April 27, 2005

London Borough of Merton – GIS
Worcester Polytechnic Institute
Worcester, MA 01609

Adrian Hewitt (Adrian.Hewitt@merton.gov.uk)

Merton Civic Centre
London Road, Morden
Surrey, SM4 5DX
United Kingdom

Dear Adrian Hewitt,

Enclosed is our report entitled City Knowledge and Municipal Data Infrastructure. It was written at the Merton Civic Centre facilities during the period March 14 through April 27, 2005. Preliminary work was completed in Worcester, Massachusetts, prior to our arrival in London. Copies of this report are simultaneously being submitted to Professors FitzPatrick and Salazar for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you and your staff have devoted to us.

Sincerely,

Andrew Burgess
Dave Keay
Robert K. Spanos
Jorid Topi

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MSF-0506

City Knowledge and Municipal Data Infrastructure

A Report Submitted to:

Professor Malcolm FitzPatrick
Professor Guillermo Salazar

London, Project Center

By

Andrew Burgess ____________________________

Dave Keay ____________________________

Robert Spanos ____________________________

Jorid Topi ____________________________

In Cooperation With
Mr. Adrian Hewitt Principle Environmental Officer

London Borough of Merton

April 27, 2005

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the London Borough of Merton or Worcester Polytechnic Institute.

This report is the product of an educational program, and is intended to serve as partial documentation for the evaluation of academic achievement. The reader should not construe the report as a working document.

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Authorship Page

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Author: Robert Spanos
Editor: Andrew Burgess

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Author: Andrew Burgess, Dave Keay, Robert Spanos, and Jorid Topi
Editors: Andrew Burgess, Dave Keay, Robert Spanos, and Jorid Topi

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Editors: Andrew Burgess, Robert Spanos

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Author: Dave Keay
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Author: Robert Spanos
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Abstract

City Knowledge is an innovative concept upon which spatially related information can be digitally managed to facilitate effective urban planning, decision–making and analysis. The London Borough of Merton is currently exploring this concept to become the basis for their geographic information system. This project proposes a preliminary structure and a set of recommendations for the future implementation of City Knowledge. A case study is also presented to illustrate its use.

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Executive Summary

This report attempts to address the London Borough of Merton's (LBM) intentions to adopt a City Knowledge (CK) solution that will help them to more efficiently manage municipal information in the Borough. The concept of City Knowledge was developed by Dr. Fabio Carrera, a Professor at Worcester Polytechnic Institute (WPI), and is the underlying idea of this report. Examples of his success are his work completed in Venice, Italy as well as in Boston, USA while advising WPI student projects.

City Knowledge is a new approach to municipal information management. It emphasizes "farming" rather than "hunting" information, in order to efficiently collect data over time. One result of adopting this concept is the presence of large amounts of information that is available on-demand for future projects. This saves departments' valuable time and money since the information can be accessed in seconds rather than hours or days. The adoption of the CK approach can also give the municipality a better understanding of itself, which can illuminate previously unseen issues. Be they good or bad, these issues could never have been addressed without a commitment to CK (Carrera, 2004).

The implementation of the CK concept in a living and working municipality is gradual, as it takes time to merge new ideas and technology with current protocols and infrastructure. *The objective of this project is to design and lay the foundations of this process.*

This project proposes to accomplish this goal through the creation of three resources. These are:

a) The Long-term City Knowledge Plan for the London Borough of Merton
b) City Knowledge Data Standards
c) A case study of how a City Knowledge based GIS would aid in the identification of a DHP distribution route.

These first two deliverables are presented as recommendations to the Borough. The third stands as a real world example of how an implemented CK approach can benefit

actual planning projects. The research methods used during this project include academic research, technical investigation, and day-to-day informal discussion.

The Long-term City Knowledge Plan for the London Borough of Merton consists of five steps.

- Step one, *City Knowledge Awareness,* was completed by a WPI project team at LBM from January to February 2005. This step introduced CK and illustrated the benefits of implementing the CK approach using several general examples.
- Step two is the current project entitled *(*Integrating City Knowledge with Existing Municipal Information Structure).
- Step three, *Department Buy-in,* will entail working with individual departments who either are not willing or able to share their data with other departments. Once step two has been completed initially, this step should begin to occur.
- Step four, *Data Assessment and Integration,* will require working closely with different departments to analyze their current information and develop standardized data tables for each. These tables should be based on the prototypes produced in the previous step. This step will also include a report on how willing or able each department is to share data in the spirit of CK. This step is complimentary to the work already done by Merton's "Intelligence & Data" initiative in the Chief Executives Department.
- This final step, *Technical Development,* should be a technical project which produces computer interface. This interface should be created using the recommendations and results from steps two and three. Once this system is developed, it should be possible for future data, such as updates, to be put in the GIS easily.

The Data Standards consist of prototype data tables. The prototype data tables have been constructed with both the current GIS and the City Knowledge approach in mind. This process required obtaining data from several key sources including the WPI DHP group, the Merton GIS department, and in the future the Merton "data sharing" team. The tables which have been drafted are not final, but rather serve as prototypes for the projects that follow to use as reference.

The final deliverable is a case study to illustrate how a CK based GIS could aid in the identification of a DHP distribution route. The case study is based on a project completed at the same time as this one. The group's task was to produce a recommendation of possible routes for a DHP distribution system. This example is meant to serve as a proof-of-concept demo supporting the CK approach combined with GIS.

It is the recommendation of this group that the three project deliverables be used in order to plan the rest of the CK process for the LBM. Additionally, the tables produced in this project can also be used as a guide and foundation for the following group's work. The third deliverable is the demo which should be used during communication exercises in which it is important to highlight the benefits of using City Knowledge and GIS together to perform second-order analysis on data. By actually implementing a CK system the final product, as outlined in step five of the Long-term City Knowledge plan the Borough will be able to gradually garner the rewards of setting up such a rewarding system.

1. Introduction

City planning plays an integral role in the social, physical, and economic make-up and well being of any community. Information is an everyday and vital component of the city planning process. More specifically, municipalities require large amounts of spatially oriented information for planning purposes. Due to the planning process's reliance on this information, its organization, integrity, cross-departmental accessibility, and updateability are constant and important issues.

In many cases, including that of the London Borough of Merton, the current methods in place for dealing with municipal information could be improved considerably. At the present time, information needed for a planning or development project is retrieved on an ad-hoc basis. When a particular department needs a certain piece of information, it must be directly obtained in the field, or must be searched for in a municipal archive. In many cases these archives are stored in a GIS and although they are in digital format, they often do not utilize database and GIS technologies to their full potential. Dr. Carrera refers to this system for information organization and retrieval as the "Hunter-Gatherer Approach." This method of information retrieval is time and labor intensive, and as such, is costly to the borough (Carrera, 2004).

The vehicle for improving this system is the City Knowledge (CK) concept, as developed by Dr. Carrera (Carrera, 2004). The implementation of CK has just begun at Merton, but its initial use in places such as Venice and Boston is very encouraging. The CK concept lays the framework for a new information organization approach in which data is considered vital municipal infrastructure, equivalent to roads or buildings. The CK approach includes the idea that all information that is gathered by any department should be stored in a specific and uniform format. The idea of accumulating municipal information in this way is referred to as the "farming approach" (Carrera, 2004). This well organized data should then be placed in a GIS and made available to other departments. Each department should retain control over the data they are responsible for. Information in the City Knowledge GIS is then available for use in planning other city projects.

In January and February of this year, another project concerning CK was conducted at Merton by a WPI team. Their objective was to present the potential benefits of the implantation of the CK in Merton. As a result of their work, the LBM has decided to further pursue the implementation of CK in Merton.

The group completing the current project has thus been asked to develop a series of recommendations for the London Borough of Merton. The LBM GIS group worked with another WPI team in Merton. This team, further referenced as the "DHP group", worked to find a route from a potential site for a combined heat and power plant to a location that needs power. In completing their project, they needed to gather data about the area they were analyzing in order to decide what would be the best path for DHP distribution system. This group gathered data using the "hunter-gatherer" approach. The GIS group developed a case study based on the data retrieval experience of the DHP group. This case study serves as a real world example to show how the full implementation of the CK approach can benefit municipal planning projects.

The Merton GIS group also developed a series of Data Standards. These serve as the foundation for the full implantation of CK in Merton. This group also developed a long-term strategy for full CK implementation, outlining what needs to be accomplished in the future for LBM to achieve this goal.

2. Background

2.1 Introduction

The objective of this chapter is to present the information that is required to understand the situation and context in which the London Borough of Merton GIS project was completed. This chapter covers information about City Knowledge, GIS, and the London Borough of Merton. Appendix D also contains background, which is relevant to the Merton DHP project, which is used as a case study in this report. This appendix covers information about environmental issues, and sustainable energy.

2.2 City Knowledge

The planning of any city project has a strong reliance on spatial data. Traditionally, this data is gathered with an ad-hoc system; if a piece of data is needed, someone has to go into the field to find it. Even though this data can potentially be reused, it is not necessarily stored in an easily accessible format. If the same data is needed for another project a year later, someone will once again have to go into the field, or spend time tracking down the information (This is known as a "plan-demanded" system). The City Knowledge concept, as developed by Dr. Carrera, revolves around the fact that data, once collected, can and should be reused for any number of future projects (Carrera, 2004). Information that is readily available when needed is known as plan-ready information. A strong database of plan-ready information is the goal of a City Knowledge system (Carrera, 2004).

Dr. Carrera distills City Knowledge down to six foundations: (1) the "middle out" approach; (2) informational jurisdictions; (3) fine-grained, distributed data management; (4) sustainable updates; (5) information sharing and (6) interagency coordination.

The *middle-out approach* to data management is, intuitively, a combination of the bottom up and top down approaches. Similarly to the bottom up approach, each individual, front-line department in a municipality will still gather their own data and develop an information system for storing and updating it continually. Along with individual departments gathering their data, an overarching system must also be developed to coordinate and combine their data. One inherent flaw in the bottom up approach is that the lack of coordination between different groups. This will unquestionably lead to data redundancy and a lack of departmental interoperability. This is where the elements of a top down approach to management come into play. While each individual department (which deals with city data in the Merton City Council) will develop their own systems for data management, larger departments will work to make sure data is compatible and does not contain redundancies. An objective of large departments is to make sure that data in their sub-departments is interoperable, since ideally data can and should be shared among departments. While this application of a top down approach will prevent the traditional "bottom-up" problems, the specifics of data management will not be so regulated and stringent so as to discourage individual departments from actually adopting this system.

Another key element of City Knowledge that is closely tied to the middle out approach, and specifically its similarities to a bottom up approach, is *information jurisdictions*. Every piece of municipal information to be gathered needs to be assigned a group to gather it. Ideally, it will be possible to choose one group to gather the data that will clearly be the main beneficiary of that data being collected. There will certainly be cases where both groups require the data, but it would still not be ideal for the data to be collected by both groups. In these cases, the cross departmental sharing of data in a City Knowledge system will show its value, as the group which does get assigned to the data will be able to share it with any other group that needs it. In the case that there is data that no group needs at the time, then a group must be assigned to gather it. Once some group actually needs to use the data, then any future updates to that data will be completed by them. These concepts of information jurisdiction are tied heavily to the concept of *fine-grained* distributed data management. The management of specific data is handled on a very small-scale basis, down to the smallest departments in a city, instead of by any centralized effort (Carrera, 2004). Changes to the individual data sets, such as those with regards to the creation and termination of different data objects i.e. roads, electricity lines, etc. are left to individual departments while the upper management is only concerned with the data being interoperable by following the six-step process outlined above.

Once jurisdiction of some data is given to a certain department, and they have dealt with the problem of setting up the initial data storage methods, *updates* to the data set must be addressed. Each group must find ways to receive and integrate updated data when it is gathered. A City Knowledge system needs to take advantage of ways to obtain this data more efficiently without a great deal of extra work. Instead of sending out a specialized team to gather data, finding ways to obtain the data by assigning additional responsibilities to jobs, which already exist, is far more efficient. For example, if the department in charge of grooming trees in a city is put in charge of maintaining tree height data, they could combine the two tasks. The tree maintainers could simply gather the tree height data, etc. while they care for the trees. As long as the department has defined a reasonable form for the incoming data, then it will be simple to assimilate it into their existing system.

The last main foundation of City Knowledge is tied to *information sharing and interagency coordination*. Before a plan demanding data system can truly be established, data between individual departments of an organization must be shared. While this is certainly a process that cannot happen overnight, it is something which could evolve over time. Dr. Carrera suggests that by getting planners and decision makers interested in the City Knowledge idea, their influence could cause the idea to be used on a small scale. Once the benefits of this are seen, the CK system will grow, as will its utility. At this point, the only step left between data as it is now, and data being a true municipal infrastructure will be interagency coordination.

2.3 Geographic Information Systems (GIS)

2.3.1 What is GIS?

Geographic Information Systems (GIS) is a computer system created with the purpose of "capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface" (www.dictionary.com search: geographic information system). In total, a GIS is a compilation of computer hardware, software, data, and trained individuals who all work together in order to create and maintain such a complex system. Simply, a GIS contains layers of information regarding geographic or spatial locations with the end result being that people can easily analyze the data and make decisions based on GIS. The end result of a properly developed GIS is the great possibility that many different individuals (such as managers) will be able to analyze a specific location using the data related to their field of expertise (separated into layers)*, which* can aid them to make a decision regarding a location while also integrating multiple layers.

For example, if the location of a new fast food restaurant was in question, one could use a GIS to solve the problem. By populating a GIS with different layers of information such as environmental damage, crime in a particular area, amount of people that pass through the area, cost of land, density of the population, average income, etc. every day the best location to place the restaurant might be more easily obtained. The London Borough of Merton has decided that a GIS will be useful in the construction of a new district energy system for the Borough because their current information system is incomplete. After collecting specific data regarding buildings, the type of soil, current and future energy usage, population density of specific areas, existing infrastructure, etc. one can make more informed decisions regarding the design of the information system to be installed.

This can eventually lead to the Borough saving money by effectively planning the district energy system and not having to incur expenses years down the line *because of a poorly designed system which was created based on incomplete speculations and unorganized information currently stored in different formats.*

The software being used by the Borough is MapInfo (obtained through MapInfo Corporation). MapInfo is not the only GIS software available; however, the Borough already has an existing MapInfo database which can read both raster and vector based data and as such this group used this software. To date, the Borough has information regarding different parts of the Borough such as electricity, water, roads, etc. MapInfo allows the user to perform, "sophisticated and detailed data analysis to increase revenue, lower costs, boost efficiency and improve service with location-based intelligence. (www.mapinfo.com)" The advantages of a GIS are many because instead of using a traditionally paper map which only allows an individual to find the coordinates or location of a specific point a GIS stores layers of information regarding geographical coordinates on the map. This means that after zooming into a particular building, one could find electricity usage, piping layout, crime rate, etc that would all be organized and segregated into different layers stored in a database. The result is that people can easily analyze data as they see fit in order to make informed decisions. The mere fact that the information is digitally stored in a database which can be accessed via anywhere in the world means that expertise can be pooled from all over the world in order to solve a problem. MapInfo seems to be well regarded and a widely used software around the world aiding in the creation GIS. If used in conjunction with a web interface the information presented by MapInfo can be displayed via a web-browser at any location in the world, offering the user with a very powerful tool with which to conduct business which has been completed by Dr. Carrera in Venice, Italy.

A Geographic Information System is effectively organized by layers of data. A layer is a division of data that corresponds to a theme such as property boundaries, electrical lines, railways, etc. Each layer is related to another by an accurate and common coordinate system. Individual layers, along with the coordinate data associated with the objects in them, contain tables of data as well. The organization of a table is a grid; each row corresponds to an object in the database, and each column represents one property of that type of object. Each object (row) in a table has a unique identifier associated with it, which allows objects in one table to reference objects in another. In a GIS, objects in tables also have spatial data associated with them so that they can be placed on a map. A layer is the combination of a table as well as the spatial information associated with the objects in it. When a layer is loaded in MapInfo, geographical objects can be clicked on to display the information in the table associated with that object. There is an example of a table in Appendix B.

2.3.2 GIS in Urban Development Projects & Benefits

The use of a GIS can help in the decision-making process regarding issues of public policy. This is true because the GIS can help display an effective allocation of resources for community and economic development. Additionally, this can in turn help create a more well-managed and efficient delivery of public services via the usage of a GIS. A GIS can also "provide a common framework—location—for information from a variety of sources" (GIS for Housing and Urban Development pg 23-24). It is specifically for this reason that the Borough of Merton has chosen to use a GIS in order to help them make decisions which affect the Borough as a whole. A GIS is also helpful in situations such as this one where being as economically efficient as possible is really to the advantage of the people living in this borough. Because this undertaking by the Borough will pool together different types of expertise, it is crucial for a GIS to be put into place. This type of system can not only help each individual (who could have access to the GIS) see how their portion of the project relates to the whole picture, but also aid management in looking at the problem from all angles. For example, an engineer might speculate as to the effects of laying down piping 10 feet below the ground. Without a GIS, it might be assumed that there are no current pipes running in the area. However, a GIS simplifies the process if populated with the specific data could tell the engineer the type of soil below the ground, if any current piping was running in the area and if there were any obstructions to laying piping down. All of this helps each individual complete his or her job with greater ease.

The GIS can also help keep everyone on the same page and allow for better information and knowledge flow between all of the individuals who are trying to solve this problem for the district.

Another key reason for using GIS is its ability to be used in the future. As more and more data is collected there needs to be a system capable of holding the data and analyzing it. The GIS being used at LBM is capable of holding new data, which could help in the creation of newer district energy solutions later on, as more data is collected for the Borough. The idea that the data is centralized (not necessarily in *one physical* database) in a database and accessible very easily from anywhere in the world makes this sort of system quite practical and appealing for a problem of this particular nature. This makes the task of updating data easy since each individual department can update it. The reliability and validity of the data will be controlled by each department as well. The Borough has already started to implement a GIS and part of the task will be to further develop this system.

2.3.3 Final Remarks Regarding GIS

City Knowledge (in conjunction with GIS) were two of the central efforts of this project specifically dealing with MapInfo in order to better aid the Borough of Merton in planning their district energy system that they will be developing. For this reason, it was essential that this group understand and exploit the strengths of GIS and City Knowledge in order to assist the Borough in this ongoing project. A web-based system is the final step in such a long-term project, which allows for easy borough-wide access to the system (see Step 5 CK GIS Development Results Chapter) so that all the necessary individuals can access and make important decisions about the future of the Borough with respect to the new district energy system or other projects.

2.4 Borough of Merton

2.4.1 People

The Borough of Merton is a thriving and culturally diverse area in south London. The population of Merton is approximately 190,000, which is expected to increase to 209,000 by the year 2016. At 74%, the majority of residents in Merton are between the ages of 16 and 74, while 19% are below 16, and 6% are older than 74 years of age (Merton Council).

2.4.2 Geography

The Borough of Merton is composed of five major areas: Wimbledon, Mitcham, Morden, Colliers Wood, and Raynes Park. The Borough covers a total area of 37.61 square kilometers (Merton Council), which is located in the southwest corner of London (see Figure 1).

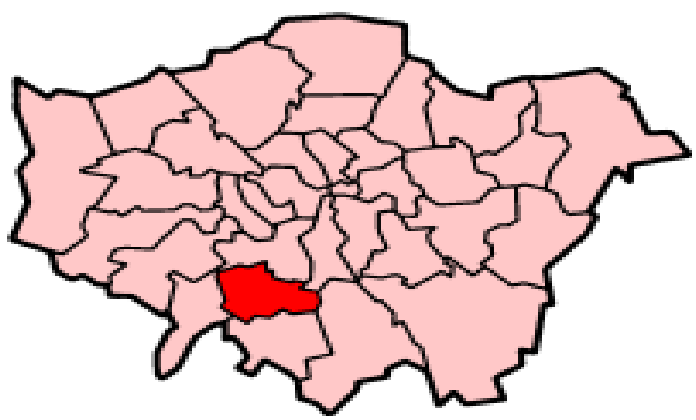

Figure 1: Location of Merton in relation to other London boroughs

2.4.3 Environment and Energy

The Merton Council has several programs and initiatives that are directly related to taking care of the environment and keeping their borough clean. The Council has strict laws governing things such as dog waste, municipal tree pruning, and litter which can all be placed in the GIS. They have two objectives they hope to achieve with regards to the environment: to provide residents with the best living conditions possible and, at the same time to meet all requirements, restrictions, and laws placed on them by other organizations. A well-constructed GIS, which follows a City Knowledge approach, can help improve the management of these physical environments.

