
stop	3	Painted U-channel	3	4	5	30
25 MPH	3	Painted U-channel	2	4	5	30
slow	3	Painted U-channel	3	4	5	30
arrow	3	Painted U-channel	2	4	5	30
blind drive	2	Painted U-channel	2	3	5	30
stop	3	Painted U-channel	3	4	5	30
slow	3	Painted U-channel	3	4	5	30
25 MPH	3	Painted U-channel	2	4	5	30
stop ahead	3	Painted U-channel	2	4	5	30
stop	3	Painted U-channel	3	4	5	30
stop	3	Round Galvenized	3	4	5	30
Street Name- Old harvard	3	Round Galvenized	3	4	5	30
Street Name- Cunningham Rd	4	Square Galvenized	4	4	5	30
stop	4	Square Galvenized	4	4	5	30
stop	4	Painted U-channel	4	4	5	30
stop ahead	4	Painted U-channel	3	4	5	30
4way intersection	3	Painted U-channel	2	4	5	30
stop	4	Painted U-channel	3	4	5	30
30 MPH	2	U-channel Galvenized	4	4	5	30
horse crossing	4	Painted U-channel	3	3	5	30
25 MPH	4	Painted U-channel	3	4	5	30
right turn	4	Painted U-channel	1	4	5	30
go slow children	2	Painted U-channel	2	3	5	30
left turn	4	Painted U-channel	2	4	5	30
arrow	1	Round Galvenized	1	1	5	30
arrow	4	Round Galvenized	4	4	5	30
arrow	4	Round Galvenized	4	4	5	30
arrow	4	Round Galvenized	4	1	5	30
30 MPH	3	Painted U-channel	3	4	5	30
blind drive	4	Painted U-channel	3	4	5	30
cattle crossing	4	Painted U-channel	4	4	5	30
cattle crossing	2	Painted U-channel	2	3	5	30
Street Name- Hill Rd	4	Painted Round	3	3	5	30
30 MPH	4	U-channel Galvenized	4	4	5	30

cattle crossing	4	Painted U-channel	4	4	5	30
30 MPH	3	Painted U-channel	4	4	5	30
right turn	3	Painted U-channel	1	4	5	30
25 MPH	4	Square Galvenized	4	4	5	30
horse crossing	4	Painted U-channel	3	4	5	30
arrow	4	Painted U-channel	3	4	5	30
arrow	4	Painted U-channel	4	4	5	30
arrow	4	Painted U-channel	3	4	5	30
arrow	4	Painted U-channel	3	4	5	30
blind drive	2	Painted U-channel	2	4	5	30
stop	4	Painted U-channel	4	4	5	30
Street Name- Tokatawan Sprin	4	Square Galvenized	4	4	5	30
stop	4	U-channel Galvenized	4	4	5	30
Street Name- Schoolhouse Ln	4	Round Galvenized	4	3	5	30
dead end	3	Painted U-channel	3	1	5	30
Street Name- Weatherbee Ln	3	Painted U-channel	3	2	5	30
Street Name- Barteau Ln	4	Round Galvenized	4	3	5	30
stop	4	Painted U-channel	4	4	5	30
Street Name- Whitcomb East L	4	Round Galvenized	4	3	5	30
dead end	1	Painted Square	1	3	5	30
stop	4	Painted U-channel	3	4	5	30
stop	4	Painted U-channel	3	3	5	30
Street Name- Picnic St	4	Painted Round	3	4	5	30
25 MPH	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
Street Name- Picnic St	4	Round Galvenized	4	4	5	30
stop	4	Round Galvenized	4	4	5	30
slow	4	Painted U-channel	4	4	5	30
25 MPH	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	3	4	5	30
stop	3	Round Galvenized	4	4	5	30
25 MPH	4	U-channel Galvenized	4	4	5	30
25 MPH	4	Painted U-channel	4	4	5	30
stop ahead	4	Painted U-channel	4	4	5	30
stop	4	Painted U-channel	3	1	5	30
Street Name- Depot Rd	4	Painted Round	3	4	5	30
30 MPH	4	Painted U-channel	3	4	5	30
RR x-ing	4	Painted U-channel	3	4	5	30
stop	4	Painted U-channel	3	4	5	30
30 MPH	3	U-channel Galvenized	4	4	5	30
stop	4	Painted U-channel	4	4	5	30
Street Name- Depot Rd	4	Round Galvenized	4	4	5	30
25 MPH	4	U-channel Galvenized	4	4	5	30
stop	4	Painted U-channel	3	3	5	30
Street Name- Prescott Ln	3	Painted Round	2	4	5	30
35 MPH	3	Square Galvenized	3	4	5	30
bus stop ahead	3	Painted U-channel	3	4	5	30