The Merton Council understands that the reduction of greenhouse gases and conservation of fossil fuels is vital to not only to meet new environmental regulations, but also to improve the quality of living in their borough. Merton has already begun investigating ways to reduce greenhouse gas emissions and fossil fuel consumption. Additionally, it should be noted that Merton is well known for PE13 regulation, which states that any building must provide 10% of its power via sustainable energy.

2.4.4 Previous Work

In the spring of 2003, the Borough of Merton hosted a WPI project group charged with investigating the feasibility of a retrofitting geothermal power system as a way of providing clean sustainable power for municipal buildings. The Borough of Woking's implementation of a sustainable power system was of particular interest to this group. The system that Woking implemented provided cleaner and more cost effective energy than the energy supplied by the national power grid (Ford, Contrino, Trexler, & Wing, 2004). This group was able to arrive at a series of conclusions by being armed with this new approach and the knowledge provided by the implementation of such systems elsewhere. One of these conclusions was that in the future, a comprehensive City Knowledge system would be vital to the power system planning process (Ford, 2004).

The group focused heavily on cost analysis and the economic perspective of the project. They concluded that a retrofitting geothermal system was not a viable option for the borough. They determined that costs associated with such a system's development and implementation outweighed the financial benefits it would provide (Aery, Butler, Giang, & Smith, 2003).

The Borough of Merton continued its investigation into the energy system issue in the summer of 2004. Once again, the Council engaged a project group from WPI. This time, they were asked to determine the feasibility of a sustainable energy system and in the fall of 2004, Mr. Hewitt published his proposal regarding Sustainable Energy and District Power. This contrasted from the previous project group's work since this feasibility study was not to be restricted by a presupposed energy generation method, such as geothermal.

In November 2004, Adrian Hewitt, the London Borough of Merton Principle Environmental Officer, published a report entitled, "Sustainable Energy District Heat and Power (DHP) scheme" for the Merton Council Strategy Board. In this document, Mr. Hewitt summarized the major issues on this topic, and how the Borough should move forward (Hewitt, 2004).

3. Research Methods

3.1 Introduction

The main ways this group me the objectives for this project included using data previously collected by groups (WPI City Knowledge group) stationed at the London Borough of Merton between January – February 2005). The WPI City Knowledge group started the City Knowledge initiative in the LBM and made the counselors aware of the benefits this concept. The additional data was in the form of archival research, case studies, interviews with individuals and organizations, and pooling data from local experts. Other relevant work includes serving as a liaison between past and current IQP groups who have completed relevant work not only with the LBM but projects completed in Venice, Italy and Boston, USA under the guidance of Dr. Fabio Carrera. With the integration of all of these sources, it was hoped that this project attained the objectives laid out that serve as a guide to help the problem Adrian Hewitt has been confronted with which is: adopting a City Knowledge approach for the Borough. The primary output upon completing this project is a list of recommendations (Data Standards in table format), which can help Merton officials to plan and mold their current GIS in the form of a City Knowledge GIS. This will in turn help to deliver services more effectively and improve the hunter-gatherer data collection process. This group will also use the WPI DHP group (also working at LBM) to exemplify how determining a route for a CHP scheme could be easily completed with a City Knowledge GIS. The research questions to be discussed in this chapter are:

- What does the London Borough of Merton plan to achieve through the City Knowledge approach?
- How can a City Knowledge based GIS be used in order to analyze an appropriate route for the CHP distribution system?

3.2 Roadmap

By conducting research this group was able to better understand the status of other municipalities with respect to implementing a GIS for a DHP solution. This is exemplified with the Borough of Woking, which has undergone similar efforts. In the following sections of this chapter, the two research questions stated above will be discussed in more detail with respect to the research methods this group used in London. In should be noted, that this group worked in tandem with the LBM DHP group who was stationed in London at the same time in order to ensure that these two projects are mutually supporting. This will be necessary for the system to-be, which will be the product of the efforts of teams working in Merton (C05) (January-February 2005) and D05 (March-April 2005). Research conducted in London consisted of interviews, archival research, reading and learning about City Knowledge, as well as other techniques listed in sections below.

Information was provided to this group by a variety of individuals who work or volunteer for the borough. This information was collected over time, as different areas of the Borough need to be attended to, such as parks and other facilities. Each department is also responsible for maintaining, as well as collecting information that is needed by the city and as such, this group will implore the middle-out methodology as described above by generating a set of guidelines and recommendations for data collection. This can be achieved by inserting specific clauses in a contract between the city and external agency. This data can be used in the City Knowledge model by any city department which finds a need for the collected information. As time passes, the amount of data available between departments will increase and form a more comprehensive network to share throughout the borough.

3.3 Research Question #1

What are the LBM's objectives by using City Knowledge within the Borough?

This overarching and broad question may appear too open ended at first glance, but after close inspection its importance becomes clear. Since this group required a complete understanding of what City Knowledge was capable of, this research question must be asked and thoroughly answered before any recommendations ware developed. For that matter, there are several specific and critical questions that must be answered in order to develop a clear understanding of the project's goals.

The specifics however, are the crux of this research question. Exactly what information does the Merton City Council hope to garner from the City Knowledge concept? In what form do they wish to get this information? Will they be using the data acquired for future projects that do not necessarily involve energy usage and delivery systems? These questions and many more were answered during the course of the two-month stay in London.

The next logical and necessary step in finding substantive answers to this research question was determining how to find the vital information. One excellent source was the project liaison, the LBM Principle Environmental Officer Adrian Hewitt as well as City Knowledge author Dr. Fabio Carrera. Since Mr. Hewitt is the officer in charge of Merton's entire power project, he was an invaluable resource in determining how to use City Knowledge to gather the data that is necessary for the DHP project. Thus it was necessary to interview Mr. Hewitt and work closely with him while at LBM. His responses were then be analyzed and used as one source for answering the major research question.

Another valuable source was Dr. Carrera who founded the City Knowledge approach in his MIT dissertation. It was necessary for this group to read his City Knowledge dissertation and grasp the concept as well as analyze the variety of examples that were mentioned. Throughout the dissertation this group found examples that were applicable to this project. Since Dr. Carrera is a professor at WPI, this group was extremely fortunate to be able to communicate with him directly

Communication with current LBM GIS Officers Gary Shaw and Mick Byrd was also a key part of this project. Their interaction with MapInfo and LBM's current GIS is direct and hands-on, as they are professionals with experience in the field of GIS. They helped guide this group through the data that LBM already possesses and with the LBM's current GIS. By analyzing what information is available, this group was able to determine what additional data the Borough should incorporate into their GIS and how that data can affect their current system. Consequently Mr. Shaw's and Mr. Byrd's input was very beneficial to the purpose of this project.

The objectives of these interviews were to determine exactly what the LBM desired and required in their GIS, and to allow this group to make recommendations concerning its future design for the purpose of the DHP project. Through the interviews with Mr. Hewitt, Mr. Shaw and Mr. Byrd this group was able to determine what the Borough's vision for this system is and how it should operate. This group took the information gathered from these two interviews and Dr. Carrera's dissertation to create a list of recommendations and guidelines (first generation of the data structure) for LBM to gather data in accordance to the City Knowledge approach.

3.4 Research Question #2

How can a City Knowledge based GIS be used in order to analyze an appropriate route for the CHP distribution system?

A City Knowledge based GIS can be a timesaving and economically efficient system for planning an effective route for implementing the CHP system. The process of implementation was significantly simplified by analyzing the appropriate data in GIS. The possession of a fully equipped GIS was a key element for the DHP group as well as other urban projects that will come up in the future. Using the City

Knowledge approach was a necessity for the coming about of a useful GIS, which will make the planning process easier for the reasons that are explained below.

A GIS can help the planning of a good route if the required information already exists in the system and not in some map or archive where they are useless. For example, there are electrical lines that are buried in LBM and having their locations in GIS would be a key for the design of this route. Accidentally running into an electrical line while implementing the CHP would be a major burden. It would cost time and money to fix as well as create legal issues for the borough. It may also create health hazards and may be an inconvenience to the public.

A map of the underground electrical network may be obtained for a vital plan like this. However, it would be more useful to have other information to come with it such as their depth at certain points, their exact coordinates and distance relation to other objects on the map. This data would be helpful to come up with shorter and less expensive routes.

Another important example is data for traffic. The DHP route needed to be implemented in areas and times where traffic will not be a major problem. If this data existed in a GIS, it would be easy to plan around this issue. A clash with traffic would be a major inconvenience with the public and create a bad feeling towards the borough's government. It is to the Borough's advantage to come up with an implementation plan that will not cause major issues with the public for many legal issues.

The electrical lines and traffic examples are just a few, whereas the real CHP project encompasses multiple issues to consider such as sewage, railways, roads, traffic, noise, ecological sensitive areas, etc. Without a well-designed GIS in place, one would have to go through all the individual maps and data which are not in usable formats, one by one. Planning a good route in this manner may turn out to be a time consuming process. GIS software can take all these 'layers' and put them together in one map. A GIS also allows one to access information about an object or an area at a certain point of the map. This makes the planning process more convenient, time saving, and economically efficient.

4. Case Study: The DHP Example

4.1 A Simple Database Example

Before the details of the data standards can be explained, the overall structure of our database needs to be described. The database is a collection of tables (as described in the background chapter). Each table will correspond to one type of physical object that will be displayed in MapInfo (such as sewer lines, water lines, and buildings). Each of these tables will be a list of attributes of the object that that table is associated with, including a unique identifier for each object. No two objects in the same table can have the same ID. This ID should not be generated manually, but instead assigned by the database software that stores the tables. This guarantees that each ID is unique.

The unique ID requires some specific explanation, as it is a concept heavily tied to database theory and analysis. The example given next is intentionally unrelated to municipal information. It is given to help explain the basic idea behind databases in general.

The following is an example of a table that could be used to store some information about students.

studentID	Fname	Lname	Major
1	David	Keay	CS
2	Andy	Burgess	ME
3	Robert	Spanos	MIS
4	Jorid	Topi	EE

Table 1: Student Data Example

In this table, each row corresponds to one object, in this case, a person. The *studentID* column is a number which is unique to this table; no two people can have the same *studentID*. Because this attribute is unique to each person, other tables which need to reference students can just reference the *studentID*.

professorID	Fname	Lname	Department
1	Malcolm	FitzPatrick	Civil Engineering
2	Guillermo	Salazar	Civil Engineering

3	John	Sanbonmatsu	Philosophy

Table 2: Professor Example Table

In this table, just as in the student table, professors have a unique identifier, *professorID*. While the actual number of a *professorID* can be the same as a number in a *studentID*, no two professors can have the same ID.

Using these unique identifiers, a table which combines information about professors and students can be created. The following is an example of a table describing which professors advise which students on projects.

professorID	studentID	Project	Term
1	3	IQP	D05
1	4	IQP	D05
2	1	IQP	D05
2	2	IQP	D05

Table 3: Advising Example Table

In this table, the numbers in the *professorID* column will only be values that are in the *professorID* column of the professors' table. The numbers in the *studentID* column will only be values which are in the *studentID* column of the students table. Based on the information in these three tables, the students Robert Spanos (*studentID* 3) and Jorid Topi (*studentID* 4) are advised by Malcolm FitzPatrick (*professorID* 1), while David Keay (*studentID* 1) and Andy Burgess (*studentID* 2) are advised by Guillermo Salazar (*professorID* 2). John Sanbonmatsu (*professorID* 3) does not advise any of the students in this example.

This method of relating objects by creating tables which associate multiple identifiers should only be used when there is a concrete relationship between objects (when they are related in some way other than just geographically). Another example of this type of relationship is that between sewer lines and manholes. Because this example is focusing on the identifiers and how data is related, the tables used will only contain some of the fields in these tables. The full tables are described in appendix C.

sewerID	Type	Content	Direction	Start_Depth	End_Depth	Diameter
1	public	surface	North	1	1	
2	public	overflow	North	1	1	
3	private	surface	East	1	2	

Table 4: Sewer Line Data

Table 4 is a table designed to encapsulate information about segments of sewer lines.

manholeID	type
1	Combined
2	surface

Table 5: Manhole data

Table 5 is designed to store information about manholes.

The relationship between sewer lines and manholes is rather simple. One sewer line may be accessible by many manholes, and one manhole may allow access to multiple sewer lines. Because of this, data relating sewer lines to manholes can be stored in a table which simply contains the ID's of the two items.

sewerID	manholeID
1	1
2	1
3	2

Table 6: Sewer and Manhole Associations

By table 6, it can be seen that the manhole with ID one allows access to the sewers with ID's one and two, and the manhole with ID two allows access to sewer three.

Associations in tables such as these are only appropriate to use when the objects have a concrete relationship other than just geographical. If the objects are related only by their locations, then a different method of data association must be used. This is explained in the next chapter.

4.2 Spatial Relationships and GIS

MapInfo, the GIS software used by the LBM, stores geographical coordinates of each object in its database. An object in MapInfo can be a point, a line, or a geographical area. The data stored about each, respectively, is a point, two points, or a shape.

MapInfo allows data to be analyzed based on this geographical data. For example, if data about how land plots are defined is stored in one table, and data about tree locations is stored in another area, then this geographical data could be used to count how many trees are on each property. Cases such as this, where data in more than one table is combined to form an analysis of that data, are called queries. MapInfo also has the ability to color a map based on queries. The following is an example of this.

Figure 2: A Map of Trees and Topographical Areas in MapInfo

This image is a map taken from a MapInfo layer which is a map of Merton. Each part of the image which is enclosed in lines is a geographical area, and each star is a tree. Using a query in MapInfo, the following image was generated.

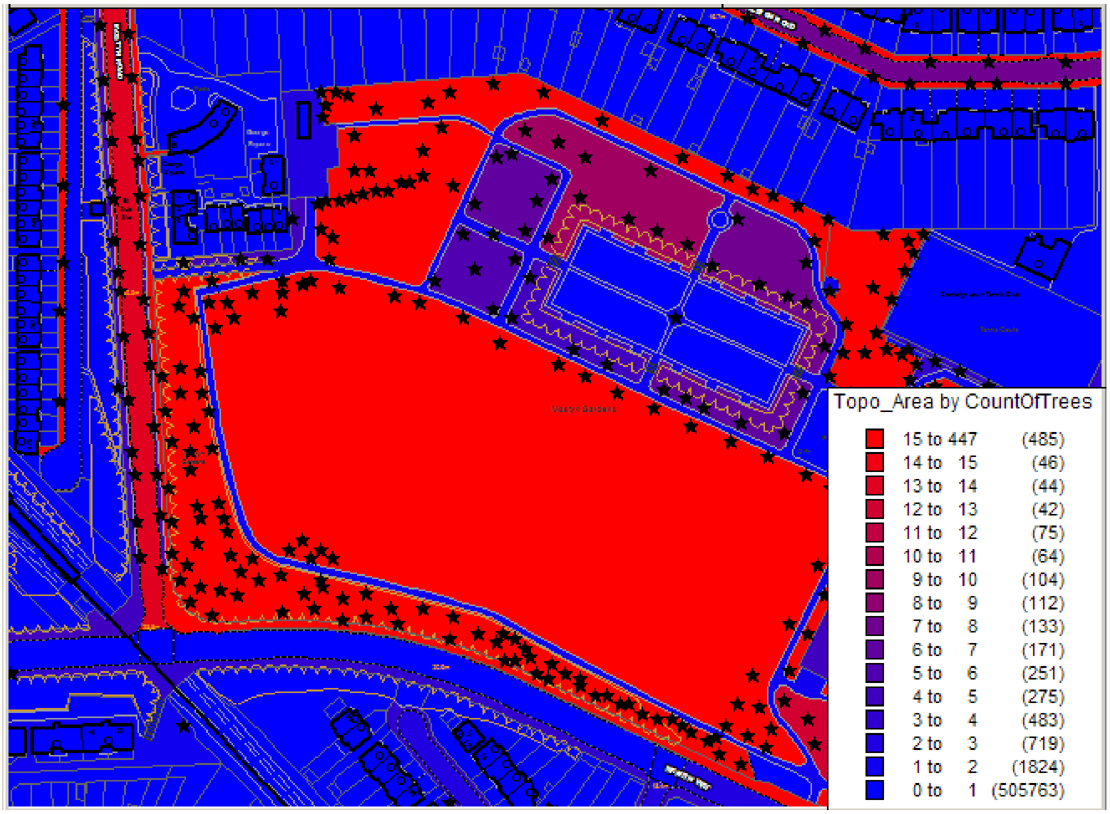

Figure 3: A Map of Topographical Areas Colored by Tree Volume

The legend describes the coloring of the map. Areas with no trees are colored blue. Areas with more trees have more red in them, so the coloring transitions from blue to purple to red as the volume of trees in an area increases. MapInfo, using just the geographical coordinates associated with the areas and trees, is able to generate a colored map based on how they relate.

This ability of MapInfo, to relate objects based on their geographical location, is what makes the power of City Knowledge so promising. Instead of only being able to analyze data on a map intuitively, by looking at the map, MapInfo can be used actually analyze vast amounts of data and generate reports on it. For example, while it might be quite difficult to find all the private properties that have public gas lines running under them by just looking at the associated maps, it would be simple to generate a map of this in MapInfo.

Data Updates and Ownership

Keeping information up to date is a vital part of an efficient and accurate CK system. CK dictates that information is kept up to date by the department responsible for it, through the use of informational jurisdictions as mentioned in the background chapter. Each piece of data in the database should be attached to a specific department in the municipality. For example, the property ownership table should be attached to the Estates Department. This relationship of department to data has two major consequences. The first consequence is that the department will be in control of their data, meaning that they will be in charge of allowing other departments or the public to view their data. This is known as Data Ownership. In the case of property ownership data, the Estates department decides who is allowed to use their data. The second consequence of this connection of department to data is that the department is responsible for the upkeep of their data. This means keeping the data that they are responsible for as up to date as reasonably possible. Again, in the case of property ownership data, the Estates department is responsible for making sure that the information that they store and share is as recent as possible.

The determination of which department should responsible for and in charge of each piece of data is one of the tasks that must be completed in the next step of CK implementation.

4.3 City Knowledge GIS vs. non-City Knowledge GIS

The previous example, which related land shapes and the location of trees, can also be used to show the difference between a GIS which was developed using a City Knowledge approach and one which was not. The data about land areas used in the above example is from a layer in the current LBM GIS named Topo_Area. This layer contains data gathered by the ordinance survey, and defines any shape (with the exception of trees) that is seen on the map in figure 1, including buildings, roads, fields, etc. The only data which is stored for each of these objects is its type (road, building, rail, etc), the date that the object was added to the map, and the location of the object. Because this is all the data that is in the GIS related to these objects, any further analysis requires accessing data outside the GIS. This can be quite time consuming, as data that is not stored this way is not easily accessible.

The following is an example of analysis which would be difficult to complete with the current layers, but rather simple in a City Knowledge based GIS. If, for example, a certain variety of tree were particularly vulnerable to a disease and required special care to keep the tree in good condition, it would be advantageous for the LBM to be able to find out all the properties which contained that tree. The LBM could then contact the owners of that property to be sure that they were properly maintaining the trees. With the current Topo_Area layer, it is possible to find out which land plots contain a certain tree, but not who owns those plots. Finding this out would require working with paper maps in the estates department, whose data might not even contain information about the plots in question.

In stark contrast to the current inefficiency, if the layers in the GIS were developed using a City Knowledge approach, then the land plot objects would contain data related to their owners. This data would be generated and submitted to the LBM through a number of channels. The first is a mass transfer of the current data held by the estates department. Any data that they have must be transferred to the new system. While this will be a time consuming first step, it will provide a strong foundation of data. Another way that data would be added to the database about property ownership could be through new regulations. When land is sold in the LBM, the council could require that the change in ownership be entered in a form on the Internet. This form could then update the GIS database. With this data contained in the GIS, a query to find out the contact information of all the property owners who would need to make special accommodations for certain trees would be simple to execute.

This is just one example, which is closely tied to the example above relating objects based on their geographical data. While the example in chapter 4.2 did show the power of GIS in this respect, this example also shows the weakness of a GIS which is not developed with City Knowledge in mind. The next chapter will more specifically contrast the current methods of data storage and access in the LBM with a City Knowledge based system.

4.4 A Data Management Example: DHP Distribution Route Analysis

The third product of this report is a case study which clearly illustrates the benefits of a City Knowledge based GIS in the planning phase of a real project in the London Borough of Merton. Completed alongside this project, a team of students from WPI (the "DHP team") completed a different project which found a route to run district heat and power distribution lines from one site to another in Merton. This example focuses on two layers in MapInfo: traffic data and property data. It will explain how the DHP team had to get the data they needed, as well as what was available, and how that compares to the accessibility of the data in a City Knowledge system.

This group showed how the data would be available in a City Knowledge based GIS by building layers to store that data, and putting sample data into the tables in the database. These tables are modeled directly on the tables developed in chapter 5, and as such accurately represent what data would be available to someone working with the City Knowledge based GIS that this project proposes. The layers that are used in these examples are being overlaid on a map of Merton that already exists. This map does not contain any information other than the geographical locations of the object. This is later referred to as the general area map of Merton.

Traffic Data

The first example of data that would be useful in analysis of a route for a DHP distribution system is traffic information. Possible routes for the distribution infrastructure involved crossing roads. This would mean that during construction, the road would have to be blocked, affecting traffic. The volume of traffic at any given intersection in the area is important information and can aid in determining which roads are acceptable to block during construction.

The data related to traffic in intersections was available to the DHP team on the Borough of Merton's network. In that way, it was quite easily accessible. The real weakness in the intersection data was the format in which it was stored. There was a spreadsheet file for each intersection, which had that intersection's traffic volume data. Unfortunately, not all the spreadsheets had the same layout, and accessing multiple intersections data was slow and tedious. Actually comparing and relating multiple intersections data would have been an extremely difficult task, if not impossible, with the data in this format. The following is an example of the data stored in a spreadsheet about an intersection:

Site No: 27154012			Grid Reference: TQ50377, 68681								
Site 12, Cranmer Road, Merton (L/C 12)											
Class Report FHWA			Sat 05-Jun-04			Channel: Northbound					
Time Begin	Total Vol.	Bin 1 Motorcycles	Bin 1 %	Bin 2 Cars	Bin 2 %	Bin 3 LGV	Bin 3 %	Bin 4 HGV	Bin 4 %	Bin 5 Buses	Bin 5 %
0:00	43	0	0	39	90.7	3	6.98	1	2.33	0	0
1:00	21	0	0	18	85.71	1	4.76	2	9.52	0	0
2:00	9	0	0	8	88.89	1	11.11	0	0	0	0
3:00	16	0	0	12	75	3	18.75	1	6.25	0	0
4:00	21	2	9.52	18	85.71	1	4.76	0	0	0	0
5:00	41	2	4.88	32	78.05	5	12.2	2	4.88	0	0
6:00	79	2	2.53	57	72.15	12	15.19	7	8.86	1	1.27
7:00	143	4	2.8	111	77.62	21	14.69	7	4.9	0	0
8:00	185	2	1.08	158	85.41	15	8.11	10	5.41	0	0
9:00	198	2	1.01	169	85.35	17	8.59	9	4.55	1	0.51
10:00	211	4	1.9	186	88.15	14	6.64	7	3.32	0	0
11:00	219	3	1.37	198	90.41	10	4.57	8	3.65	0	0
12:00	212	4	1.89	180	84.91	19	8.96	8	3.77	1	0.47

Table 7: Existing Traffic Data

Traffic data that is stored in the way that our project defined in chapter 5 would be easily accessible through the proposed GIS. Any intersection on a map would have a series of arrows drawn on it. The following figure is an example of an intersection with these arrows.

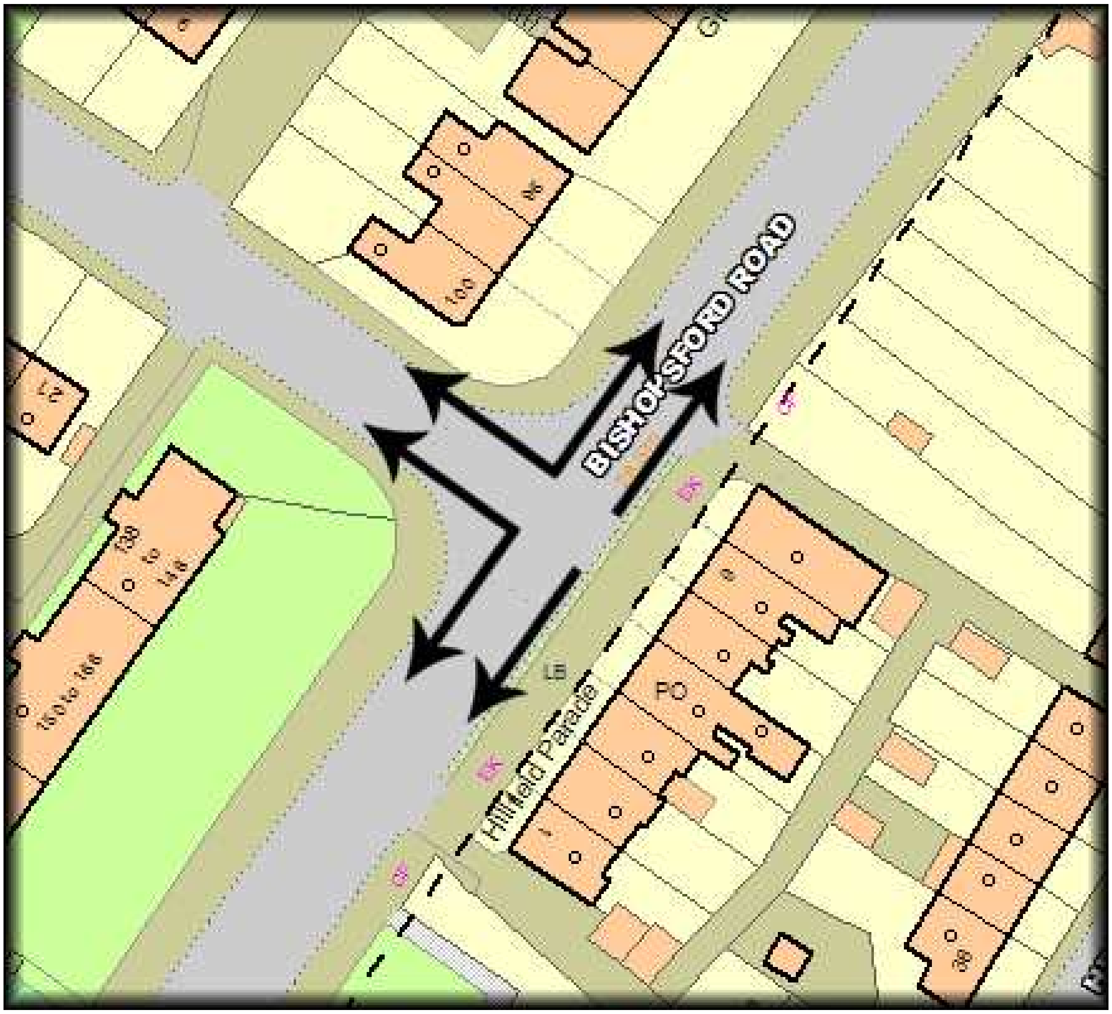

Figure 4: Traffic Data Arrows

Each arrow represents a path that a vehicle can take through that intersection. The following map is colored to simply explain how the arrows in the map correspond to paths through the intersection.

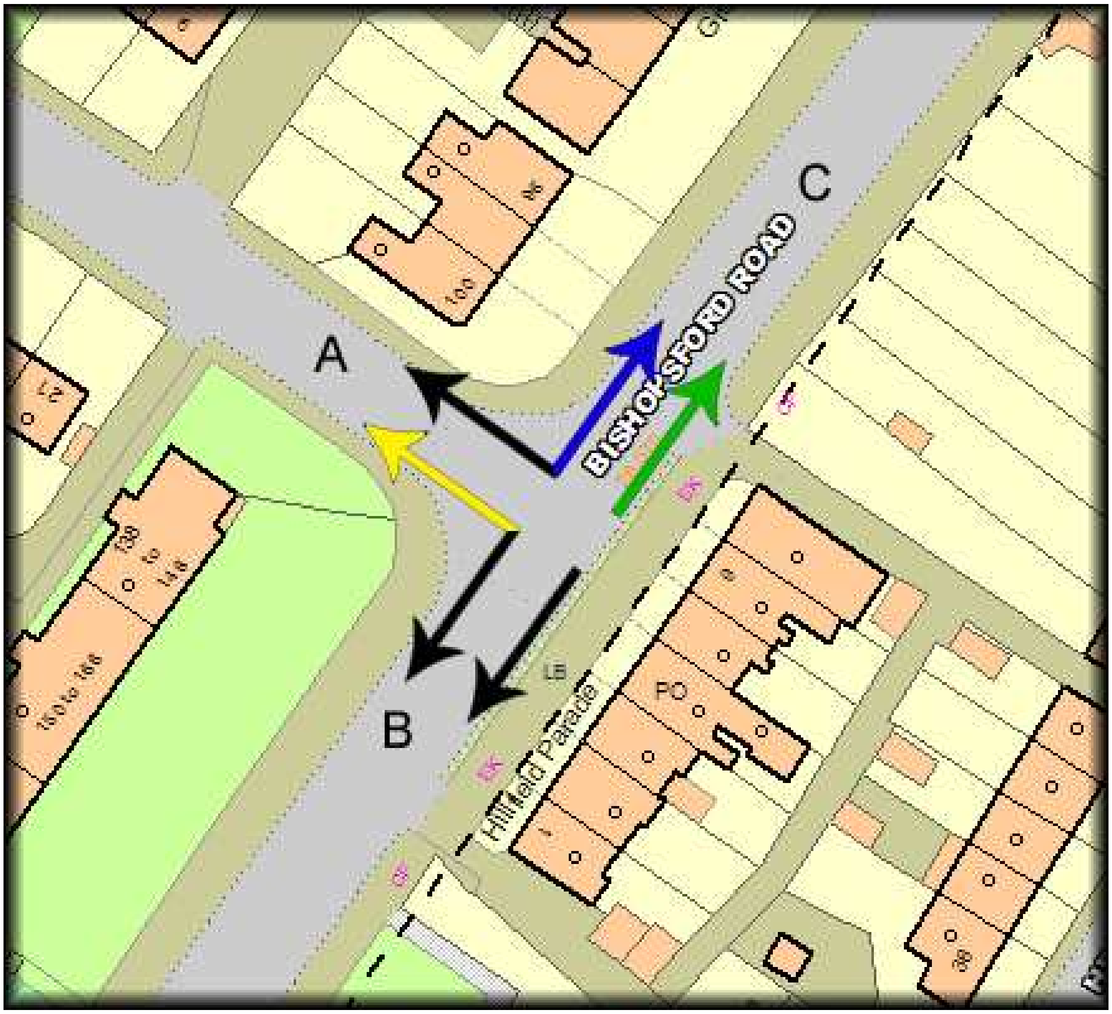

Figure 5: Traffic Arrows Explained

The yellow arrow on the map represents the path through the intersection beginning on the road marked B and ending on the road marked A, the blue arrow represents the path from B to C, and the green arrow represents the path from A to C.

By clicking on one of the arrows, a user could view a list of all the traffic records associated with that intersection. The user would initially be presented with a list of the dates and times of all these records.

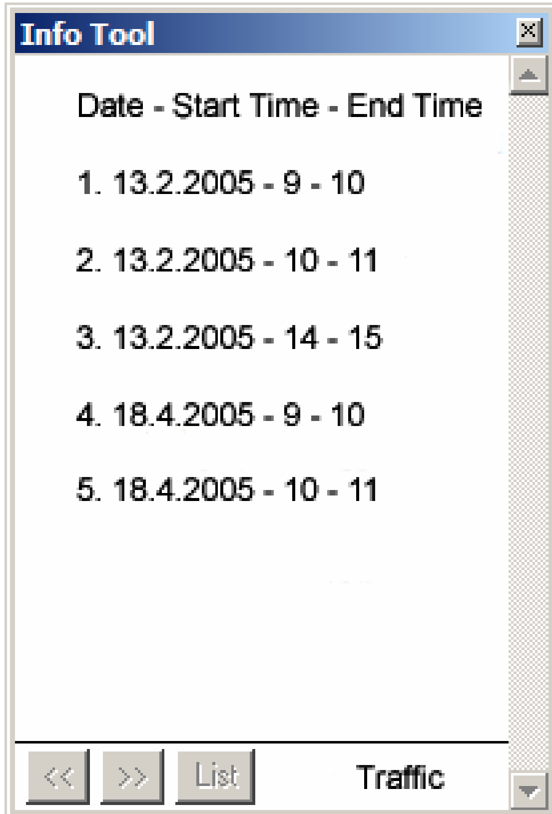

Figure 6: Traffic Records

Once the user selects a record by its time and date, MapInfo can display the volume of vehicles, bicycles, and pedestrians who crossed the intersection at that time. It could be presented similarly to how sewer or electric data about a certain line was shown.

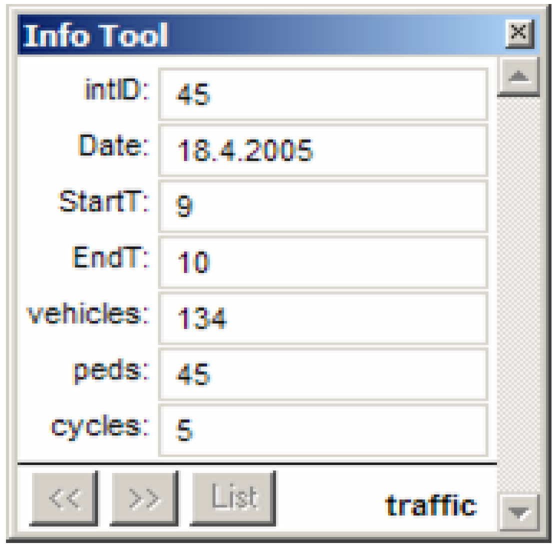

Figure 7: Traffic Data

In this case, information about an intersection that was collected between 9 and 10 AM on 4/18/2005 is displayed. During this time, 134 vehicles, 45 pedestrians, and 5 bicycles were counted.

Intersections could also be colored based on the volume of traffic in them, so that a decision about which can be blocked for construction can be made.

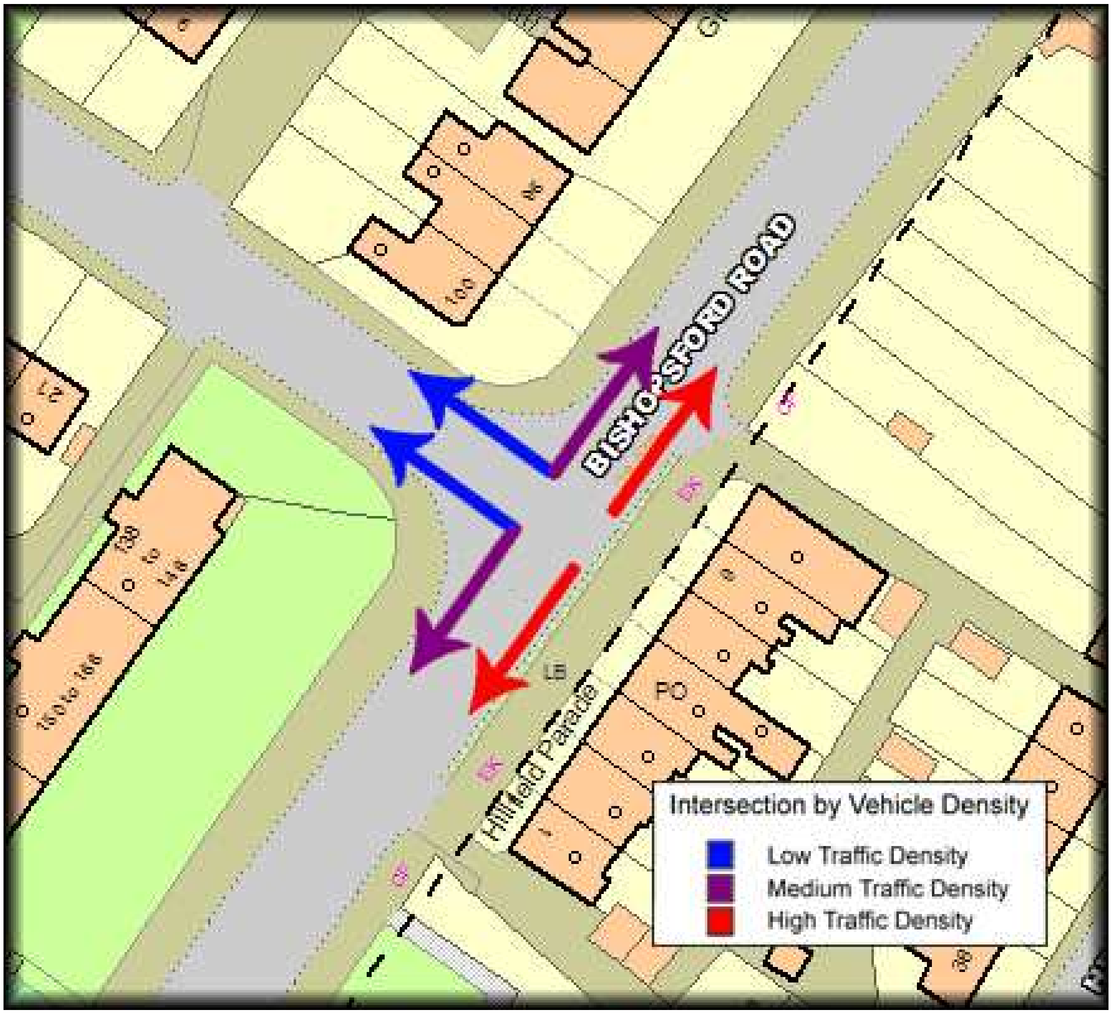

Figure 8: Traffic Map Colored by Density

In this map, blue arrows represent paths with low traffic volume, purple represent medium traffic volume, and red represent high traffic volume. Based on this, a distribution route which does not cross Bishopsford Road would be ideal, because that has more traffic volume than the side road connected to it.

By using a map with colored intersections, a person planning a DHP distribution route would be easily able to see which roads are acceptable to dig under. This could not be done easily using data in the form that it was available to the WPI team who completed a DHP distribution route plan concurrently with this project. While this layer in the GIS might not contain more data than is in the spreadsheets, the fact that it is in a standard format and that multiple intersections data can be compared shows the strength of a City Knowledge based GIS.

The street maintenance department, a division of the environment and regeneration department, maintains traffic data in the LBM. They will continue to maintain this data when it is stored in a City Knowledge based GIS, but will need to use new methods of storing the data. These methods are described in chapter 4.2 of this paper.

Property Ownership Data

A second type of data that would be beneficial to have in a GIS when planning a DHP distribution route is property ownership data. Information about whether a certain plot of land is public or private property, as well as whom the owner is, greatly affects the difficulty of placing distribution infrastructure on that property. While a municipality has the right to dig on land they own, they cannot arbitrarily dig on private property. If a landowner wished, they could prevent any work being completed on their land.

Land ownership data is held by the estates department in the LBM. Currently, this data is only in paper form and only notes whether land is public or private. In order to find out if a certain area is an acceptable place to plan a route, the DHP team had to work with the estates department to find the map containing that area. Once they did this, they could not find out any data beyond whether or not it was owned by the LBM. In a more complete City Knowledge system, information about who actually owns each property would be accessible through a layer in a GIS, so that it could easily be combined with other data.

The following is the map from the example of traffic data above, with a piece of property selected. Information relating to that property is displayed in a window on the map.