25 MPH	4	U-channel Galvenized	4	4	5	30
dangerous curve	4	Painted U-channel	3	4	5	30
island	4	U-channel Galvenized	4	4	5	30
Stop/Street Name- Liberty Sq	4	Painted U-channel	4	4	5	30
island	4	Painted U-channel	4	4	5	30
stop	4	Painted U-channel	4	4	5	30
35 MPH	4	U-channel Galvenized	4	4	5	30
blind drive	4	Painted U-channel	2	4	5	30
35 MPH	3	U-channel Galvenized	4	4	5	30
hidden drive	4	Painted U-channel	3	1	5	30
Street Name- Osceola Dr	4	Round Galvenized	4	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
25 MPH	4	Painted U-channel	2	4	5	30
go slow children	3	Painted U-channel	4	4	5	30
stop ahead	4	U-channel Galvenized	3	4	5	30
RR x-ing	3	U-channel Galvenized	3	4	5	30
stop	4	Painted U-channel	4	4	5	30
slow	4	Painted U-channel	2	4	5	30
30 MPH	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	3	4	5	30
RR x-ing	4	Painted U-channel	4	4	5	30
Street Name- Davidson	4	Round Galvenized	4	4	5	30
30 MPH	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
blind drive	4	U-channel Galvenized	3	4	5	30
dead end	4	Painted U-channel	3	4	5	30
Street Name- Littleton Rd	4	Painted U-channel	3	4	5	30
slow	3	Painted U-channel	4	4	5	30
30 MPH	3	Painted U-channel	2	4	5	30
go slow children	2	Painted U-channel	2	4	5	30
go slow children	3	Painted U-channel	4	4	5	30
go slow children	2	Painted U-channel	2	4	5	30
RR x-ing	3	Painted U-channel	3	4	5	30
25 MPH	3	Painted U-channel	2	4	5	30
arrow	4	Round Galvenized	4	4	5	30
arrow	4	Round Galvenized	4	4	5	30
arrow	4	Round Galvenized	4	4	5	30
arrow	4	Round Galvenized	3	4	5	30
reduce speed children	4	Painted U-channel	4	4	5	30
stop	4	Square Galvenized	4	4	5	30
Street Name- Sargent Rd	3	Painted Round	2	4	5	30
go slow children	4	Square Galvenized	3	4	5	30
25 MPH	4	Painted U-channel	2	4	5	30
RR x-ing	3	Painted U-channel	2	4	5	30
stop ahead	4	Painted U-channel	4	4	5	30
Stop/Street Name- Sargent Rd/Littlefield	4	Painted U-channel	3	4	5	30
Street Name- Cobleigh Rd	4	Round Galvenized	4	4	5	30
stop	4	Painted U-channel	4	4	5	30

stop	4	Painted U-channel	4	4	5	30
Street Name- Reed Farm Rd	4	Round Galvenized	4	3	5	30
25 MPH	4	Painted U-channel	4	4	5	30
go slow children	4	Painted U-channel	4	4	5	30
stop	4	Painted U-channel	4	4	5	30
Street Name- Blanchard Rd	4	Round Galvenized	4	4	5	30
Street Name- Inches Brook Ln	4	Round Galvenized	4	4	5	30
15 MPH	4	U-channel Galvenized	4	4	5	30
15 MPH	4	U-channel Galvenized	4	4	5	30
stop	4	U-channel Galvenized	4	4	5	30
stop	4	U-channel Galvenized	4	4	5	30
Stop/Go Slow Children	4	U-channel Galvenized	4	4	5	30
one way	4	U-channel Galvenized	4	4	5	30
do not enter	4	Square Wooden post	4	4	5	30
one way	4	U-channel Galvenized	4	4	5	30
stop	4	U-channel Galvenized	4	4	5	30
no parking fire lane	4	Painted U-channel	4	4	5	30
25 MPH	4	Painted U-channel	3	4	5	30
dangerous intersection	2	Painted U-channel	2	4	5	30
merging traffic	3	Painted U-channel	2	4	5	30
stop	4	Painted U-channel	3	4	5	30
arrows	3	Round Galvenized	4	4	5	30
25 MPH	3	Painted U-channel	3	4	5	30
dangerous intersection	4	Painted U-channel	2	4	5	30
stop	4	Painted U-channel	3	4	5	30
4way intersection	3	Painted U-channel	2	4	5	30
stop	4	Square Galvenized	4	3	5	30
Street Name- Summer Rd	4	Painted Round	2	4	5	30
Street Name- Pine Pasture Rd	4	Round Galvenized	4	4	5	30
stop	3	Painted U-channel	3	4	5	30
Street Name- Pine Hill Rd	4	Painted Round	3	4	5	30
30 MPH	3	Painted U-channel	4	4	5	30
Stop/Street Name- Pine Hill	4	Painted U-channel	3	4	5	30
dead end/Street Name- Kendal	4	Round Galvenized	4	4	5	30
25 MPH	4	Painted U-channel	4	4	5	30
stop	4	Painted Square	2	4	5	30
Street Name- Cedarwood Rd	4	Painted U-channel	4	4	5	30
dead end	4	Painted U-channel	4	4	5	30
Street Name- Windmere Rd	4	Round Galvenized	4	4	5	30
Street Name- Woodward Ln	4	Painted Round	2	4	5	30
Street Name- Howard Ln	4	Painted Round	2	1	5	30
Street Name- Bicentennial Way	4	Painted Round	4	4	5	30
Street Name- Coolidge Farm R	4	Round Galvenized	4	4	5	30
Street Name- Whitney Ln	4	Painted U-channel	4	4	5	30
Street Name- Pierce Ln	4	Round Galvenized	4	4	5	30
Street Name- Pierce Ln	4	Round Galvenized	4	4	5	30
Street Name- Mayfair Dr	4	Round Galvenized	4	3	5	30
Street Name- Robinson Rd	4	Round Galvenized	4	4	5	30

Street Name- Robinson Rd	4	Round Galvenized	4	4	5	30
Street Name- Hager Ln	4	Round Galvenized	4	4	5	30
Street Name- Morse Ln	4	Round Galvenized	4	4	5	30
Street Name- Houghton Ln	4	Round Galvenized	4	4	5	30
Street Name- Steele Ln	4	Round Galvenized	4	4	5	30
one way	4	Painted U-channel	4	4	5	30
one way	4	Painted U-channel	4	4	5	30
no parking	4	Painted U-channel	3	4	5	30
one way	4	Painted U-channel	3	4	5	30
do not enter	4	Phone pole	4	4	5	30
one way	4	Painted U-channel	4	4	5	30
arrow x4	4	Painted U-channel	4	4	5	30
one way	4	Painted U-channel	4	4	5	30
Street Name- Old Harvard Rd	4	Painted U-channel	3	4	5	30
slow	4	Painted U-channel	4	4	5	30
arrow	2	Painted U-channel	3	4	5	30
arrow	3	Painted U-channel	3	4	5	30
arrow	3	Painted U-channel	4	4	5	30
Street Name- Richardson Rd	4	Painted U-channel	4	4	5	30

Appendix A.3 Guard Rails

COMMENT	MATERIALS	GPS_LENGTH	GPS-LENGTH(ft)	CONDITION
STOW 2	Concrete and steel cable	0.045	237.6	1
MIDDLE 1	Concrete and steel cable	0.137	723.36	2
liberty sq 1	Steel	0.13	686.4	4
Sargent 1	Steel	0.036	190.08	4
Sargent 2	Steel	0.037	195.36	3
Codman Hill 2	Concrete and steel cable	0.016	84.48	2
Codman Hill 1	Concrete and steel cable	0.304	1605.12	2
Codman Hill 4	Concrete and steel cable	0.221	1166.88	2
Codman Hill 3	Concrete and steel cable	0.229	1209.12	2
Hill 2	Steel	0.024	126.72	3
Hill 1	Steel	0.025	132	4
Hill 4	Wood and Steel	0.036	190.08	1
Hill 3	Wood and Steel	0.079	417.12	1
Middle 4	Concrete and steel cable	0.149	786.72	2
Middle 2	Concrete and steel cable	0.272	1436.16	2
Middle 3	Concrete and steel cable	0.016	84.48	1
Liberty Square 2	Steel	0.022	116.16	4
Liberty Square 3	Concrete and steel cable	0.157	828.96	1
Liberty Square 4	Steel	0.172	908.16	3
Depot 2	Concrete and steel cable	0.044	232.32	3
Depot 1	Concrete and steel cable	0.043	227.04	3
Littlefield 1	Wood and Steel	0.024	126.72	4
Littlefield 2	Wood and Steel	0.038	200.64	3
Burroughs 1	Concrete and steel cable	0.037	195.36	1
Pine Hill 1	Steel	0.044	232.32	3

Stow 1	Concrete and steel cable	0.034	179.52	1
Stow 3	Concrete and steel cable	0.031	163.68	1

Appendix A.4 Sidewalks

Street Name	Expected Lifetime	GPS_LENGTH	Condition	Material
cobleigh	20	1153.505	3	Bitoumunous
swanson	20	2649.412	4	Bitoumunous
tamarack	20	1880.885	3	Bitoumunous
meadow	20	2386.417	3	Bitoumunous
steele ln	20	1315.099	3	Bitoumunous
houghton ln	20	1244.939	4	Bitoumunous
morse ln	20	652.048	3	Bitoumunous
hager ln	20	1622.095	3	Bitoumunous
robinson	20	5885.557	4	Bitoumunous
school house ln	20	1077.301	3	Bitoumunous
cedarwood	20	672.866	3	Bitoumunous
stonehedge	20	1391.192	3	Bitoumunous
massachusetts ave	20	184.959	4	Bitoumunous
massachusetts ave	20	44.824	4	Bitoumunous
massachusetts ave	20	1997.887	4	Bitoumunous
avebury ln	20	1440.541	3	Bitoumunous
waite	20	1721.145	3	Bitoumunous
boxmill	20	1137.954	3	Bitoumunous
guggins	20	1862.548	3	Bitoumunous
inches brook ln	20	739.792	3	Bitoumunous
blanchard	20	1089.65	3	Bitoumunous
reed farm rd	20	3771.447	3	Bitoumunous

Appendix A.5 Storm Drains

Street Name	Condition	Expected Life Time
tamarack 11 and 12	3	20
tamarack 13	3	20
tamarack 14 and 15	3	20
tamarack 16	3	20
tamarack 16 and17	3	20
tamarack 18 and19	3	20
meadow 1 and 2	3	20
meadow 3 and 4	3	20
meadow 5 and 6	3	20
meadow 7 and 8	3	20
meadow 9 and 10	3	20
meadow 11 and 12	3	20
meadow 13 and 14	3	20
meadow 15 and 16	3	20
meadow 17 and 18	3	20
meadow 19 and 20	3	20
cedarwood 1	3	20
cedarwood 2	3	20
cedarwood 3	3	20

cedarwood 4	3	20
cedarwood 5	3	20
cedarwood 6	3	20
kendall 1	3	20
kendall 2	4	20
kendall 3	3	20
kendall 4	3	20
kendall 5	3	20
kendall 6	3	20
flagg hill 1	3	20
flagg hill 2	3	20
windmere 1	3	20
windmere 2	3	20
windmere 3	3	20
windmere 4	3	20
windmere 5	3	20
windmere 6	3	20
windmere 7	3	20
windmere 8	3	20
windmere 9	3	20
windmere 10	3	20
windmere 11	3	20
windmere 12	3	20
windmere 13	3	20
windmere 14	3	20
summer 1	3	20
pine hill 1	3	20
pine hill 2	3	20
stone hedge 1	3	20
stone hedge 2	3	20
stone hedge 3	3	20
stone hedge 4	3	20
stone hedge 5	3	20
stone hedge 6	3	20
stone hedge 7	3	20
stone hedge 8	3	20
stone hedge 9	3	20
stone hedge 10	3	20
stone hedge 11	3	20
stone hedge 12	3	20
applewood 1	3	20
applewood 2	3	20
applewood 3	3	20
applewood 4	3	20
applewood 5	3	20
applewood 6	3	20
baldwin 1	3	20
liberty sq 1	3	20
liberty sq 2	3	20
liberty sq 3	3	20
liberty sq 4	3	20