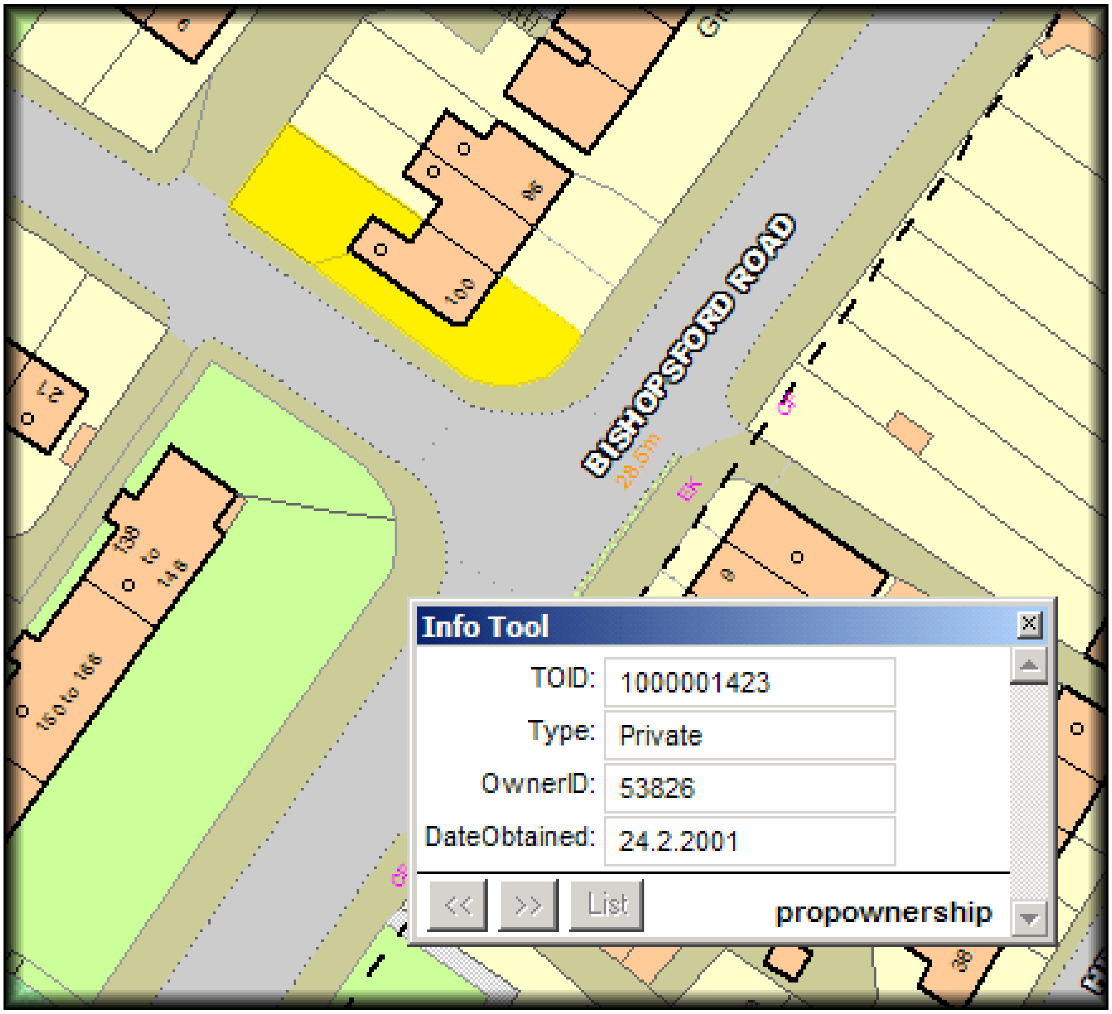

Figure 9: A Selected Private Property

The field TOID is a unique identifier for a property, and is generated by the Ordinance Survey. The field Type notes whether or not the land is public or private. The field OwnerID references another table (not shown here), which would contain information about the owner of the land, and DateObtained refers to when the current landowner acquired it.

The map can also be colored based on the property ownership information.

Figure 10: Property Colored by Ownership Data

This map has land property shapes colored by their ownership type. Publicly owned properties are red and privately owned properties are blue. By viewing the map like this, it would be very simple for a person planning a DHP route to avoid properties which are privately owned.

The data stored in this GIS layer would be owned and maintained by the Estates department, just as it is now. Property ownership data could be entered into the City Knowledge GIS in a few ways. One of these ways is to have all the data that the estates department currently has placed in a map. This process, while a large task, would result in a MapInfo layer that is far easier to access than their current data. Another way that new data could be entered into the GIS is when property changes owners. When this happens, the LBM could require the new owner to submit a change in ownership form to them. They could then enter this data into the database easily, and keep their information up to date. The methods described in chapter 4.2 expand on ways that data can be maintained in a City Knowledge GIS.

Putting together the layers

One final way that the CK based GIS is far more powerful than the current system of data storage in Merton, as it relates to the specific DHP transmission project, is analysis of multiple data sets at once. When the DHP team completed their work, many of the data sets they worked with were independent. It was not quick or easy for the team to put together data about different topics geographically and compare them.

If the CK approach were fully implemented, this would have been significantly quicker and easier. In this case, data about the topics listed in this example would have already been stored and updated in the GIS by the Street Maintenance department (for traffic data) and the Estates department (for property data). The group completing the DHP project could have simply loaded multiple layer files by accessing the previously stored information.

In the following map, the two layers discussed above (traffic and property ownership data) are all being displayed in one map.

Figure 11: Map with Traffic and Property Ownership Coloring

In this map, both layers discussed above are displayed and colored. Because both can be displayed at once, they can be easily related, and as such neither layer will be ignored in an analysis of a DHP distribution route. A person trying to find an acceptable route would be able to far more efficiently do so using a City Knowledge based GIS, as opposed to the current systems in use.

5. Data Structure Foundations for City Knowledge GIS

Introduction

The most important use of this section will be in the completion of the third part of the five-step plan developed as part of this project and laid out in Chapter 6. The third step of the plan requires a team to work with the departments in the Borough who are responsible for data that will be in the CK based GIS. They will determine exactly which data fields the departments are willing and able to generate and update for the database. These data tables will be in the same format as those outlined in this chapter.

This fourth step is a large one. It requires a tremendous amount of interaction with departments, as well as technical knowledge. This technical knowledge is what this chapter provides. The creation of the CK based data tables will be based on the guidelines and prototypical tables in this chapter.

The objective of this chapter is to provide the following group with a running start. Because the group completing the third step will have these recommendations, they will be able to focus their time on creating well-planned and organized tables.

5.1 Data Standards Presented and Explained

The development of standards for the data that will be used in the CK based GIS is an important step in the early development of the system. These standards will be useful to those continuing this work, as they can use them to determine which departments in the LBM have data that will be easy to convert to a format which can be imported into the GIS. The standards will also be useful to the software implementation team, who can directly model the GIS layers after the tables outlined below.

These standards were developed in the form of tables, or lists of properties of objects that will be stored in the GIS. Because tables cannot be developed for all specific data that will be in the GIS, this group chose to work with the WPI DHP team to develop standards for data related to the development of a distribution path for a DHP system. Because the DHP project, namely the determination of a DHP Distribution system route can cover a great distance, and many kinds of areas, it requires analysis of several factors. This group compiled the following list of GIS objects to develop data standards for:

- Electricity
- Water Pipes
- Sewer
- Roads
- Traffic
- Trees
- Conservation Areas
- Noise

As stated in Chapter 2, each object in the GIS has a series of properties associated with it along with a unique identifier. An outlined table structure for each of the elements listed above can be found in Appendix C: Data Table Standards. The tables discussed directly in this chapter are used as examples.

5.2.1 Frequently Occurring Fields

Unique Identifier – ID

The concept of associating unique identifiers with each record in a table may seem simple, but it is a fundamental concept central to a City Knowledge based GIS. As shown in the simple database example above, these identifiers are necessary to relate data to other data.

Every table designed in this report contains a unique identifier field of some sort. In some cases, the GIS tables that already exist contain a unique identifier field. If one was not present in the table, or no table exists at all, then the proposed data section of that table contains a unique identifier field.

It is important to note that there are two options when choosing how to generate these unique IDs. One way is to let the database program which stores the data automatically assign a unique identifier to a record when it is added to a table. When the database assigns these IDs it insures that these values are unique. An example of a unique identifier value created might be "0934820". These are often auto-incrementing, meaning that the database simply increases the number by one each time a new record is added. The other approach and the one preferred by Dr. Carrera, is what is known as "Talking Codes." These codes would be created by someone entering information into the database. These codes would not only consist of a string of numeric digits, but also contain the information about the object that the record represented. For example, if a record corresponded to a particular tree, then the unique identifier for that tree might be made up of the first three letters in the name of the park in which the tree resides along with a unique number. An example of a "talking code" might be "WIC_042", where the first three characters are letter indicating that the tree is located in Wimbledon Common, and the last three are incremental numeric values.

Although the "Talking Codes" method has some good qualities, this group recommends the Borough use a purely database-assigned numeric unique identifier method. There are several reasons for this recommendation, one of which is the fact that the Borough's current GIS contain hundreds of thousands of objects. The sheer logistics of having a human enter new unique identifiers for each of the currently existing objects is simply unrealistic. Also, the several currently existing tables contain numeric (i.e. non-talking) identifiers, usually found as the "Central Asset ID". Also, LBM currently utilizes maps provided by the Ordinate Survey, which use numeric identifiers and not "Talking Codes".

It is also necessary to discuss how these identifiers will be dealt with when new objects are cataloged and when information about existing objects is updated.

When new records are stored in the database they are inserted into the appropriate table and the database software adds a computer generated numeric unique identifier in the ID field. With this method of ID generation, the user does not need to know the ID of the new tree. However, the ID would be available once they stored the new tree record in the table. This is more efficient than having the user create a new talking code for the tree. It also eliminates the possibility of the user entering an incorrect ID, thus protecting the integrity of the information. For example, when a new tree is cataloged, the user enters all the information for the tree except for the tree's unique identifier. The user does not need to enter the tree's unique identifier because as soon as the new record is inserted into the Tree table, then the database software enters a computer generated unique identifier for that tree.

The process for the update of information about existing objects is different, and slightly more complex. In this case, it is necessary for the person, department, or organization that is updating information to know the unique identifier assigned to the objects being updated. To resolve this issue, the unique identifier of the objects being updated must be made available when new data is collected, so that the updated information can be associated with the appropriate object. The insertion of this updated data into the database is done based on the unique identifier assigned to the updated data when the data was collected.

Suppose data about certain trees needs to be updated. The reason for the update may be that certain trees have a certain disease and data about their health needs to be collected frequently. Once the unique identifiers of all the trees which have that disease are found, MapInfo is used to show these trees on a map along with their unique identifiers. The person going into the field could bring this map with them and easily record any changes to the health of each tree, referencing the updated information based on the unique identifiers shown on the map.

Comments

Another field that appears in all of the data tables listed in this document is Comments. This field is beneficial since there are sometimes bits of information that are convenient or necessary to store about a particular object in the GIS, but cannot be encapsulated in any of the fields in the table. The Comments field can serve as a catchall for information that simply does not belong in any other field of the table.

5.2.2 Example Data Standards

The tables detailed below and in Appendix C are examples of the headings, and therefore the categories of information, that should be stored in the database for each type of data. These titles will then become the fields which can be viewed within each table's related layer in MapInfo. There are also descriptions of the data that heading represents, and what type of data goes under those headings.

Each table is split into 3 sections. The first is the information that is currently available to the Borough. In the cases where this section is left out, it is because there is no information available on that topic. The second section is the DHP Plan Demanded Data. This is data that would have been helpful to the DHP project, had it also been currently included in the GIS. The final section is the Proposed Data, which is data that according to the concepts of City Knowledge should become part of the GIS.

The rest of this chapter consists of a few of the several tables designed during this project. The first is the Sewers Section. This section is made up of three tables: a Sewer Pipe Data Table, a Manholes Table, and a Sewer Line – Manhole Relation Table. The reasoning behind each of these tables is laid out below each one in paragraph form.

Sewers

In the case of sewer data, the data the Borough has was in the form of software provided by the Thames Water Utilities.

Sewer Pipe Table

Currently Available Sewer Pipe Data:

- Type – type of sewer line the object is.
  - Possible values: Public, Private, Trunk, Rising, Storm, Highway.
- Content – material transported in the sewer line.
  - Possible values: Foul, Surface, Sludge, Combined, Overflow, Trade Effluent.
- Direction – the direction the contents of the line are flowing most.
  - Possible Values: North, South, East, and West.

DHP Plan Demanded Sewer Pipe Data:

- Start_Depth – depth in meters below the surface at which the line starts, i.e. where the contents are moving away from.
- End_Depth - depth in meters below the surface at which the line ends, i.e. where the contents are moving towards.
- Diameter – diameter of the pipe in meters.

City Knowledge Proposed Sewer Pipe Data:

- sewerID – a unique ID for each sewer line segment.
  - A numerical value determined by the database.
- Pipe_Material – the material that the pipe is made of
  - Any material that sewer pipes are made from.
- Comments – Any information that is not appropriately stored in any other fields in the table.
  - A text string.

Manhole Table

Currently Available Manhole Data:

- Type – type of manhole the object is.
  - Possible values: Combined, Foul, Surface, Proposed, Joint, Backdrop, Other, Abandoned

Proposed Manhole Data:

- manholeID – a unique ID for each manhole.
  - A numerical value determined by the database.
- Comments – Any information that is not appropriately stored in any other fields in the table.
  - A text string

The Currently Available Sewer Pipe Data section lists the information that can be determined presently by looking at the maps produced by the 3rd party software. The DHP Plan Demanded Sewer Pipe Data section consists of fields that have been determined to be necessary for an ideal assessment of a proposed DHP distribution route.

The City Knowledge Proposed Sewer Pipe Data section is made up of fields that, if incorporated, would add depth to the current GIS. The number of fields that make up this section will increase over time, as departments are directly consulted about what further information would be useful to store.

The fields that comprise the Manhole Data section were also gleaned from Thames Water Utilities software. The 3rd party software contains both sewer pipe and manhole information on the same maps.

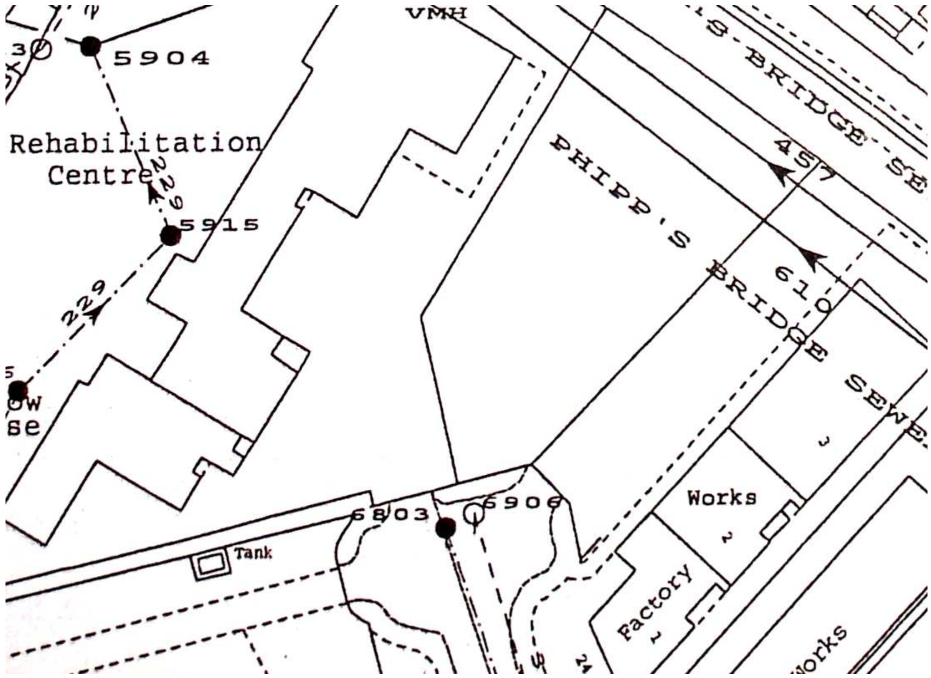

Figure 12: Thames Water Utilities Sewer Map

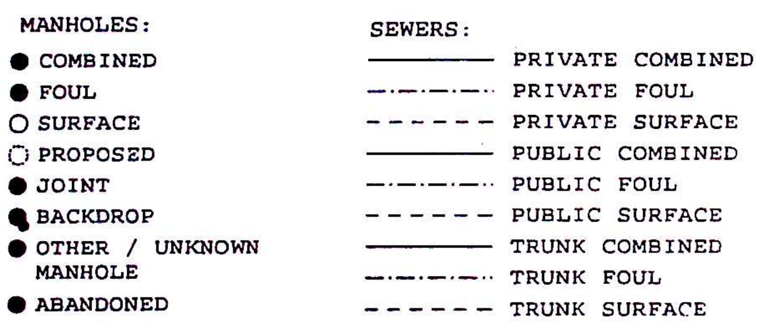

Figure 13: Thames Water Utilities Sewer Map Key

Sewer Pipe – Manhole Relation Table

- manholeID - a unique ID for each manhole.
    - A numerical value determined by the database.
- sewerID – a unique ID for each sewer line segment.
    - A numerical value determined by the database.

Relations Explained:

One concept of CK is that in any instance where a logical relationship can be made between two different types of objects, such as sewers and manholes, they should be. This is done through the use of what is called a "Relational Table." This table, as shown above, needs only to consist of two fields: one field to contain the unique ID's of one type of object, and one to contain the unique ID's of the other type of object. Each record in the table represents a distinct relationship between two objects of different types.

Sewers and Manholes

In the case of sewers and manholes, it is logical to store information about which manholes are connected to which sewer lines, and vise versa. This table allows for a user to find which manholes access a particular sewer line, and which sewer lines a particular manhole provides access to.

With this information stored in the GIS the user can open the sewer layer, which is directly linked to the sewer table, and thus be able to view the location of each sewer line with other spatially oriented information. The user will then have the ability to click on specific sewer lines on the map and view properties that are associated with them from the table with which they are linked. The user will also be able to analyze an area based on this information to generate intelligent maps or perform statistical analysis. This same example is explained in section 4.1 of this document.

Traffic Table

Proposed Traffic Data

- intersectionID – The unique ID of the intersection.
    - A number generated by the database.
- roadID_entering – The ID of the road segment from which cars are entering the intersection.

- roadID_leaving – The ID of the road segment from which cars are leaving the intersection.
- collectionDate – The date the traffic information was gathered.
    - Possible Values: a date value.
- startTime – The beginning time of the measuring interval.
    - Possible Values: a time value.
- endTime – The ending time of the measuring interval.
    - Possible Values: a time value.
- measuredValue – The number of items counted during the specified time interval.
- unitOfMeasure – The item that was counted during the specified time interval.
    - Possible Values: motor vehicle, cycle, person, bus, or any other object counted during the measurement.
- Comments – Any information that is not appropriately stored in any other fields in the table.
    - A text string.

The Traffic Table consists solely of proposed data. Although the Borough does possess traffic volume data, it is currently in the form of excel files.

6. Long Term City Knowledge Plan for the LBM

6.1 Analysis of the 5 Step Plan

While the initial objective of this project was to develop a City Knowledge system for Merton, at the advice of Dr. Carrera, it was decided that this was an unattainable objective. Instead, a plan was developed which will result in a City Knowledge system as described by Dr. Carrera. There are five steps which need to be completed in order to implement a City Knowledge system in Merton.

Step 1: City Knowledge Awareness – WPI IQP Winter 2005

The first step to the development of a long-term plan for City Knowledge for LBM was a report by the WPI project team in early winter 2005. This report reviewed the concept of City Knowledge and showed its benefits, and was used to convince Merton officials of the value of the concept. This project needed to happen in order to justify the cost of developing and integrating a CK system in the Borough of Merton. Adrian Hewitt, LBM Environmental Officer, then encouraged the development of a CK based GIS.

Step 2: Data Structure Foundations – WPI IQP Spring 2005

Before the CK concept can be fully implemented, the foundations of the database structure used to store the data must be laid out. This foundation, in the form of CK based GIS guidelines and prototypical data tables, is generated during this step. A case study is also presented using the DHP Distribution Route Determination project carried out in the spring of 2005. This case study serves as an illustration of how the implementation of the CK approach can benefit municipal planning projects. Step two was the focus of this project, and is described in great detail in this report.

Step 3: Department Buy-in

This step will require working with the departments who are either not willing, or able to share their data with other departments. The objective of this step is to show these departments the benefits of a CK system. This is quite similar to the first step in this plan, but on a more intimate scale. The objective will be to persuade individual departments to participate in the CK system. While it is not expected that all departments in Merton will go along with this plan, it is expected that some will see the value in the CK system and be willing to migrate their current system.

Step 4: Data Assessment and Integration

This step will require working closely with different departments to analyze their current information and develop standardized data tables for each. These tables should be based on the prototypes produced during step two. The end result of this will be well-designed and standardized data tables that will be inserted into a GIS and populated in the future. Step four will also include a report on how willing or able each department is to share data in the spirit of CK. This step is complimentary to the work already done by Merton's "Intelligence & Data" initiative in the Chief Executives Department.