liberty sq 5	3	20
liberty sq 6	3	20
liberty sq 7	3	20
liberty sq 8	3	20
liberty s9	3	20
liberty sq 10	3	20
liberty sq 11	3	20
liberty sq 12	3	20
liberty sq 13	3	20
liberty sq 14	3	20
liberty sq 15	3	20
liberty sq 16	3	20
liberty sq 17	3	20
liberty sq 18	3	20
liberty sq 19	3	20
liberty sq 20	3	20
liberty sq21	3	20
liberty sq 22	3	20
liberty sq 23	3	20
storm drain	3	20
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storm drain	3	20
codman hill 1	4	20
pierce 1	3	20
pierce 2	3	20
pierce3	3	20
pierce 4	3	20
pierce 5	3	20
pierce 6	3	20
pierce 7	3	20
pierce 8	3	20
pierce 9	3	20
pierce 10	3	20
old harvard 1	3	20
old harvard 2	3	20
sholan 1 *PRIVATE*	3	20
sholan 2 *PRIVATE*	3	20
sholan 3 *PRIVATE*	3	20
sholan 4 *PRIVATE*	3	20
burroughs 1	3	20
burroughs 2	3	20
burroughs 2	3	20
burroughs 3	3	20
burroughs 4	3	20
burroughs 5	3	20
burroughs 6	3	20
burroughs 7	3	20
burroughs 8	3	20
burroughs 9	3	20
burroughs 10	3	20
burroughs 11	4	20
burroughs 12	3	20
chester 1	3	20
chester 2	2	20
chester 3	2	20
whitney 1	3	20
whitney 2 and 3	3	20

coolidge 1	3	20
coolidge 2	3	20
coolidge 3 and 4	3	20
coolidge 5	3	20
coolidge 6	3	20
coolidge 7	3	20
coolidge 9	3	20
fifers1 and 2	3	20
fifers 3	3	20
fifers 4 and 5	3	20
fifers 6 and 7	3	20
fifers 8	3	20
tamarack 1 and 2	3	20
tamarack 3	3	20
tamarack 4 and 5	3	20
tamarack 6	3	20
tamarack 7 and 8	3	20
tamarack 9 and 10	3	20

Appendix B Value Estimating Reports and Database

The data infrastructure we created has tables for roads and for all of the road related assets. It also includes extra tables that hold some statistical information. Each table has fields for the name or comment, condition, dimensions if they are needed, original value, expected life time, and date of installation or repairs.

To make the data entry into these tables easier, we created a form for each table. The following figure is an example of one of the forms we created:

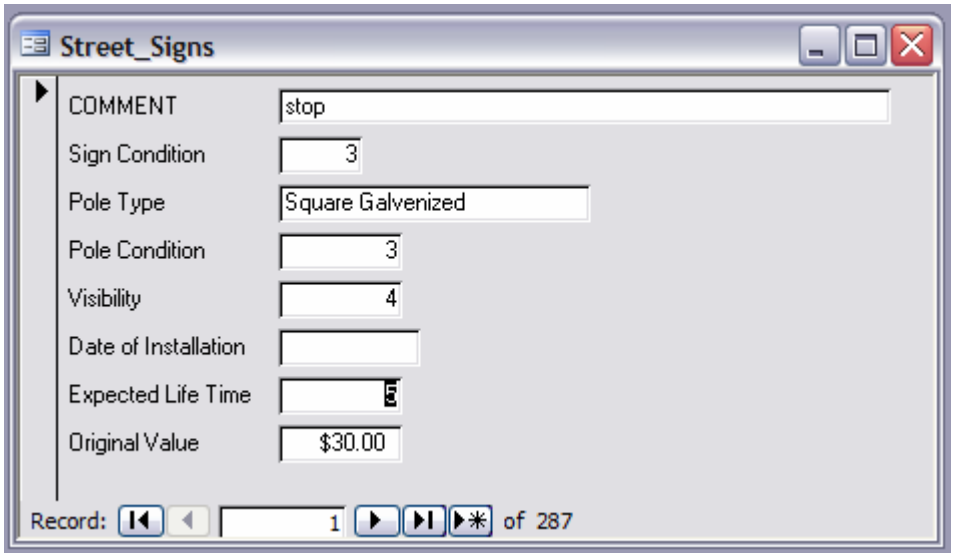

Figure 38 A Sample Form

The database also includes reports for each asset. The reports list important information about each asset and also generate values for them. At the end of each report, there is a total sum for the values that were generated.

To determine the value of a road or a road related asset we used a linear depreciation over the expected lifetime. This value was calculated by subtracting the age of the road or asset, which the Datediff() function calculated using the current date and date of installation, from the expected lifetime, then that was divided by the lifetime. This would end up returning a percent of total value. This would then be multiplied by the original value of road or asset. For sidewalks and roads, the original value is the cost per square foot of the surface. If any of the values are below zero, it is because they have

outlived their expected lifetime; then $0.00 is automatically entered into the value field. Then all of these values are totaled at the end of the report. The last page of the Storm Drains report is on the next page. Some of the table needs to be filled in by the town of Boxborough so all values are returning $0.00:

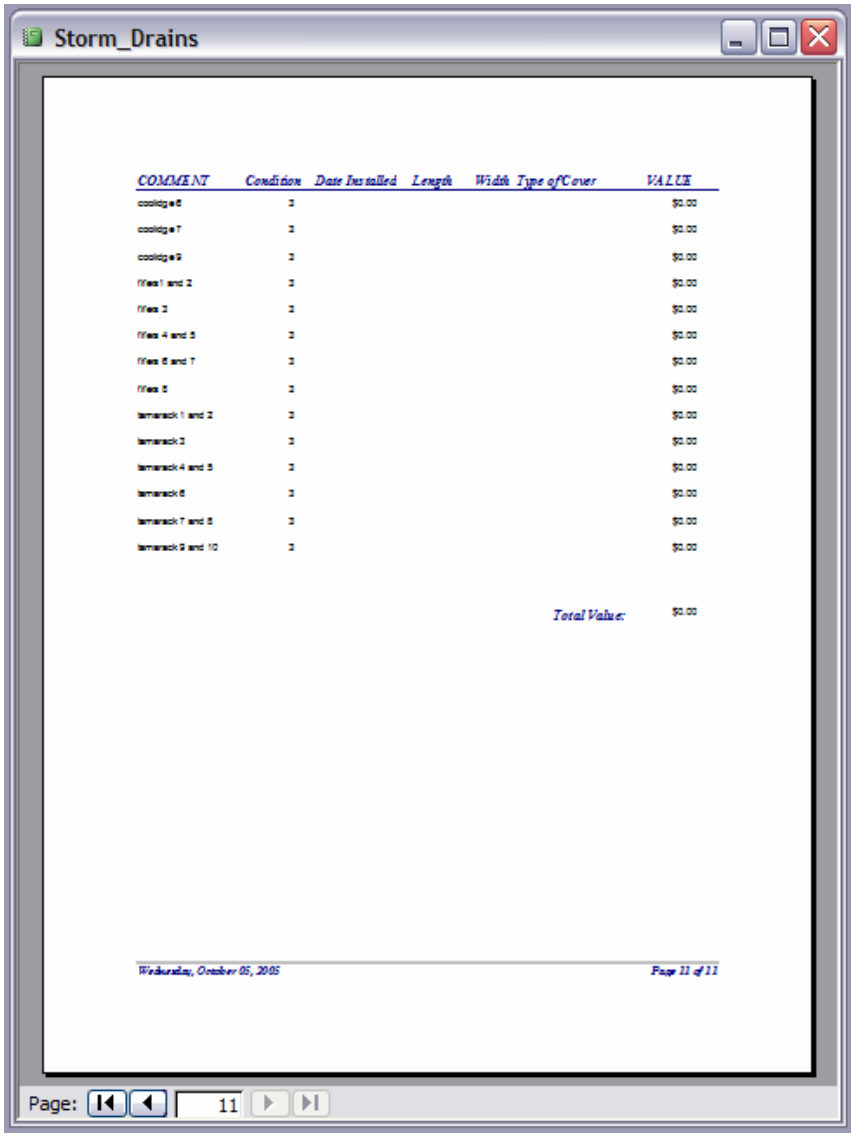

Figure 39 A Sample Report Page

Appendix C How to Modify and Update the Database

This Microsoft Access database is easily modified and can be changed to report on other useful information. By adding new columns to the existing tables, or creating new tables for something else, the reports could contain additional fields with more calculated information. In this section, the step by step process of modifying our database to include information on plowing costs. The report will make an approximation of the plowing cost using the average driver's pay, road length, average driving speed, average gas efficiency of the truck, and the price of gasoline per gallon. The average driving speed and the average gas efficiency will be constants. The price per gallon will be a value the user enters when the report is opened. A table will be created for the drivers and their pay rates. The average of their pay rates will be calculated from the table.

First off, the table needs to be created. In the database window (Figure 40), under the 'Objects', select 'Tables', this will open the tables view where you can create a new table.

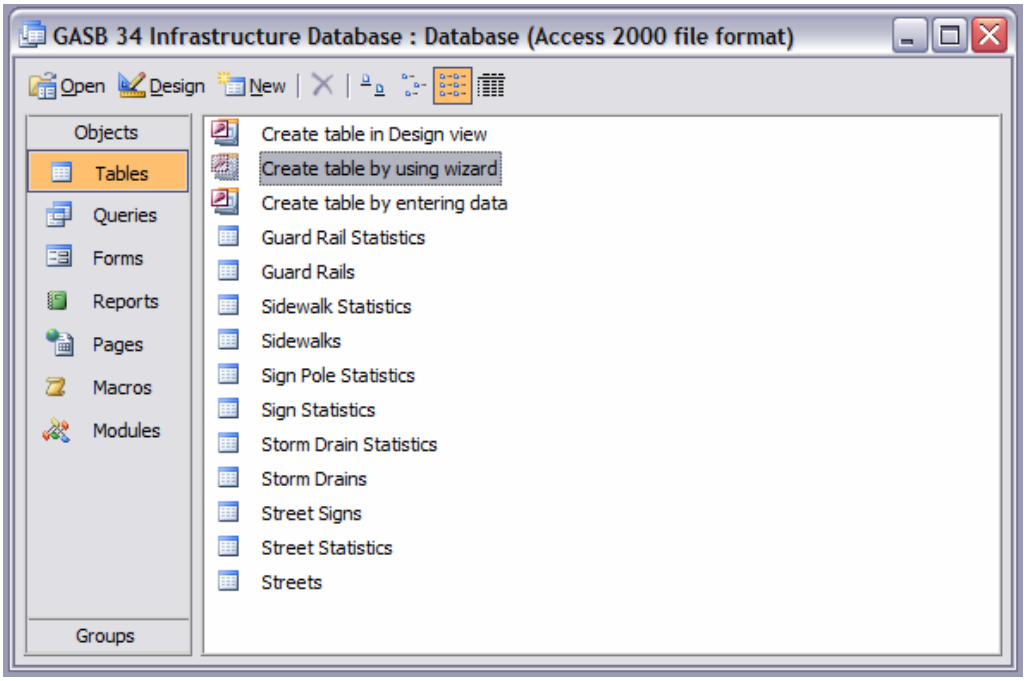

Figure 40 Table View

In this view, select the ‘Create table by using wizard’. This will bring up the table wizard as seen in Figure 41. Make sure the ‘Business’ radio button is selected, then select ‘LastName’, ’FirstName’, ’Employee’, ’Salary’ from the ‘Sample Fields:

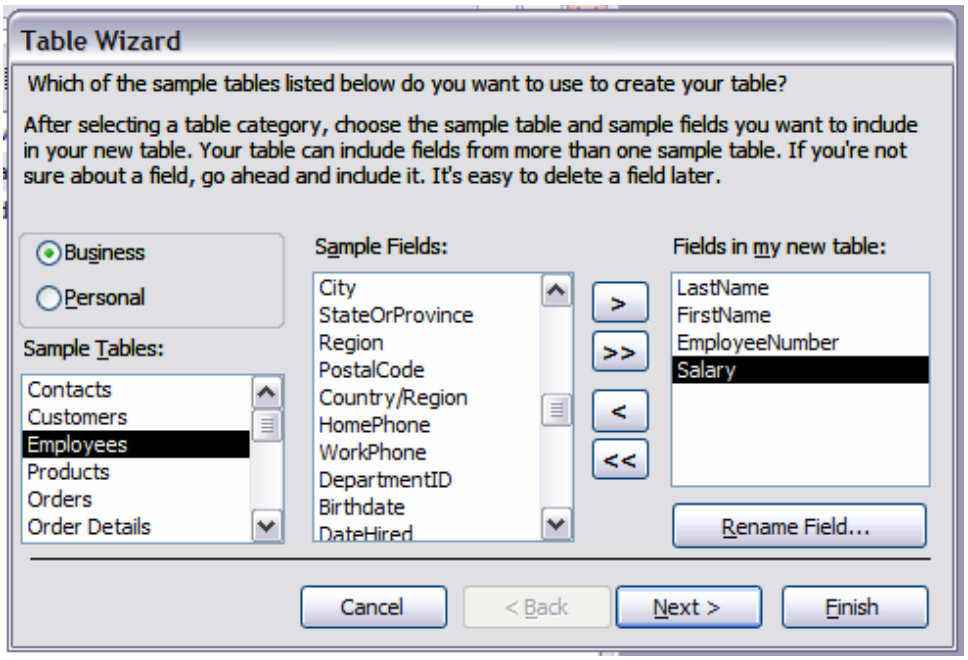

Figure 41 Table Wizard

Once all of the desired fields are selected, click the finish button. The Table Wizard will close and the new table will open. The data can be entered now, or a form can be made to help ease data entry in the future.

To make a form, ‘Forms’ needs to be selected in the database window, and the ‘Forms’ window will open on the right. In this window, select ‘Create form by using wizard’. In the wizard (Figure 41), make sure that the ‘Tables/Queries’ drop menu has ‘Tables: Employees’ selected, and select all of the available fields.

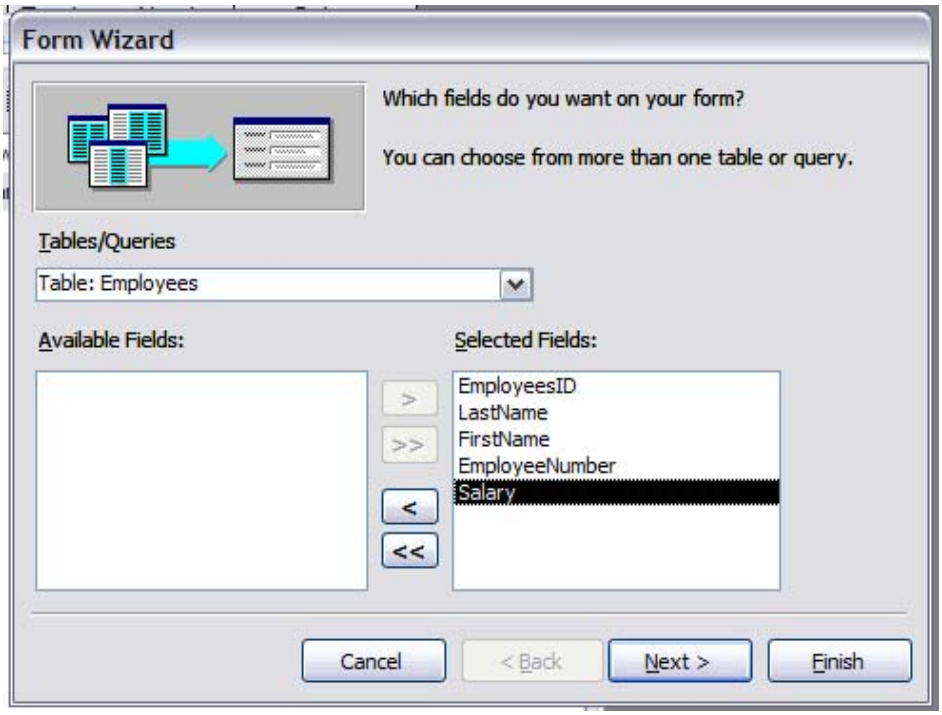

Figure 42 Form Wizard

When you click 'Finish', the wizard will close and then a new form will open (Figure 43). The data can be entered using this form and all of it will be stored in the appropriate field on the table.

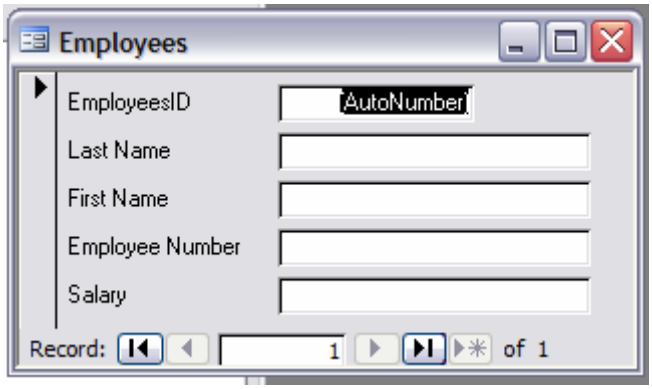

Figure 43 Employees Form

The last object that will be created is the report. Select 'Reports' under 'Objectives' in the database window, and the 'Reports' window opens to the right. In this window, select 'Create report by using wizard'. In the wizard, go into the 'Tables/Queries' drop menu and select 'Tables: Streets', and select Street Name and

Length (miles). Click 'Next' button three times. The page currently displayed allows the layout of the report to be changed. For reports with more columns, a landscape layout should be used. Click 'Next' two more times, at the top of this window will be the title of the report. This report will be named 'Estimated Plowing Cost'. Then click 'Finish', and the new report will open up. The report still needs fields to calculate the plowing costs for the roads. In the top left corner of the Access window, click on the 'Design View' button: . Right click on the report and select 'Toolbox', as shown in Figure 44.