Step 5: Technical Development

The final step in implementing a CK system in the LBM is the actual software development. This Using the foundations and standards set in steps two and three for the GIS database, along with the knowledge of individual departments gathered in steps three and four, this team will write a system so that data gathered by individual departments can be imported into layers in a GIS. Once this system is developed, it will be possible for future data, such as updates, to be put in the GIS. While this team will not be able to write systems for all possible kinds of data, the process should be easily reproducible once it has been done for some data, so future teams will easily be able to write similar migration software. This project will tie together the work of the previous four steps and complete the development of a City Knowledge based GIS.

Once these five steps are complete, then the LBM will have the initial stage of a CK system implemented. It will still take time to get data from the participating departments into the GIS, but the gears will be in motion. Once some departments have successfully begun using the CK system, departments which are not participating will be able to see its utility, and will join the system as well.

7. Conclusions and Recommendations

This seven-week period in Merton was a very enlightening experience in which the project goals were not always clear. This was the case because the LBM was in the very early stages of the development of City Knowledge. Very early in during this project it was crucial for this team to map out a long-term plan for Merton, which would encourage the migration to a City Knowledge system for the London Borough of Merton. The benefits of this plan (which were based on the City Knowledge concept) developed with the assistance of Adrian Hewitt would serve as a map for the LBM laying out the necessary steps for the complete conversion to a CK system. This project contains three deliverables which are: 1) *Example of GIS & CK, highlighting the benefits of CK for the LBM.* 2) *Data Structure Foundations for City Knowledge GIS (Tables for MapInfo designed by this team)*. 3) *The Long-term City Knowledge Plan for the LBM*.

Upon the completion of the long-term 5-step plan, the efforts of the group were focused on the generation of the data storage system for City Knowledge for the LBM. This was the task that consumed the most time during this project because it not only required that that this group liaise with different individuals in the Merton Council in order to find out the most information possible regarding the existing GIS system but also take the time to read and learn about City Knowledge as described in Dr. Carrera's PhD dissertation. Additionally, this group worked with the Internet Technology (IT) team in the council and was able to become more informed regarding the manner in which the GIS was not only used and constructed. This process required liaising with the WPI Merton DHP group, Adrian Hewitt, Gary Shaw, among others in order to assist this team in obtaining copies of the data the Merton Council had access to (For individual job titles refer to Appendix A). The final resource, which was crucial to designing the tables recommended by this team, was assessing the current GIS implemented by the Merton Council in order to see what possible suggestions could be made.

After completing the tables this group focused its efforts on designing an example of our tables in MapInfo to serve as a proof-of-concept demo supporting the City Knowledge methodology. This example was identified as an important part of this project not only so that the work completed during the seven-week period in Merton could be displayed and understood in a clear manner by viewers, however more importantly so that the idea of City Knowledge could be spread again and again by Adrian Hewitt or any other individual in the Council which would have interests in supporting this idea due to projects they have undertaken. By having a simple and concrete example of City Knowledge encapsulated into MapInfo it is possible that the benefits can be very easily demonstrated in an easy-to-view presentation manner. For this reason this group recommends that the plan that has been developed be used as a guide in order to adopt the City Knowledge process. It is important to remember that City Knowledge does not grow overnight, rather it is a long-term process, which if followed can create a very good flow of information throughout an organization or Council such as Merton. Generally speaking, the example which has been created will serve as a communication document which can easily explain to both the technically and non-technically oriented savvy individuals what benefits are associated with City Knowledge and additionally display the ways in which City Knowledge can save time and make organizations more efficient and profitable in the long-term. Organizations can save money by implementing the methods described in Dr. Fabio Carrera's PhD dissertation (demonstrated in Venice, Italy) by planning out carefully which information will be needed across different departments and thinking of the benefits of the organization as a whole, rather than each individual department.

The case study created explained the advantages that can be achieved not only by using MapInfo and GIS to analyze maps in digital format, however to exploit the true benefits of City Knowledge which greatly facilitate the way in which information is used and gathered. As a result, this case study will additionally serve to prove to the Merton legislators that City Knowledge is a worthwhile methodology to adopt, while explaining the benefits to the implementation of such a system.

As stated earlier on in this document, this group has completed step 2 of the 5-step City Knowledge plan (discussed in the previous chapter), and the third step can be put into motion. This means that the work that this group completed with regards to the Data Storage System outlined in this document will serve both as a guide and a basis for the next team to continue their work when they work with each individual department in converting their data and creating concrete tables. This group recommends that the following team use the tables that were created as examples to commence their work because the City Knowledge approach was followed during the design phase of these tables.

It is the recommendation of this group that the three items noted as project deliverables be reviewed by Merton employees in order that the LBM can have a plan of action, an example to show the benefits of a City Knowledge & GIS working hand in hand which is the ultimate goal of such a project. It is important to remember that this document outlines a preliminary structure for the future implementation of CK and therefore, these tables may need further development. The more concrete versions of the database tables will be created during the next phase in which a team will go out to all the departments and form more specific tables.

References

Aery, Alison Lee. Butler, Jason Draper. Giang, Max. Smith, Meghan Elisabeth. (2003). Feasibility Assessment of a Geothermal Heat Pump. (WPI IQP)

Carrera, Fabio. (2004). City Knowledge: An Emergent Information Infrastructure for Sustainable Urban Maintenance, Management and Planning. (MIT Dissertation).

Casavant, David. Guay, Michael. Kevin Moore. Joshua Morin. (2005). Merton City Knowledge. (WPI IQP)

Committee on Review of Geographic Information Systems Research and Applications at HUD: Current Programs and Future Prospects (CB). (2003). GIS for Housing and Urban Development. Washington DC: National Academies Press.

Contrino, Joseph. Ford, Jeffrey. Trexler, Jonathan. Wing, Allison. (2004). Sustainable Energy in London Borough of Merton. (WPI IQP)

Energy Information Administration. Carbon Emission. Retrieved from the World Wide Web on 2/04/05
http://www.eia.doe.gov/emeu/cabs/euro.html

Energy Information Administration. Kyoto Protocol. Retrieved from the World Wide Web on 2/04/05
http://www.eia.doe.gov/oiaf/kyoto/kyotorpt.html

ERSI, 2004. GIS.com – Your Internet guide to GIS (Geographic Information Systems), 2/2/2005. http://www.gis.com

Hewitt, A. (2004). *Sustainable Energy District Heat and Power (DHP) Scheme*. London Borough of Merton: Plans & Projects, Environment & Regeneration.

Kyoto accord takes effect.
http://www.cnn.com/2005/TECH/science/02/16/kyoto.ap/index.html. Feb. 16, 2005. Cnn.com.

MapInfo, 2004. MapInfo Corporation, 2/6/05. http://www.mapinfo.com

Merton Council. (2005). London Borough of Merton Home Page. 2/2/2005.
http://www.merton.gov.uk

Petchers, Neil. (2003). Combined heating, cooling & power handbook: technologies & applications: an integrated approach to energy resource optimization. New York: Fairmont Press.

UK Department of Trade and Industry. Energy Future. Retrieved from the World Wide Web on 2/04/05
http://www.dti.gov.uk/energy/whitepaper/ourenergyfuture.pdf

Wright, Richard T. & Nebel, Bernard J. Environmental Science: Toward a Sustainable Future, 8th Ed. Prentice-Hall Inc.: Upper Saddle River, NJ, 2002.

Appendix A: Mission and Organization (Merton Council)

Merton is a borough located in the southwest corner of London. The Borough has its own local administration structure called the Merton Council, which deals with issues within the Borough. Recently appropriations have been made in order to fund the implementation of City Knowledge as documented by Dr. Carrera. This type of funding is what allows endeavors such as this project to take place and contribute towards Merton's objective of adopting City Knowledge in their Borough. Policy within the Merton Council is set by the Councilors, who ultimately make the decisions whether the Council's time, money and effort should be spent towards any particular initiative.

Merton's mission statement is, "Merton—A great place to live, work and learn." This project is related to Merton's mission statement because by implementing City Knowledge in the Borough the community and Merton Council will be able to benefit from the increased information flow and accessibility as well as the ability for many organizations to complete their jobs more efficiently. Currently the process of obtaining information from an external organization such as a water company, etc. can be long and tedious. This process might mean obtaining written consent from an organization in order to access their data. With City Knowledge ideally this information will be stored in the GIS and appropriate parties will have access to the data they need in order to complete their jobs. The process of obtaining data using City Knowledge would be almost instantaneous whereas the current situation might take weeks as mail is exchanged between parties and data is sent to the Council. After looking at the recommendations and examples described in this report one can begin to grasp the benefits of migrating to City Knowledge and the variety of ways which it can be applied to scenarios throughout the Borough.

The people associated with this project and their jobs titles are listed below:

Adrian Hewitt- Principle Environmental Officer. Project sponsor and individual who this group worked for.

Declan Stegner – GIS Manager. During this project Declan Stegner helped this group obtain data and answered questions regarding current tables structures in the GIS and cleared up any other doubts and questions this group had.

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Mick Byrd- Business Systems Manager. During this project Mick Byrd helped this group obtain data and answered questions regarding current GIS.

Gary Shaw- GIS Consultant. During this project Gary Shaw helped this group obtain data and answered questions regarding current tables structures in the GIS and cleared up any other doubts and questions this group had.

Included below is that original letter sent to WPI from Adrian Hewitt which identifies the original topic and associated information about the Merton Council and previous IQPs completed at Merton.

WPI London Centre Project Proposal Form
Paul Davis, Dean, Interdisciplinary and Global Studies Division
Worcester Polytechnic Institute, Worcester, MA 01609 USA
1 508 831 5212 (office), 5485 (fax), pwdavis@wpi.edu

Term required for the project (please delete as appropriate):
D term - March 2005

Organisation name and address
London Borough of Merton
Plans and Projects Section
Environment and Regeneration Department

Proposer's name and contact information
Adrian Hewitt
Merton Civic Centre
London Road, Morden
Surrey, SM4 5DX

United Kingdom
Dial from USA 011 44 208 545 3457 - Dial from UK 020 8545 3457
adrian.hewitt@merton.gov.uk

Additional Information:

- **Sector:** Local Authority
- **Size of Organization:** 3,000 employees
- **Site(s):** Merton Civic Centre
- **Accommodation for students:** Plans & projects section; shared desk with access to others and PC's/phones (Hot desking)
- **Hardware:** PC's
- **Software to be used on project:** Microsoft office
- **Past IQP projects (please include year)**
    - 2004 - Sustainable Energy District Heat & Power
    - 2003 - Funding for Sustainable Development.
    - 2003 - Geothermal ground source heat exchange technology.
    - 2002 - Asia Urbs Sustainable Construction manual.
    - 2002 - Sustainable Development construction guides.

Student requirements:

Knowledge and interest in:

- GIS mapping, City Based Knowledge and data management.
- Sustainable development.
- Sustainable energy generation and distribution technology.
- Human geography and public consultation.

Title:
Web based City Based Knowledge GIS data acquisition and management system.

Background

Responding to a European Union directive, the London Borough of Merton is committed to reducing its overall carbon emissions. One of the most effective ways of doing this is to use sustainable energy generating and distribution technologies. The long-term aim is to develop a borough wide district heat and electric power network driven by a series of combined heat and power units. Merton believes that it can do this in a way that generates a revenue stream for the Council.

In order to proceed with such a scheme it will need to undertake a systematic process of Geographical Information System based mapping. The intention is to combine the mapping required for progressing a district heat and power (DHP) scheme, with information relevant to a range of other municipal maintenance and management activities. This database will be the foundation upon which Merton can develop a City Based Knowledge system that will streamline and improve these maintenance and management activities.

Problem statement and objectives[1]

Merton currently has a borough wide GIS MapInfo database which has every property and landmark identified by a toid. However, there is as yet very little information about the individual buildings such as usage, energy, occupancy etc in the database.

As the data is acquired, Merton will need a sophisticated system for feeding it in to the database and accessing and managing it once it is there. Also, the Council needs a web-based system that automatically lodges future information as soon as it clears the knowledge horizon. Therefore Merton Council needs WPI to design and build a web-based Geographical Information System suitable for a City Based Knowledge initiative.

The project will involve:

- **Researching City Based Knowledge.**
- **Familiarization with Geographical Information Systems.**
- **Researching existing web-based knowledge acquisition and management systems.**
- **Design and build a web-based information feed in system.**
- **Trial out the system using information acquired by WPI students on the Jan 05 High Path Housing Estate research project.**
- **Liaise with Merton GIS officers.**
- **Presenting findings and demonstrate system to Merton officers and politicians.**

[1] What are the core issues? What outcomes you seek? If you favour particular approaches, please identify them. Note that careful problem definition and selection of methodologies or approaches are key steps in the preparation phase in the US. You will be consulted regularly when that work begins.

Appendix B: Example of a table, as described in section 2.3.1.

This table contains information about addresses in Merton. The first row of the grid, in bold, is made up of labels of the properties which are stored in the table. Each additional row corresponds to an object with an address (a building or part of a building).

- The *OSAPR* is the unique identifier associated with each address location. In this case, this identifier was generated during a survey of geographical features in the UK.
- The *Throughfare_Name* is the street the address is on.
- The *PostTown* and *Postcode* correspond to the general area the address is in.
- The *Easting* and *Northing* are the coordinates of the address.
- *Address* contains the actual postal address of the object.

OSAPR	**Throughfare_Name**	**PostTown**	**Postcode**	**Easting**	**Northing**	**Address**
AP1U328F5TX40PKGYH	HOVE GARDENS	SUTTON	SM1 3EZ	525951.7	166039.2	1 HOVE GARDENS SUTTON SM1 3EZ
APWH328F6TY40PK0YH	HOVE GARDENS	SUTTON	SM1 3EZ	525981.8	166018.3	10 HOVE GARDENS SUTTON SM1 3EZ
APWH328F7TY40PK0YH	HOVE GARDENS	SUTTON	SM1 3EZ	525981.8	166018.3	11 HOVE GARDENS SUTTON SM1 3EZ
APDM338F5RJ40PK00H	HURSTCOURT ROAD	SUTTON	SM1 3JF	525556.9	166018.2	1 HURSTCOURT ROAD SUTTON SM1 3JF
APBE328Y5RM40PKGYH	HURSTCOURT ROAD	SUTTON	SM1 3JF	525556.9	166012.8	3 HURSTCOURT ROAD SUTTON SM1 3JF
APDM338F6RJ40PK00H	HURSTCOURT ROAD	SUTTON	SM1 3JF	525557.9	166007.2	5 HURSTCOURT ROAD SUTTON SM1 3JF
APFW338F5RK40PK00H	HURSTCOURT ROAD	SUTTON	SM1 3JF	525558.7	166002.3	7 HURSTCOURT ROAD SUTTON SM1 3JF
APWY328Y5TB40UKGYH	REIGATE AVENUE	SUTTON	SM1 3JJ	525661.6	166303.3	100 REIGATE AVENUE SUTTON SM1 3JJ
APPY328Y5TB40UK0YH	REIGATE AVENUE	SUTTON	SM1 3JJ	525658.6	166301.8	102 REIGATE AVENUE SUTTON SM1 3JJ
APBU328Y5TB40UK0YH	REIGATE AVENUE	SUTTON	SM1 3JJ	525652.9	166293.9	104 REIGATE AVENUE SUTTON SM1 3JJ
APWP328Y5TA40UK0YH	REIGATE AVENUE	SUTTON	SM1 3JJ	525646.4	166285.9	106 REIGATE AVENUE SUTTON SM1 3JJ
APKK328Y5TA40UK0YH	REIGATE AVENUE	SUTTON	SM1 3JJ	525641.2	166278.3	108 REIGATE AVENUE SUTTON SM1 3JJ
AP9H328Y5TA40UK0YH	REIGATE AVENUE	SUTTON	SM1 3JJ	525636.4	166274.3	110 REIGATE AVENUE SUTTON SM1 3JJ
APKM338F5TX40QK00H	ROSE HILL	SUTTON	SM1 3EX	525961.1	166089.8	100 ROSE HILL SUTTON SM1 3EX
AP52338F5TX40QK00H	ROSE HILL	SUTTON	SM1 3EX	525954.1	166052.1	90 ROSE HILL SUTTON SM1 3EX
AP55328Y5TX40QKGYH	ROSE HILL	SUTTON	SM1 3EX	525954.3	166059	92 ROSE HILL SUTTON SM1 3EX
APBA328Y5TX40QKGYH	ROSE HILL	SUTTON	SM1 3EX	525956.9	166069.3	94 ROSE HILL SUTTON SM1 3EX
APDD328Y5TX40QK0YH	ROSE HILL	SUTTON	SM1 3EX	525958.4	166074.1	96 ROSE HILL SUTTON SM1 3EX

Appendix C: Data Standards Tables

Water Distribution Data

Water Pipe Data

Currently Available Pipe Data

- Type – What kind of water pipe the object is
    - Possible values: Distribution Main, Trunk Main, Supply Main, Fire Main, Metered Pipe, Transmission Tunnel, Raw Water Main, Other Water Company Main, Proposed Main, Private Main, Other.
- End of Piping – What is at the end of a water pipe (none when a segment of pipe does not terminate).
    - Possible Values: Blank Flange, Capped, End, Emptying Pit, Undefined End, Manifold, None.

DHP Plan Demanded Pipe Data

- Depth – How far underground the pipe is in meters.
- Width – The width of the pipe in meters.
- Owner (Company, city, etc.) & Contact Info (Name and telephone number of contact).

Proposed Pipe Data

- PipeID – a unique ID associated with each pipe segment.
    - A numerical value determined by the database.
- Last Update - when the pipe was last viewed/surveyed.
    - A Date Value
- Maintenance Required – If, when the pipe was last viewed/surveyed, it required maintenance.
    - Possible values – urgent, routine, none.

Hydrant Table

Currently Available Hydrant Data

- Hydrant Type
  - Possible values: Single, Double.
- Hydrant Use – What the water in the hydrant is used for
  - Possible Values: Fire, Washout, Raw Water, and Private.

DHP Plan Demanded Hydrant Data

- OwnerID – The ID of the owner
  - A value from the ID field in the Owners table.

Proposed Hydrant Data

- HydrantID – a unique ID of the hydrant
  - A number generated by the database.
- PipeID – The water pipe that connects to the hydrant
  - A value from the ID field in the Water Pipe table.

Valve Table

Currently Available Valve Data

- Valve Type
  - Possible values: Open General Purpose Valve, Closed GPV, Air Valve, Automatic Air Valve, Pressure Valve, Pressure Reducing, Reflux, Stopcock.
- Valve Use
  - Possible values: Butterfly, Bypass, Emptying, Waste Water, District Boundary, Stand Shut, Zonal Pressure Valve, Air Valve, Air Cock, Automatic Air Valve, Pressure Sustaining, Pressure Controlling, Other.

DHP Plan Demanded Valve Data

- OwnerID – The ID of the owner (would this be the same as the owner of the pipe that this is connected to?).

Proposed Valve Data

- ValveID – a unique ID of the valve
    - A number generated by the database.
- PipeID – The water pipe that connects to the valve
    - A value from the ID field in the Water Pipe table.

Supply Assets

Currently Available Supply Asset Data

- Use of Asset
    - Possible Values: Booster Station, Pumping Station, Inspection Shaft, Pumping Shaft, Service Reservoir, Tower Works, Other.

DHP Plan Demanded Supply Asset Data

- OwnerID – The ID of the owner (would this be the same as the owner of the pipe that this is connected to?).

Proposed Supply Asset Data

- PipeID – The ID of the pipe connected to the asset
    - A value from the pipeID field of the water pipe table
- Water Capacity – How much water can be contained in the supply asset, if applicable (such as in the case of a Reservoir).
- Last Update (when the pipe was last viewed/surveyed).
    - Possible values: A date value.
- Maintenance Required– Whether the Asset required maintenance the last time it was viewed/surveyed.
    - Possible values: Urgent, Routine, None.

Noise

Proposed Noise Data

- Sensitivity - Whether the area is sensitive to noise or not 0 or 1.
  - Possible Value: where 0 is not sensitive and 1 is sensitive.
- Zoning Type – The zoning of the area where the object is located.
  - Possible Values: residential, commercial, industrial.
- Decibel Average - The average value of decibels recorded in a certain area.

This table was constructed in order to take into account the amount of noise that can exist at any one time in a particular area. These three fields encompass whether an area is sensitive to noise or not. Most areas will be noise sensitive such as residential areas or parks however there can sometimes be places such as fields or unoccupied land where noise will not play any factor.

This table is relevant to the WPI DHP team because while determining a route for the DHP scheme noise should be taken into account if the route will go through a plaza, town square, park, etc. The GIS user can later gauge the importance of such noise disruption in order to determine if noise should be taken into account. The Zoning Type field will display to the GIS user what sort of area the noise is associated with.

Roads

Proposed Road Segment Data

- roadID – The ID of the road segment.
  - This is the TOID code present in the topo_area table.
- surfaceType – The type of material that the road segment surface is made up of
  - Possible Values: Concrete, Asphalt, and Sealed Granular.

- maintenanceRequired – The category of maintenance necessary determined when the road segment was last updated.
    - Possible Values: Urgent, Routine, None.
- createDate – The date that the road segment was first created.
    - A date value.
- lastUpdated – The date the road segment was last updated.
    - A date value.
- lastUpdatedNote – What was done when this road segment was last updated.
    - A text string describing what was done last update.

Intersections

Proposed Intersection Data

- intersectionID – The unique ID of the intersection.
    - A number generated by the database.
- surfaceType – The type of material that the intersection surface is made up of.
    - Possible Values: Concrete, Asphalt, and Sealed Granular.
- maintenanceRequired – The category of maintenance necessary determined when the intersection was last updated.
    - Possible Values: Urgent, Routine, None.
- createDate – The date that the intersection was first created.
    - A date value.
- lastUpdated – The date the intersection was last updated.
    - A date value.
- lastUpdatedNote – What was done when this intersection was last updated.
    - A text string describing what was done last update.

Proposed Road – Intersection Relations

- intersectionID – The unique ID of the intersection.
    - A number generated by the database.

- roadID – The ID of the road segment.
    - This is the TOID code present in the topo_area table.

Environment

Conservation Areas

Currently Available Conservation Area Data

- ConservationArea_Code – The unique ID of the conservation area.
- Area_Name – The name of the conservation area.
- Area_Hectares – The amount of area covered by the conservation area in hectares.
- Area_Acres – The amount of area covered by the conservation area in acres.
- Designated – The date the area was designated as a conservation area.
- Comments – Any user comments about the area.

Proposed Conservation Area Data

- Policy_Number – The policy number of the area.
    - Possible Values: NE1, NE2, NE20, or the number of any other Merton environmental policy.
- Policy_Name – The name of the policy covering that area.

Appendix D: Case Study Background - DHP Relevant Information

Environmental Issues

The motive for the creation of the main project (the design of a new power-generation plan) is due to the issue of global warming. This section describes Global Warming and its impact in more detail and helps the reader understand the importance of reducing the emission of greenhouse gases. It also describes the legislations that have been implemented regarding this issue.

Global Warming

The Earth is a planet with very reasonable conditions for supporting life largely due to its ability to convert sunlight into the right amount of heat. In accordance to its distance from the sun, the Earth would be a colder planet if it did not possess its unique atmosphere and life would be very different from how we know it. It is the Earth's greenhouse gases (heat-trapping gases) that allow the warm temperatures that we have today.

Carbon dioxide (CO_2), water vapor and other greenhouse gases are necessary components in the Earth's atmosphere for life to exist within. The light energy that the Earth receives from the sun is absorbed and converted to heat by the Earth's surface. The greenhouse gases that are naturally present at the Earth's troposphere serve as a wall for the heat that is produced from the surface. They prevent the beneficial heat on the planet's surface from going into space. Greenhouse gases reflect infrared heat energy back on Earth and are responsible for temperatures and weather conditions that support life as we know it today.

French scientist Jean-Baptiste Fourier first recognized the greenhouse effect in the year 1827 and it is confirmed today (Wright & Nebel, 2001). Nitrogen (N_2) and Oxygen (O_2) gases compose most of the Earth's atmosphere; however they do not have the greenhouse effect that carbon dioxide and the other rare greenhouse gases do. Our climate and temperature is dependent on the concentration of these gases at the Earth's troposphere. According to Richard T. Wright and Bernard J. Nebel, if these gases were absent, our average temperatures would be about 20 ºC colder (Wright & Nebel, 2001). The exact opposite would occur if the concentration of these gases were to be higher.

The artificial generation of carbon dioxide from burning fossil fuels is slowly adding to the natural greenhouse gases that already exist (Wright & Nebel, 2001). The concentration of carbon dioxide in the Earth's atmosphere has increased significantly in the past 50 years and a large part is owed to human activities such as burning fossil fuels and deforestation (Wright & Nebel, 2001). This issue has lead to a major concern for Global Warming that may result in devastating changes of climate in years to come (Wright & Nebel, 2001).

Carbon Emissions

The differences in carbon dioxide levels in the Earth's atmosphere may have a big impact on the Earth's energy storage. Swedish scientist Svante Arrhenius first reasoned this some 100 years ago (Wright & Nebel, 2001). He was the first to argue that carbon emissions might increase the carbon dioxide concentration in the atmosphere. However, there was no concern about this issue at the time so there were no major studies conducted until about half a century later (Wright & Nebel, 2001).

Charles Keeling started the first measurements for carbon dioxide levels in Hawaii in the year 1958. Since then, measurements have been conducted constantly and they have showed a major increase in carbon dioxide levels in the Earth's atmosphere. The carbon dioxide atmospheric levels rose exponentially from 1958 until the 1970's when an energy crisis occurred. The increase was linear for about two decades (1970-1990) and has risen exponentially since (Wright & Nebel, 2001).

The primary reason for the increase of carbon dioxide levels comes from the burning of fossil fuels as was determined by Arrhenius. When fossil fuels are burned they release large concentrations of carbon dioxide. The mass of carbon dioxide released is usually three times the mass of the fossil fuel that was burned. Recent statistics show that about 6.6 billion metric tons of fossil fuels are burned every year so 24 billion metric tons of carbon dioxide are released into the atmosphere each year (Wright & Nebel, 2001). These statistics imply that a serious increase in temperatures is inevitable unless something is done to decrease carbon emission. The carbon dioxide atmospheric levels in 2001 have increased by 35% since the Industrial Revolution (Wright & Nebel, 2001). This represents a great concern among the developed industrialized nations who currently share most of the responsibility for carbon emission on Earth.

Legislation

The severity of Global Warming has led to some major legal negotiations between various countries. This section describes what has been done to address this key environmental issue.

European Union

The major industrialized nations are aware of the greenhouse gas emission problem and are committed to finding alternative options for producing energy. In fact, the United States contributed about 30% of emissions in the world while only containing 5% of the world's population. In December of 1997, the United Nations held negotiations with more than 160 countries for limitations on the release of greenhouse gases. The convention was held in Kyoto, Japan and the agreement is called the Kyoto Protocol in which the European Union (EU) was a major participant.

The EU is very committed about reducing greenhouse gas generation. Carbon dioxide emission is a serious issue in Europe at the present because the gas accounts for 80% of the total greenhouse gas emission in the continent. In 2002, only 5% of the power consumption in the EU was accounted from renewable sources. The union is attempting to increase that number to 22% by the year 2020 (Energy Information Administration).

According to the Kyoto Protocol, the EU nations are required to reduce their carbon emission by 12.5% by the year 2008-2012 versus the year 1990. In the year 2002, the members of the EU accounted for 14% of the world's carbon emissions. The United Kingdom (UK) is accountable for a large portion ranking second among the members with 553 million metric tons per year (Energy Information Administration). The UK was one of the 15 EU nations that signed the Kyoto Protocol on April 29, 1998 and ratified it on May 31, 2002.

United Kingdom

Because of its geographical position, the UK finds it necessary to offer a major contribution to prevent global warming and ruinous flooding in its islands. Due to their sincere efforts, they have national goals that lay beyond the expectations of the EU. It is their goal to reduce greenhouse gas emissions by 20% of the 1990 levels by 2010 instead of the 12.5% that is required by the Kyoto Protocol. According to the UK Department of Trade and Industry, the country's main direction is cutting greenhouse gas emissions by 60% of the present level by the year 2050 (UK Department of Trade and Industry).

The UK government is aware that it needs to start planning rapidly if they are to achieve the 60% goal in a successful manner. They need to introduce a plan in a suitable manner so they can allow time for all of the affected parties to adjust. This needs to be done to prevent any last minute changes that would be necessary for businesses and the economy. Their primary objective however, remains to reduce the greenhouse gas emission levels by 20% by the year 2010. The London Borough of Merton has expressed their need to start planning a successful method of adding alternative energy sources so the borough can meet the government's goal (UK Department of Trade and Industry).

Sustainable Energy, SHP, and CHP

Sustainable Energy

One area that has been researched to deal with the problem of greenhouse gas emissions is sustainable energy. Sustainable energy is energy that can be produced economically and safely, minimizing damage to the environment, and without depleting a limited supply of fuel (Wright & Nebel, 2002).

Cogeneration or tri-generation where heat, cooling and electricity are generated in the same place and delivered to individual buildings is one form of sustainable energy (Petchers, 2003). This can greatly produce the amount of energy required more efficiently for a given area, and as such reduce the greenhouse gas emissions from that area. Sustainable energy systems can also use alternative and renewable fuel sources. These include hydrogen fuel cells, wind power, solar power, and energy from waste. The Borough of Merton plans to implement a combined power and heat system augmented by renewable technologies to reduce their carbon emissions (Ford, Contrino, Trexler, & Wing, 2004).

Separate Heat and Power

Producing all the electricity at a large central plant and then delivering it to individual buildings is the most common method of power generation, as well as what is currently used in Merton. This is done by running high voltage power lines from the main power plant to local substations. These substations then supply the power to local buildings using lower voltage wires. Once the power is delivered, it is used to power appliances, heat water & buildings, and cool buildings. The method that individual buildings use to heat and cool water and buildings can vary greatly from building to building. This system is rather inefficient, because heat which is generated when the power is produced is wasted, and then the power is just used to generate more heat. This excessive power generation leads to excessive greenhouse gas emissions. One way that this problem can be solved is using combined heat and power, or cogeneration (Petchers, 2003).

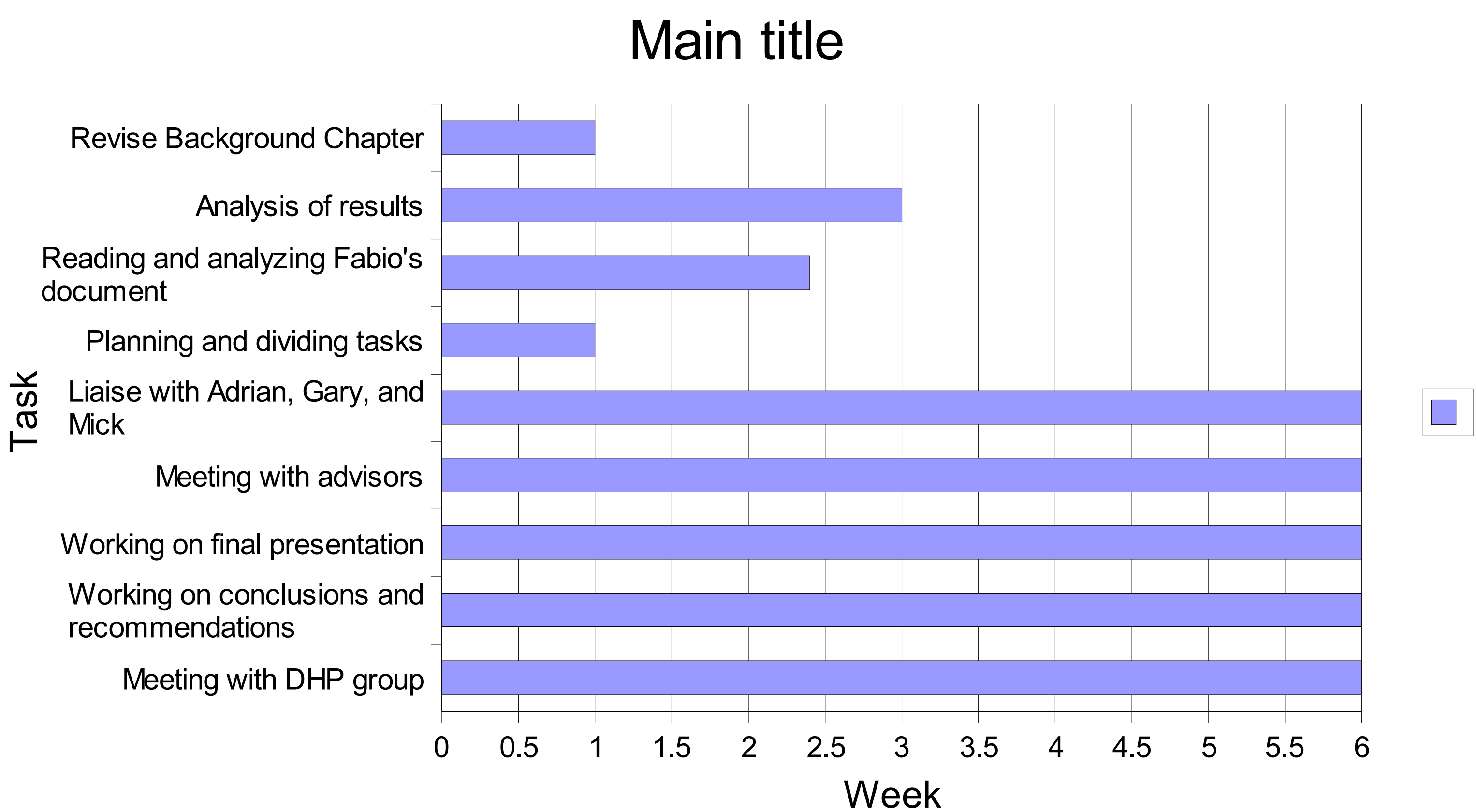
Combined Heat and Power

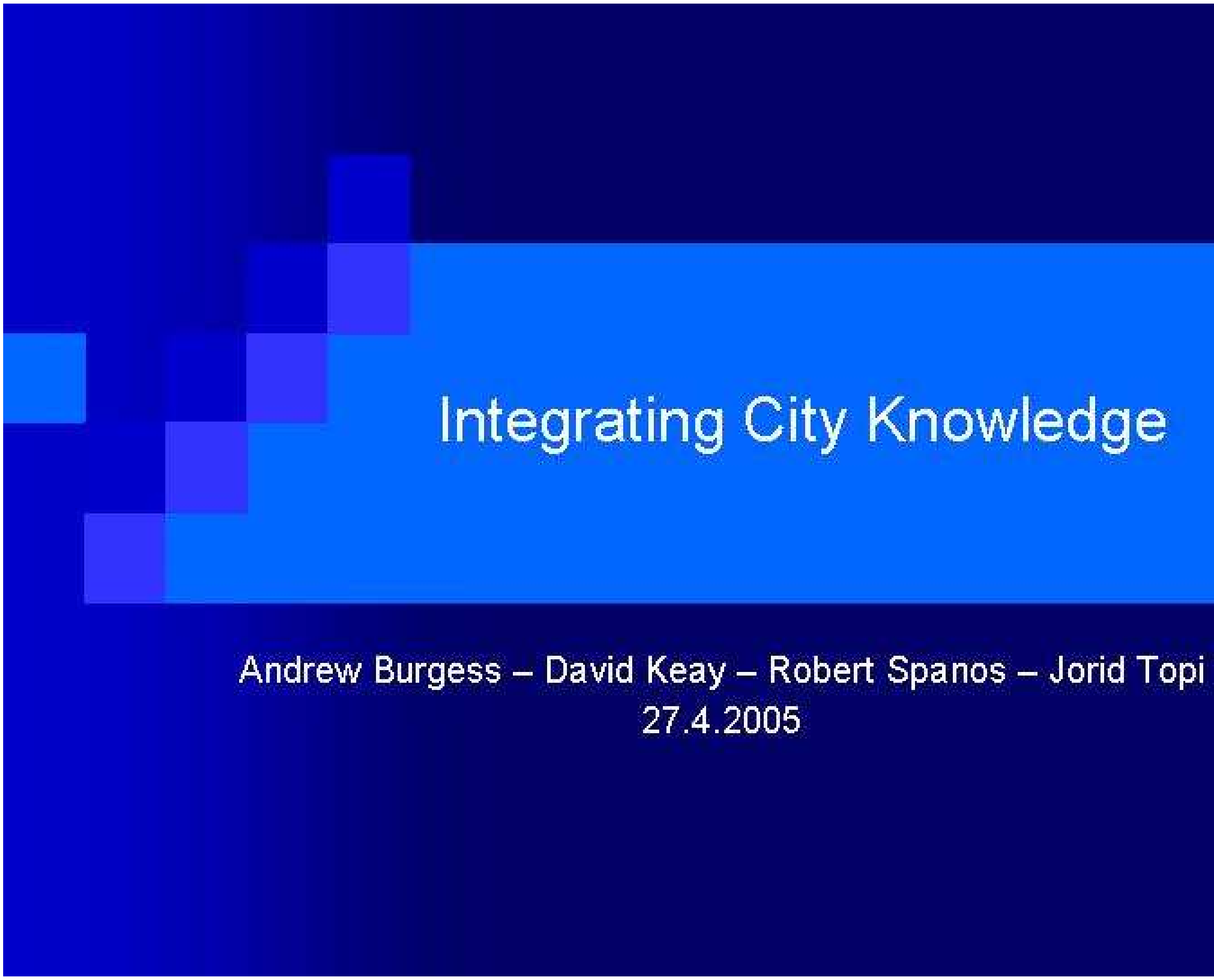
Combined Heat and Power (CHP), or cogeneration and tri-generation, is a solution to the problem of wasted and redundant heat generation associated with traditional power systems. CHP is a system where the same fuel source that produces power is used to produce heat. Power is generated at small, local stations. The heat generated during power generation is then delivered to individual buildings alongside the power system. Because heating, something which is usually a large drain on the power system, is no longer using electricity in buildings, their power requirements drop greatly (Petchers, 2003). Testing in this area showed that 30 units of electricity and 45 units of heat, as generated from a separate heat and power system, used 154 units of fuel. The same heat and power, generated from a combined heat and power system, used 100 units of fuel (Ford, Contrino, Trexler, &Wing, 2004). The delivery system for a DHP system is rather different from that used for a national grid system. Instead of power being generated at one large station, wired to substations, and then wired to individual buildings, power is generated at multiple small stations, which then connect directly to the individual buildings. These stations also deliver hot and cold water (tri-generation) to the buildings, which is generated using the byproducts of the power generation. This water is delivered to the individual buildings using a series of pipes that are generally laid along with the power lines (Petchers, 2003). The most modern technology used a combined pre-insulated all-in-one system.