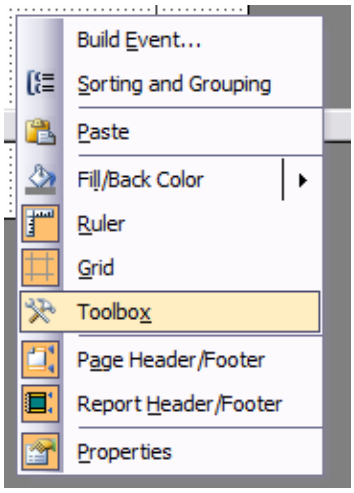

Figure 44 Report Design View, Right-click

In the Toolbox (Figure 45), select the '**ab**|' button: This is the textbox button; it allows you to place textboxes on the report. There will be 2 text boxes added to the report, one for the 'Detail' of the report, and two for the report footer. The '**ab**|**'** button will create two text boxes when you drag one out. Delete the left text box in the 'Detail' area.

Figure 45
Textbox Button

In the ‘Page Header’ area, we will add a label that says ‘Cost’. To do this, select the ‘**Aa**’ button and drag a box to right of the ‘Page Header’ area and write in ‘Cost’. Change the left text box in the ‘Report Footer’ to ‘Total Cost:’. The following figure shows what the design view should look like at this stage:

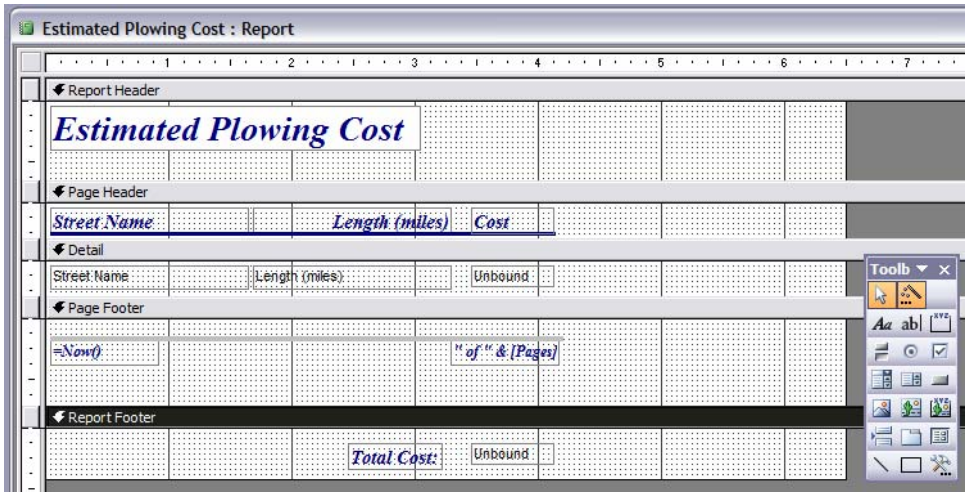

Figure 46 Report Design View

Now equations need to be entered into the remaining boxes so that their values can be calculated. In the ‘Detail’ area, right click on the box that says ‘Unbound’, and click on Properties. The window in Figure 47 will appear. Change the name of the field to ‘Cost’. Then click to the right of the ‘Control Source’ where a ‘…’ button appears. This will bring up a window where an expression can be entered. This expression will calculate the cost of plowing each road in the town.

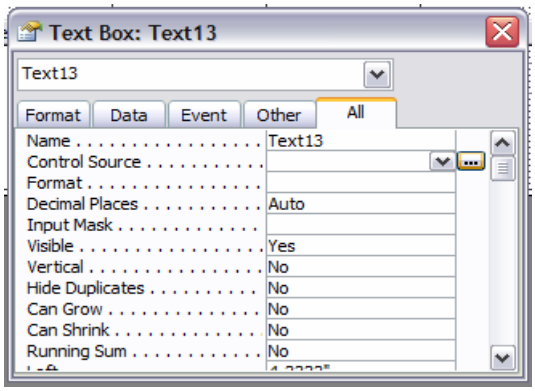

Figure 47 Properties Window

To calculate the cost of plowing each road, we used the following equation:

Cost = (Road Length / Average MPH)* Average Salary + Road Length * Cost per Gallon of fuel / Truck Fuel Efficiency

For this example, Average MPH will be 25, and Truck Fuel Efficiency will be 17. We have to calculate Average Pay Salary of the employees entered into the table. This is easily done with the Davg() function.

Cost = (Road Length / Average MPH)* Davg(Salary) + Road Length* (Cost per Gallon of fuel / Truck Fuel Efficiency)

To enter this into the expression area, you must start with an equal sign. After that, then select '<Field List>' in the middle box. This gives a list of all the fields in the right most box from the selected folder in the left most box. Double-click the 'Length(miles)' field and it will appear where the cursor is in the expression box. Type Divide by('/') 25 and multiply('*'). Then, in the left most box double click 'Functions' and click 'Built-in functions' below that. Select 'Domain Aggregate' in the middle box and double click 'DAvg' in the right most box. Then inside the DAvg() function in the text box, highlight '«expr»', then type ' "[Salary]" '. Highlight '«domain»' and type ' "Employees" '. Delete the comma and '«domain»' but leave the close parentheses. Then outside the DAvg() function, type '+', then select 'Estimated Plowing Cost' in the left most box then '<Field List>' in the middle box and double click 'Length (miles)' in the right most box. Then type multiply ('*') then [Price of gallon of fuel]. When the report is run, a prompt will ask for the price of a gallon of fuel. Next, type '/ 17'. The equation should look like this:

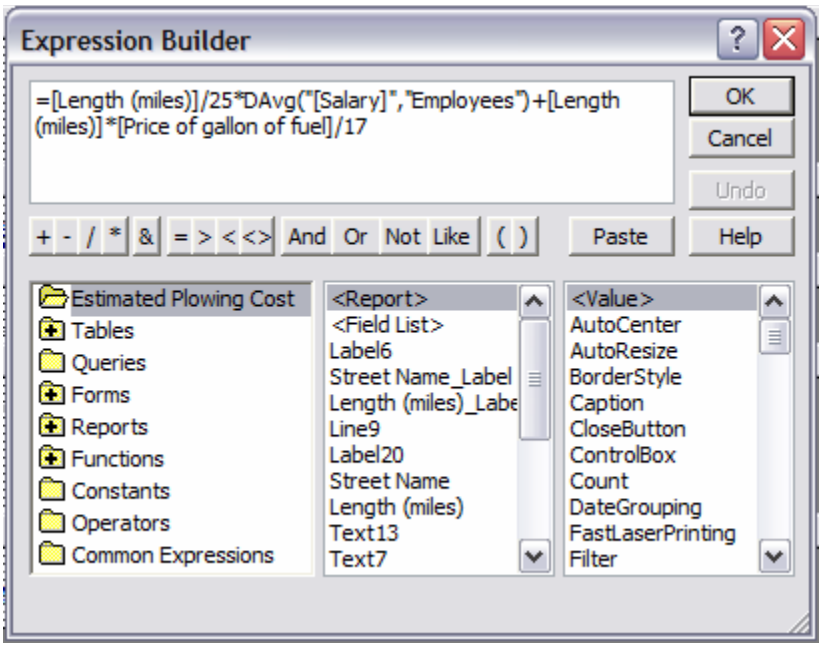

Figure 48 The Cost Formula

Now all we need is to write the total function, which is simply a sum of the separate costs. Select and copy the entire function you just wrote. Click Format on the tab strip in the properties window. Click the drop box next to "Format….." below that and select Currency as is highlighted in Figure 49.

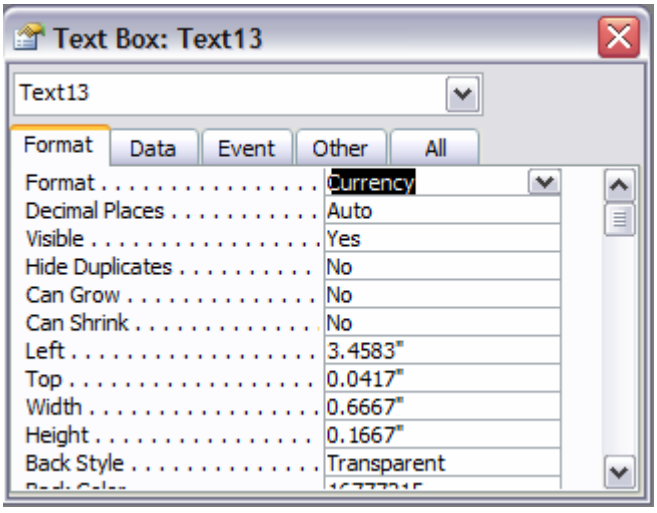

Figure 49 Format Tab

Now double click on the text box next to Total Cost in the footer of the report. Bring up the expression builder again. In the left most box double click Functions and

click Built-in Functions, in the middle box click SQL Aggregate, in the right box double click Sum. Highlight '«expr»' and paste the previous formula in. The expression should look like the one in Figure 50. Click Ok. Now click Format on the tab strip and set the format for this textbox to Currency as well. Save the changes and the report is finished and ready to run.

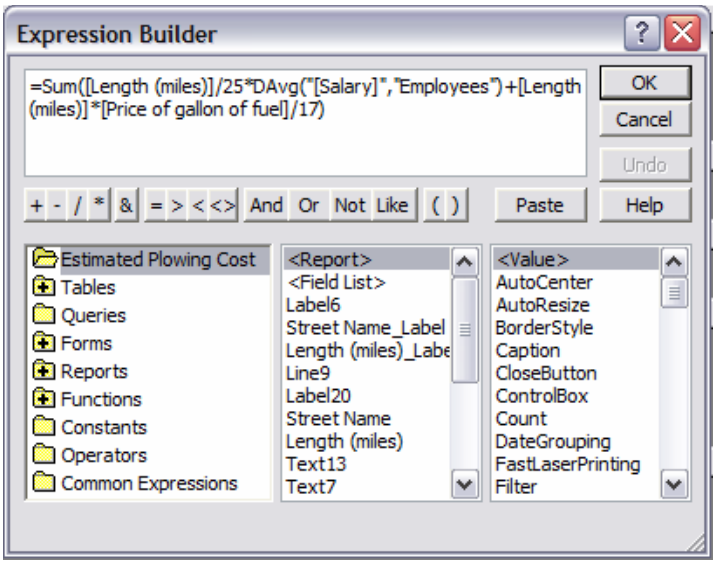

Figure 50 The Total Cost Formula

Appendix C Annotated Bibliography

- **National Transportation Library Website**, http://ntl.bts.gov/ :
  This website proved to be very useful as it contained many documents covering many areas of road maintenance, expenditures/revenues, mileage, etc. for different states and the nation itself

- **Bureau of Transportation Statistics Website**, http://www.bts.gov/ :
  This website contained pages with useful statistical data relating to transportation, including road and funding information.

- **The Town of Boxborough Website**, http://town.boxborough.ma.us/ :
  This website contained useful information pertaining to the Town of Boxborough, contact information to gain more background information, form of government and more.

- **The Massachusetts Website,** http://www.mass.gov/ :
  This website yielded useful information on budgeting, and distribution of money to local towns

- **The Moody Website,** http://www.moodys.com/ :
  This website contained information relating to bond ratings and municipal credibility

- **The GASB Organization Website**, http://www.gasb.org/ :
  Information that was needed for GASB Statement 34 was readily available one this site.