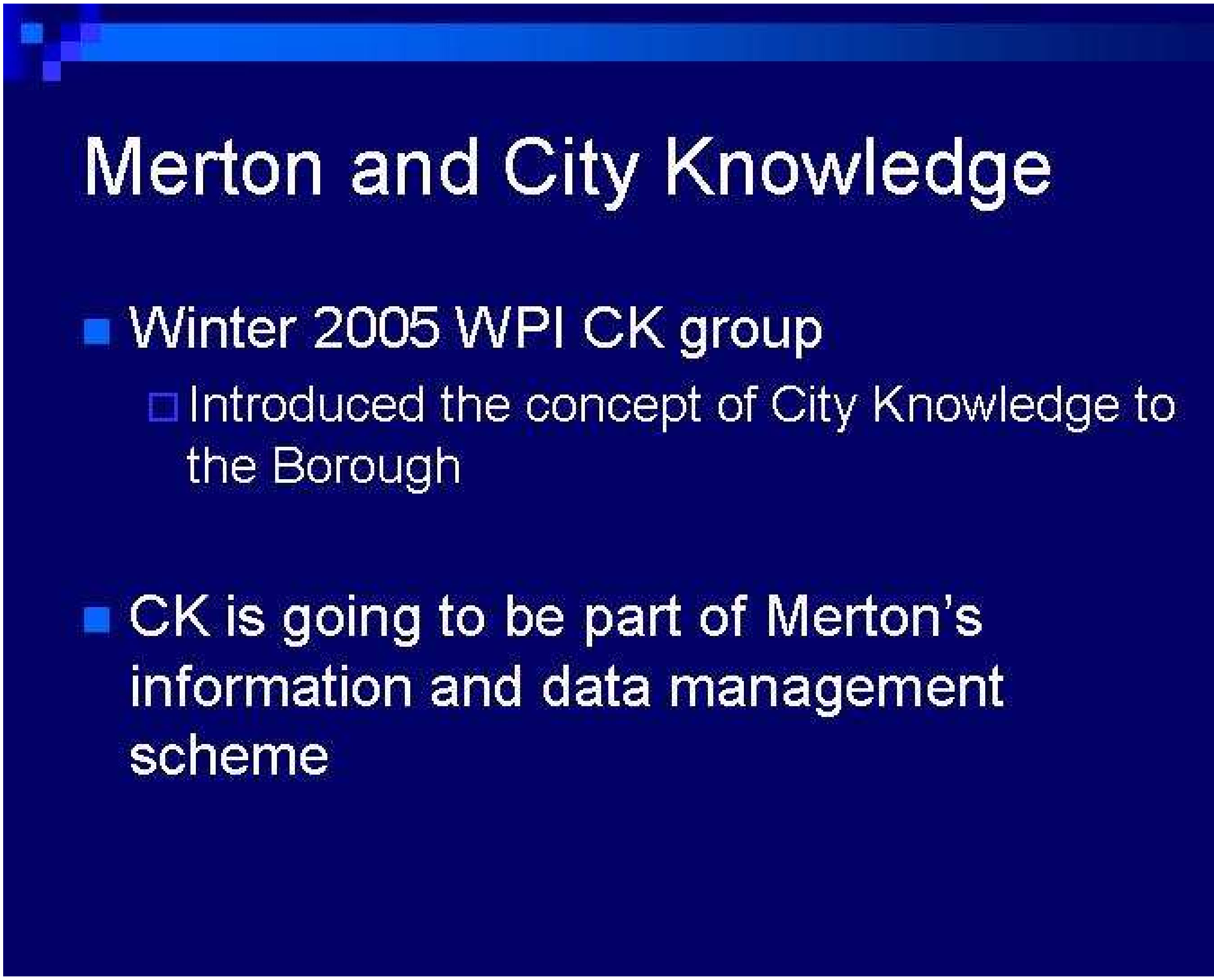
Similar CHP Systems

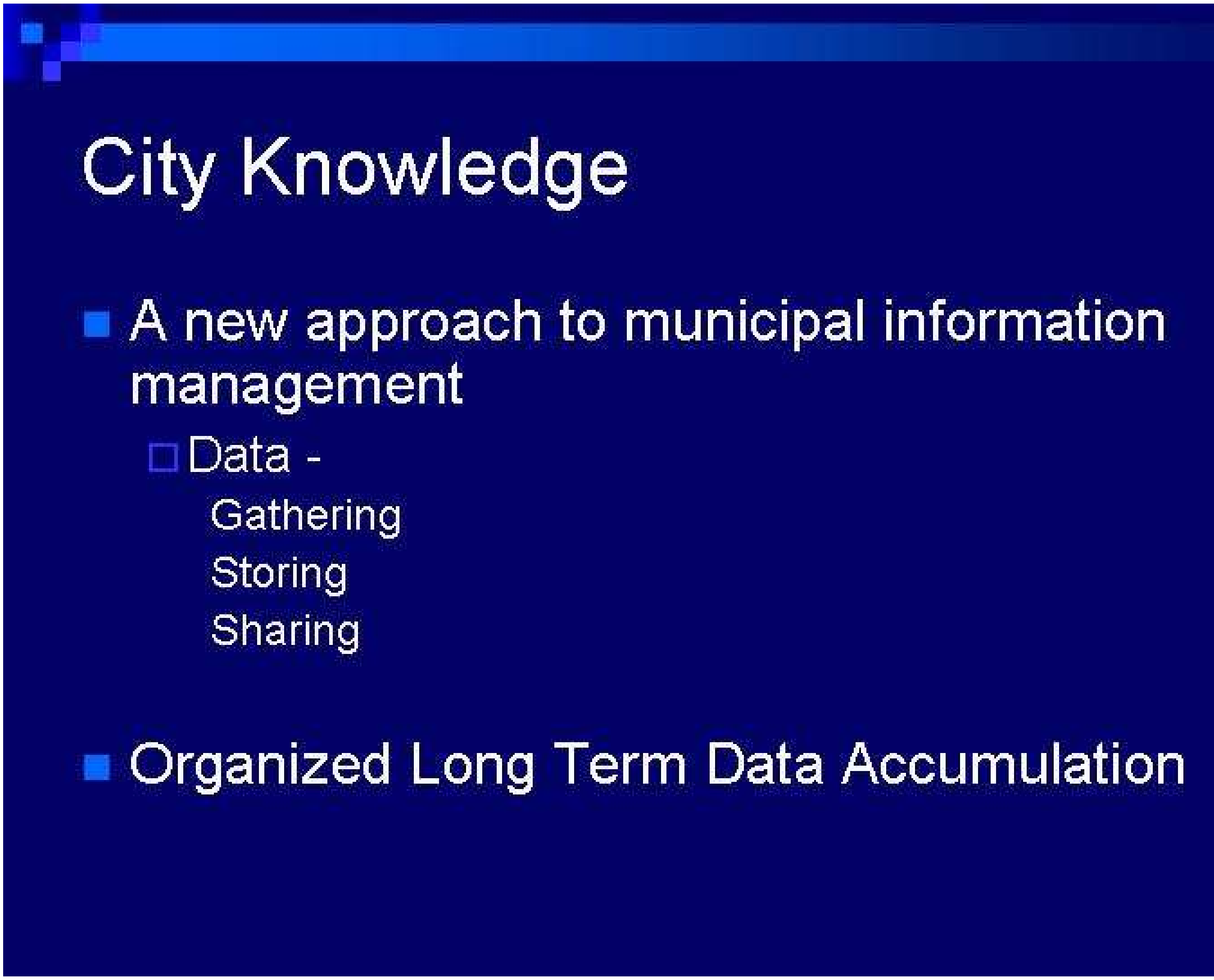
The Borough of Woking implemented a combined heat and power system to reduce their carbon emissions (Hewitt, 2004). Prior to this development, the Borough of Woking used the national grid system with individual heating and cooling solutions in each building. They developed a district heat and power system using six CHPs (private power and heat stations). Power and heat are delivered from each of the six stations to the surrounding area with a “private wire and duct system”; power is delivered through wires, while hot and cold water is delivered through pipes. This system reduced the energy consumption in Woking by forty-four percent and carbon emissions by seventy-two percent. It also has the benefit of removing the reliance on a public system, and because the municipality owns a percentage of the infrastructure it can generate income. Merton hopes to recreate the level of success that took place in Woking (Hewitt, 2004).

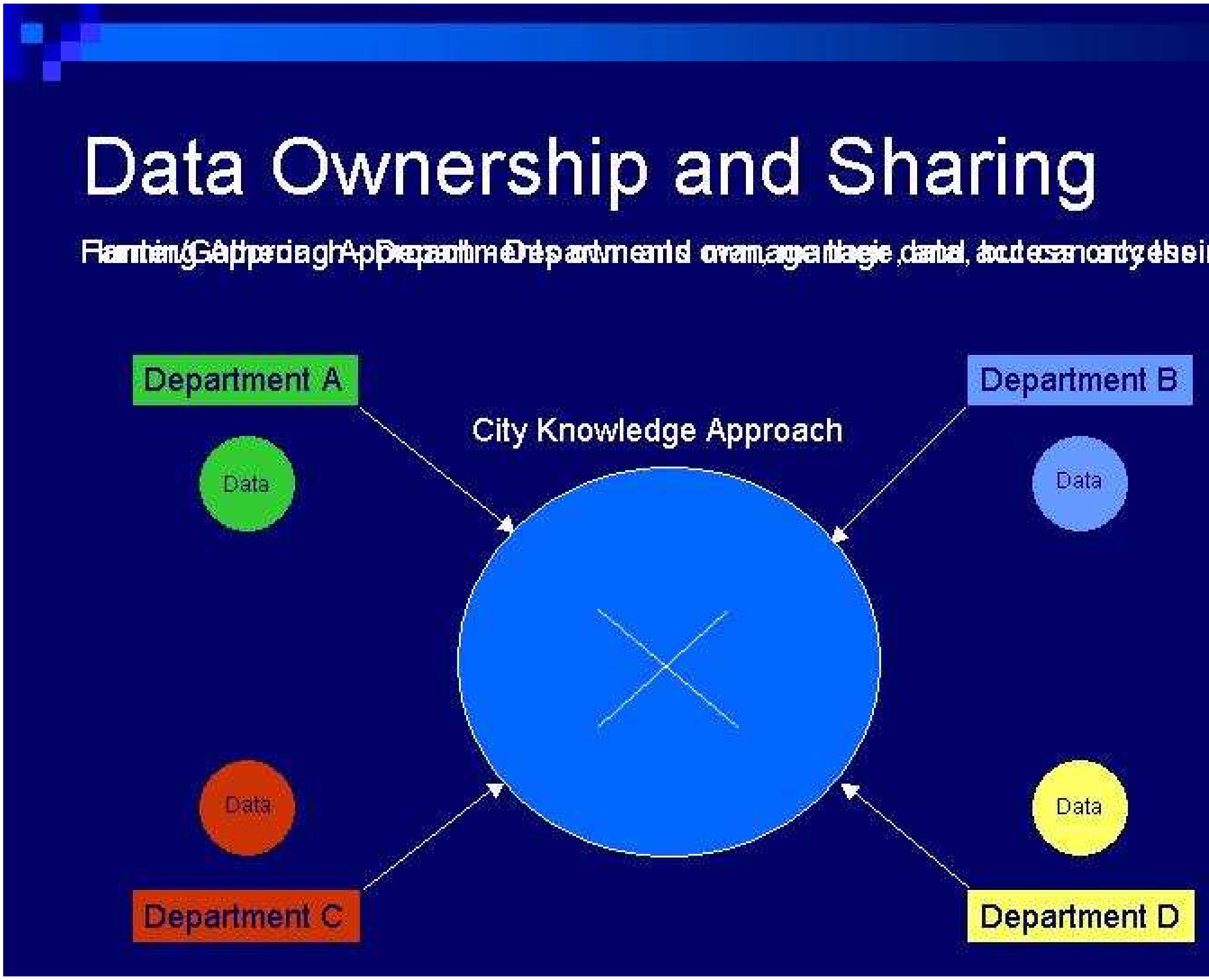
Appendix E: Gantt Chart

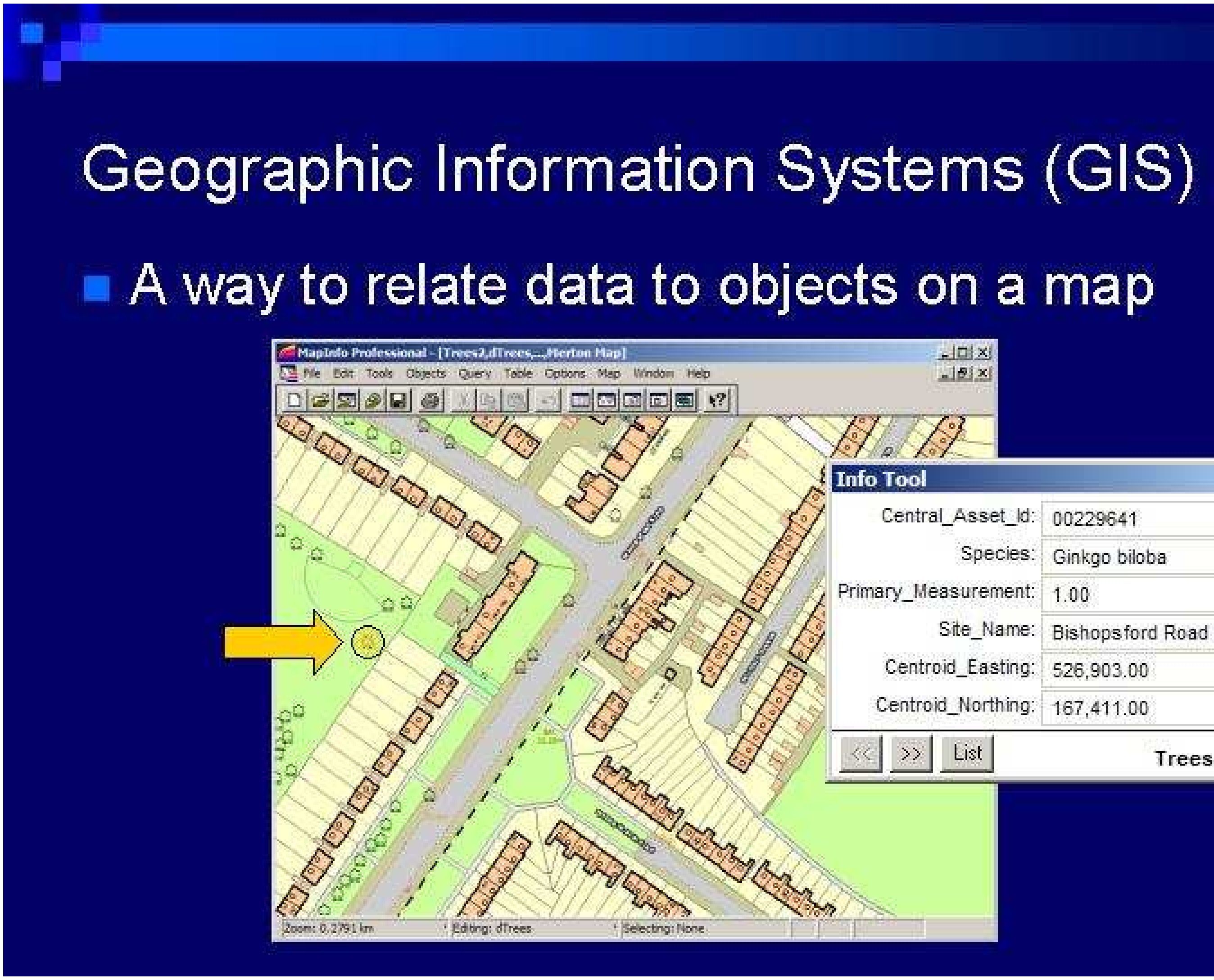


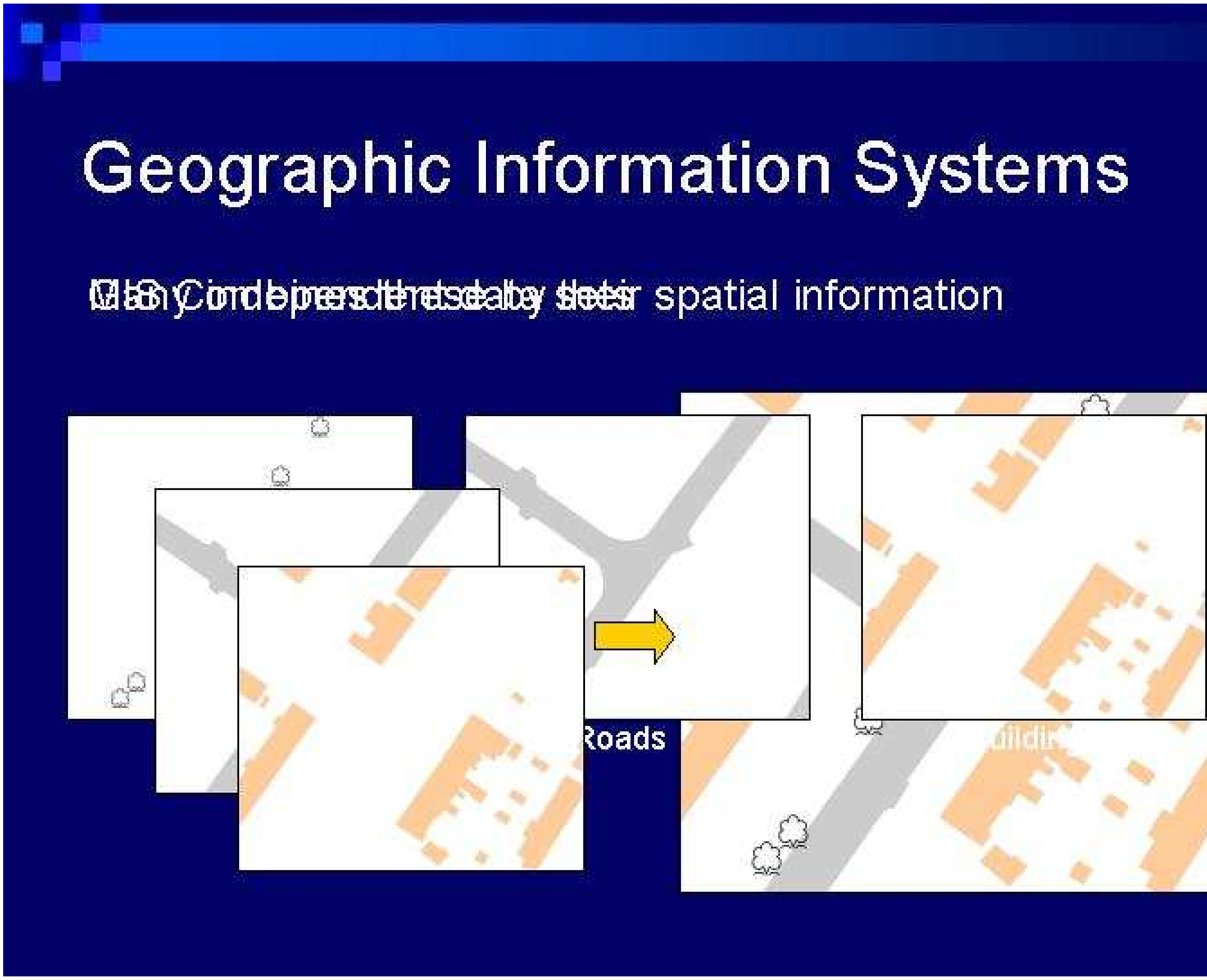

Integrating City Knowledge
Andrew Burgess – David Keay – Robert Spanos – Jorid Topi
27.4.2005


Merton and City Knowledge
Winter 2005 WPI CK group
Introduced the concept of City Knowledge to the Borough
CK is going to be part of Merton's information and data management scheme


City Knowledge
A new approach to municipal information management
Data -
Gathering
Storing
Sharing
Organized Long Term Data Accumulation

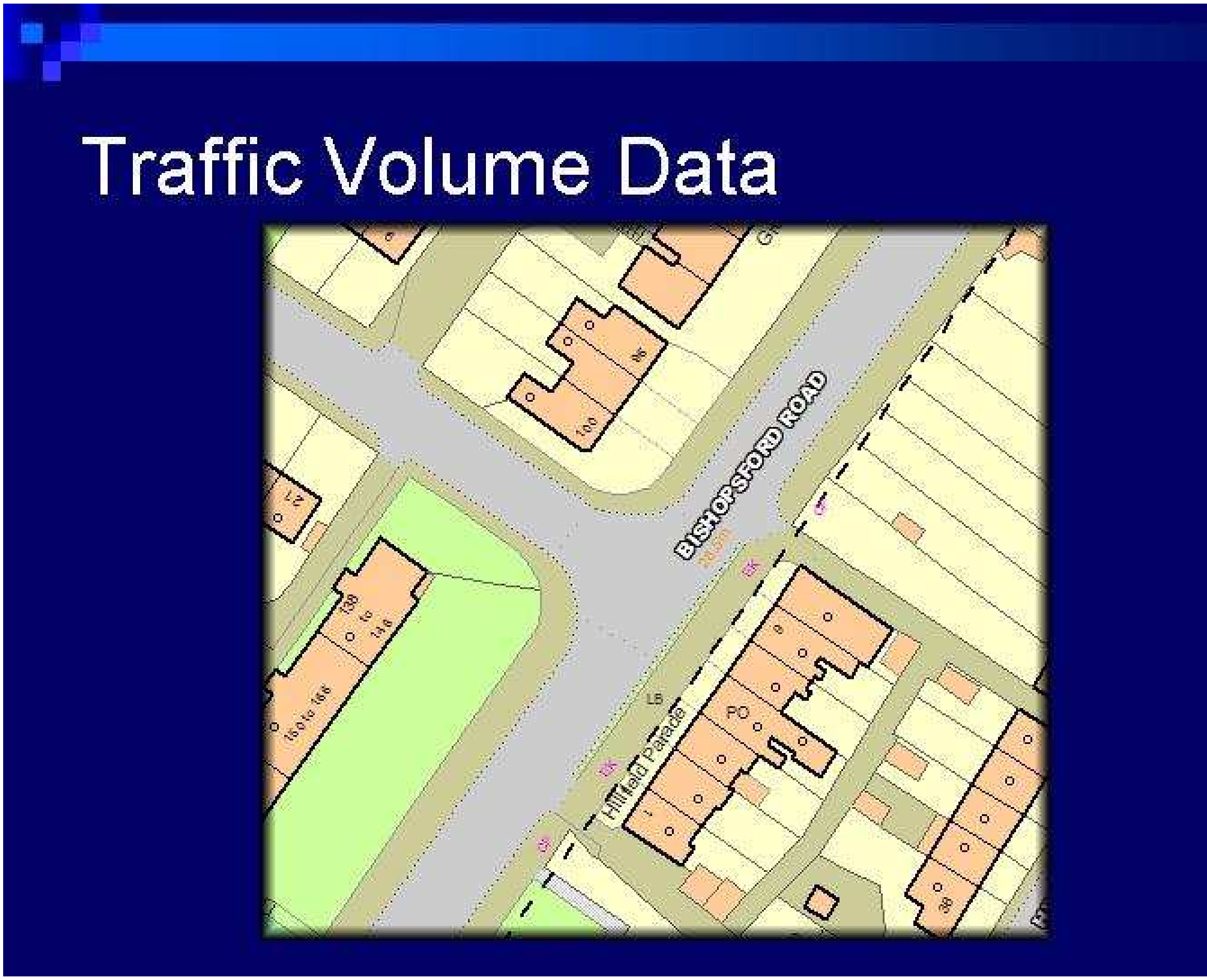

Data Ownership and Sharing
Department A
City Knowledge Approach
Department B
Data
Data
Data
Data
Department C
Department D


Geographic Information Systems (GIS)
A way to relate data to objects on a map
MapInfo Professional - [Trees2,dTrees,...,Merton Map]
File Edit Tools Objects Query Table Options Map Window Help
Info Tool
Central_Asset_Id: 00229641
Species: Ginkgo biloba
Primary_Measurement: 1.00
Site_Name: Bishopsford Road
Centroid_Easting: 526,903.00
Centroid_Northing: 167,411.00
<< >> List
Trees
Zoom: 0.2791 km
Editing: dTrees
Selecting: None

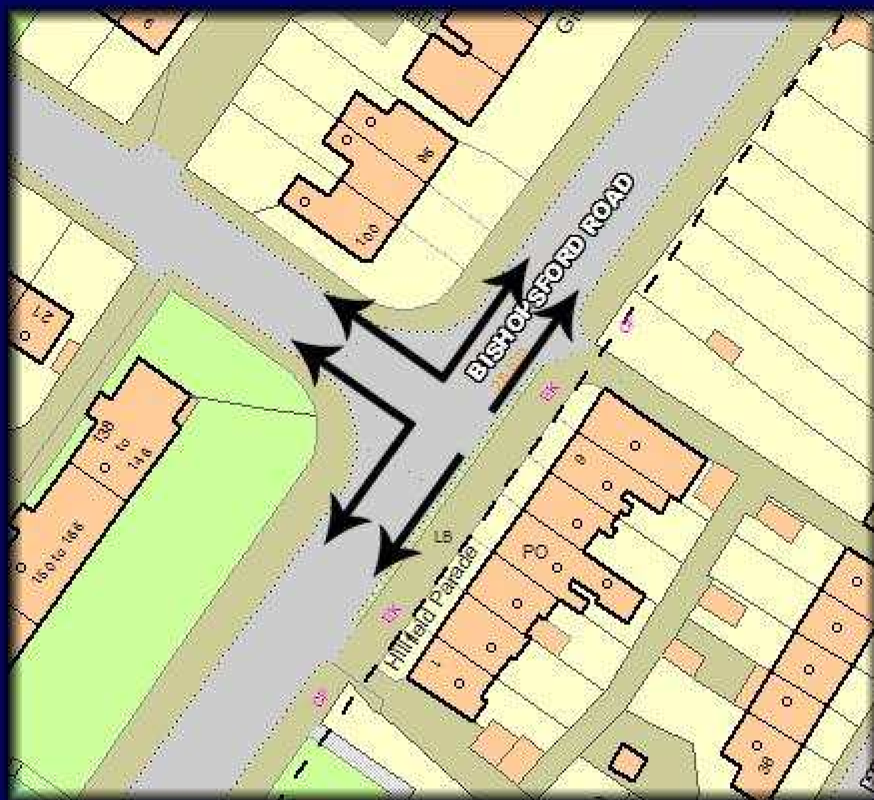

Geographic Information Systems
spatial information
Roads

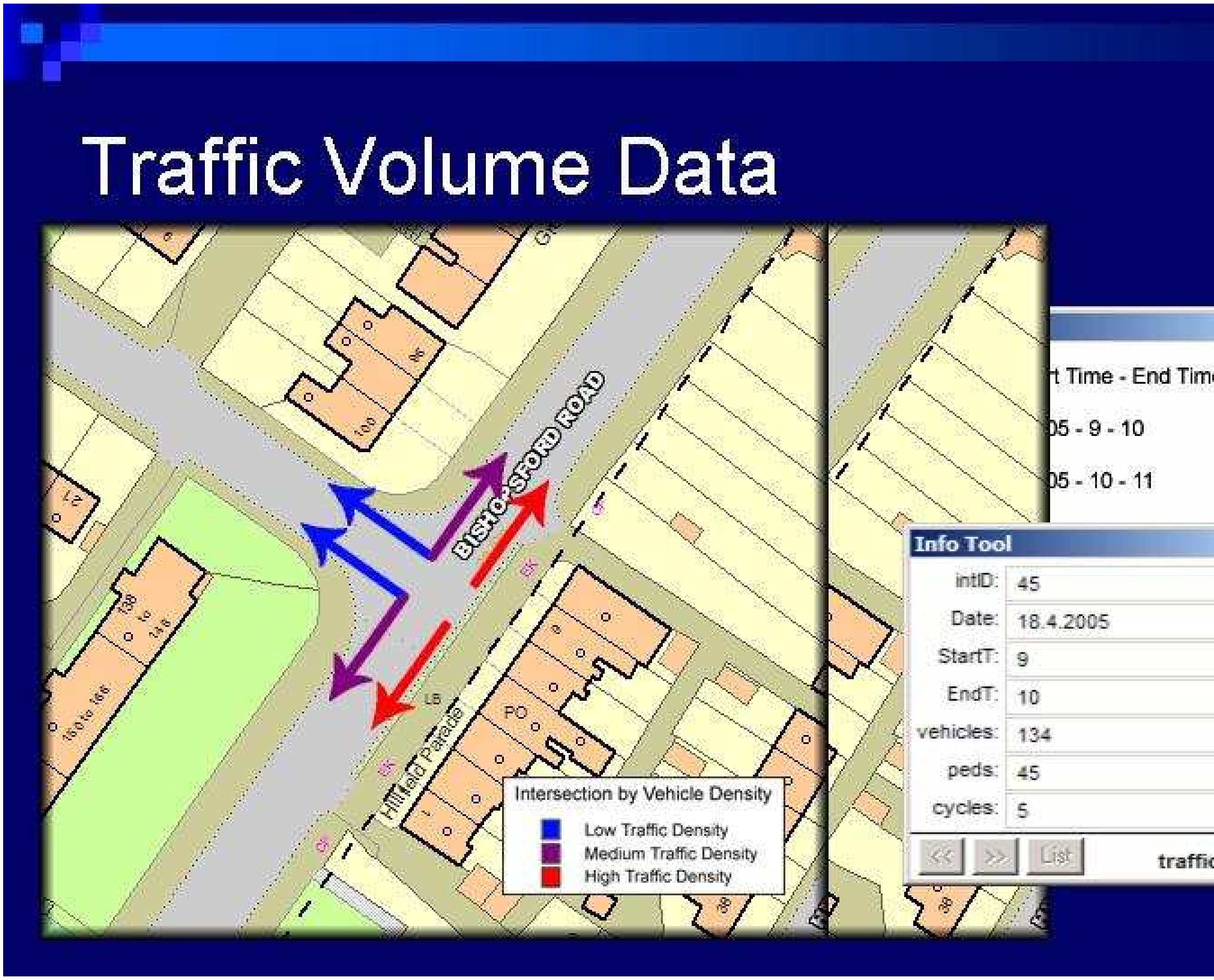
A CK Case Study in Merton

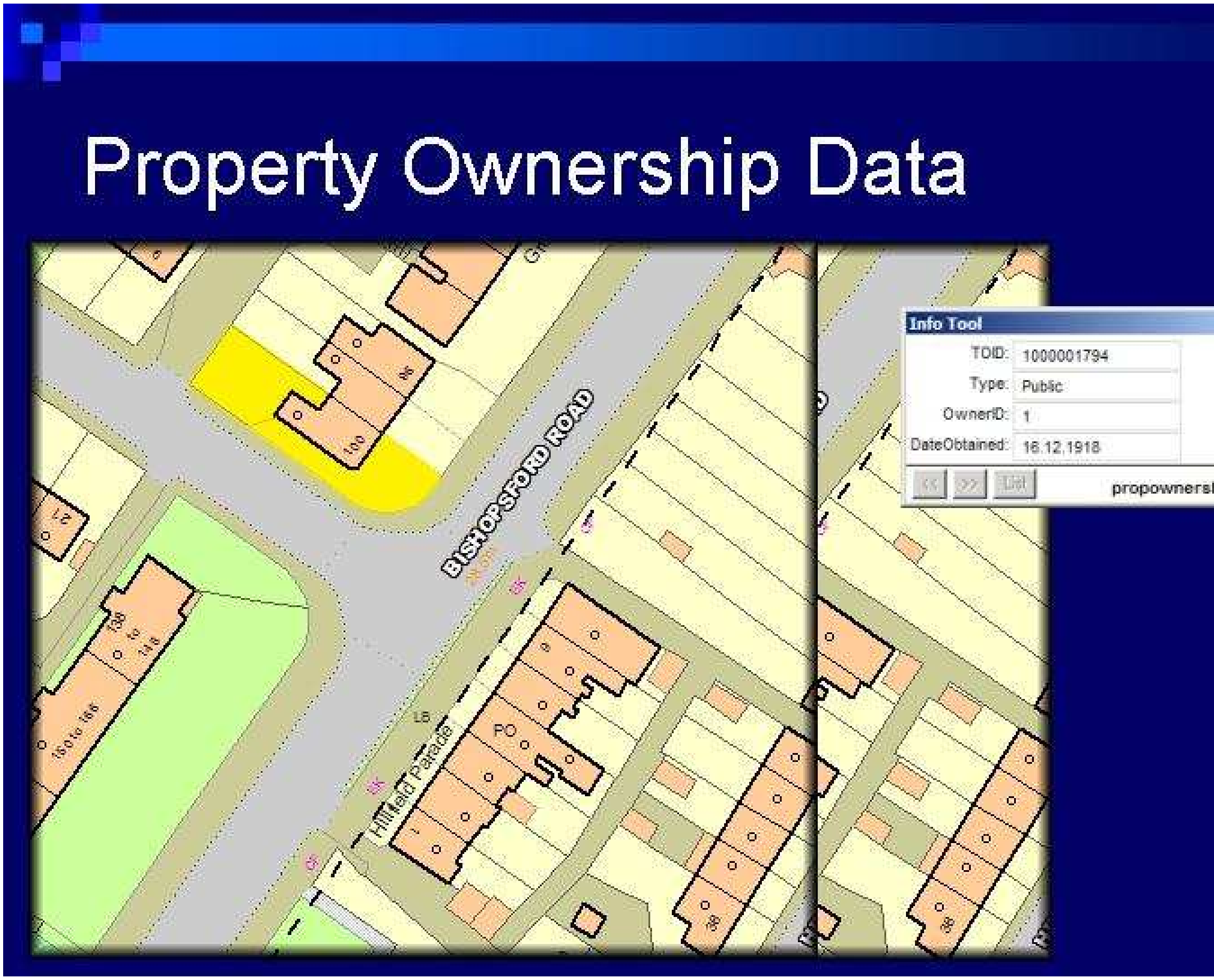
- Assessing potential DHP distribution routes
- Current data management methods compared to the City Knowledge approach


Traffic Volume Data
BISHOPSFORD ROAD
Hillfield Parade
PO
LB
150 to 166
138 to 146
100

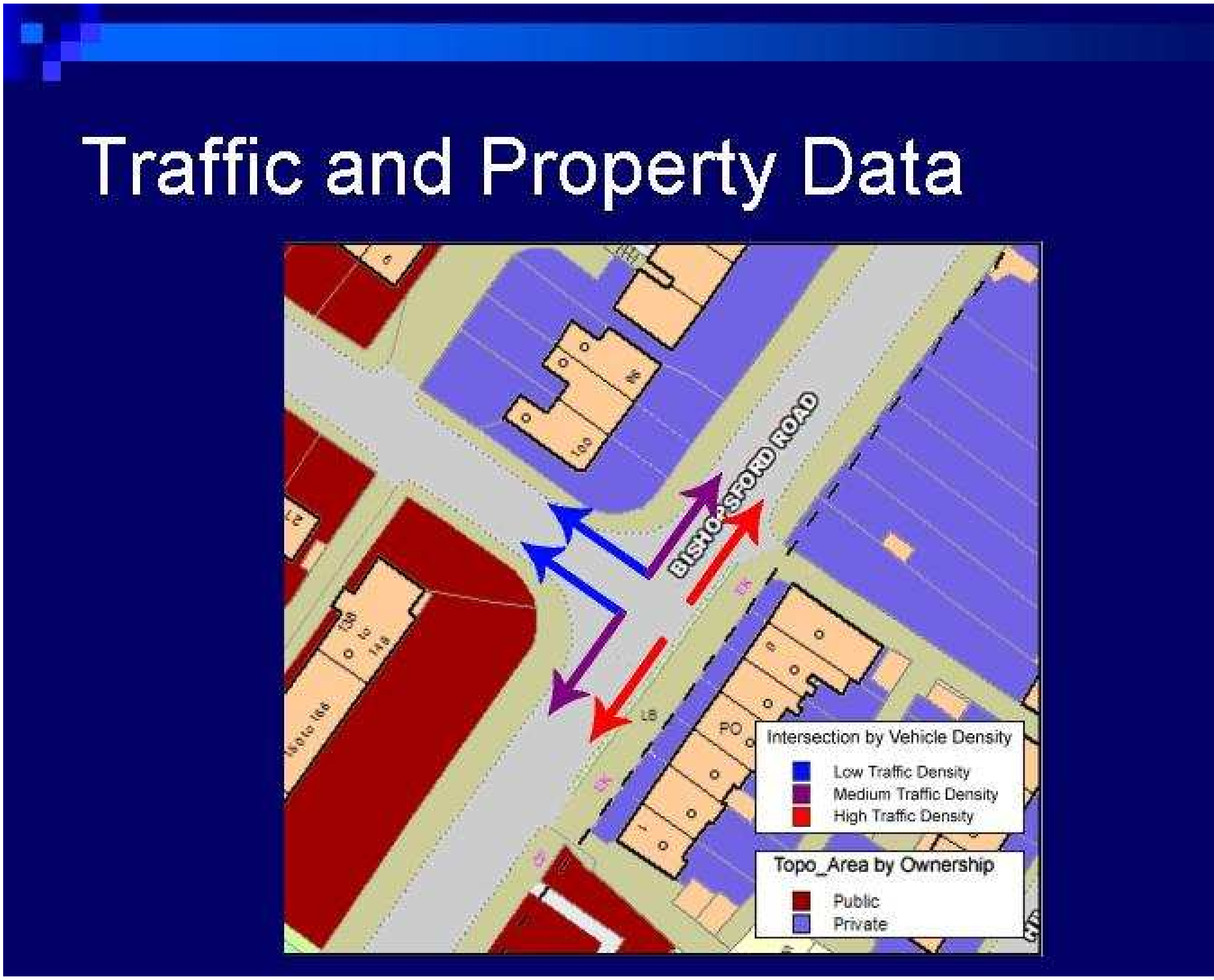
Traffic Volume Data



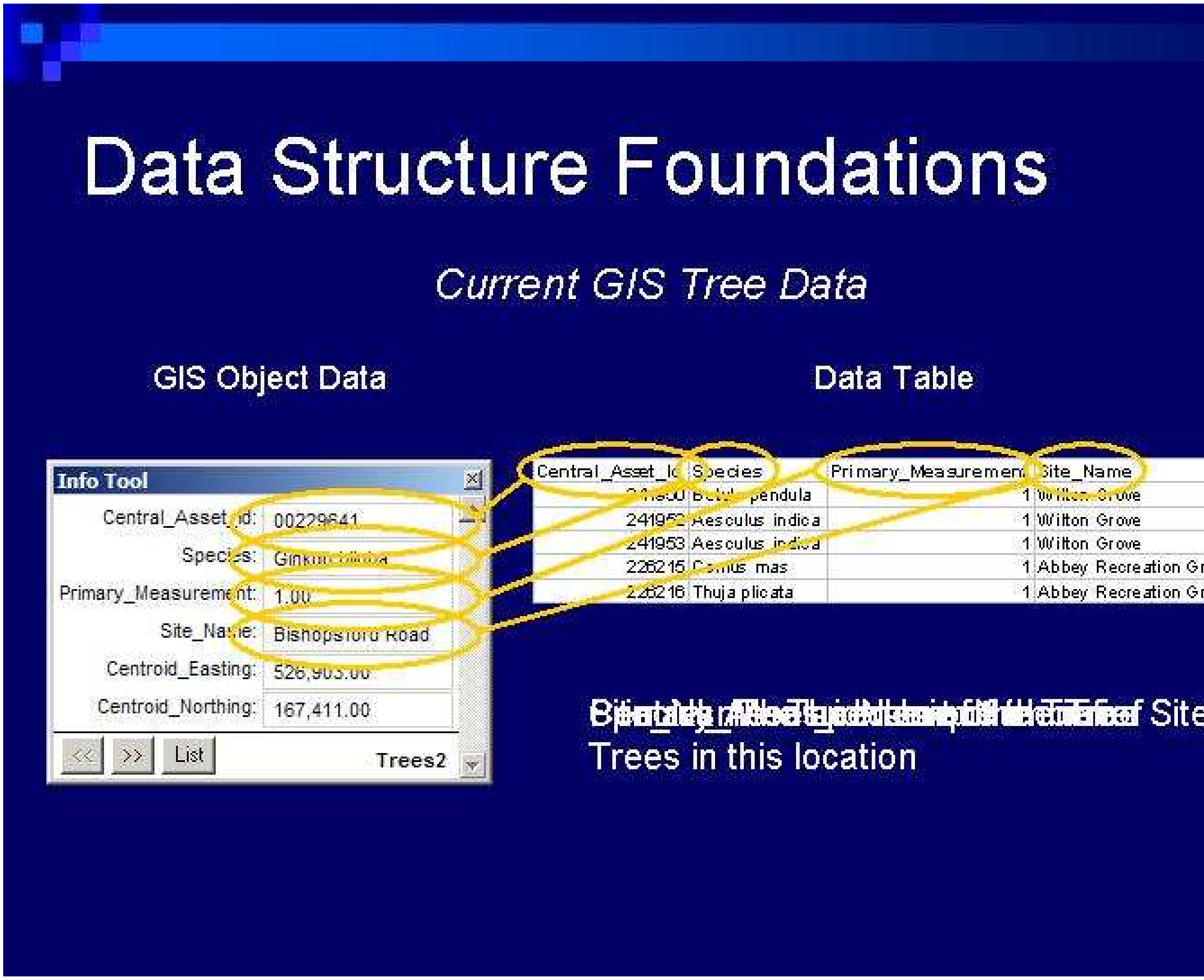

Traffic Volume Data
BISHOPSFORD ROAD
Hillfield Parade
Intersection by Vehicle Density
Low Traffic Density
Medium Traffic Density
High Traffic Density
Info Tool
intID: 45
Date: 18.4.2005
StartT: 9
EndT: 10
vehicles: 134
peds: 45
cycles: 5


Property Ownership Data
Info Tool
TOID: 1000001794
Type: Public
OwnerID: 1
DateObtained: 16.12.1918
List
BISHOPSFORD ROAD
Hillfield Parade
PO
LB


Property Ownership Data
BISHOPSFORD ROAD
PO
LB
Topo_Area by Ownership
Public
Private


Traffic and Property Data
Intersection by Vehicle Density
Low Traffic Density
Medium Traffic Density
High Traffic Density
Topo_Area by Ownership
Public
Private


Our Project
Integrating City Knowledge with Existing Municipal Information Infrastructure
Our Objective:
To start building the foundation of City Knowledge in Merton
Data Structure Foundations

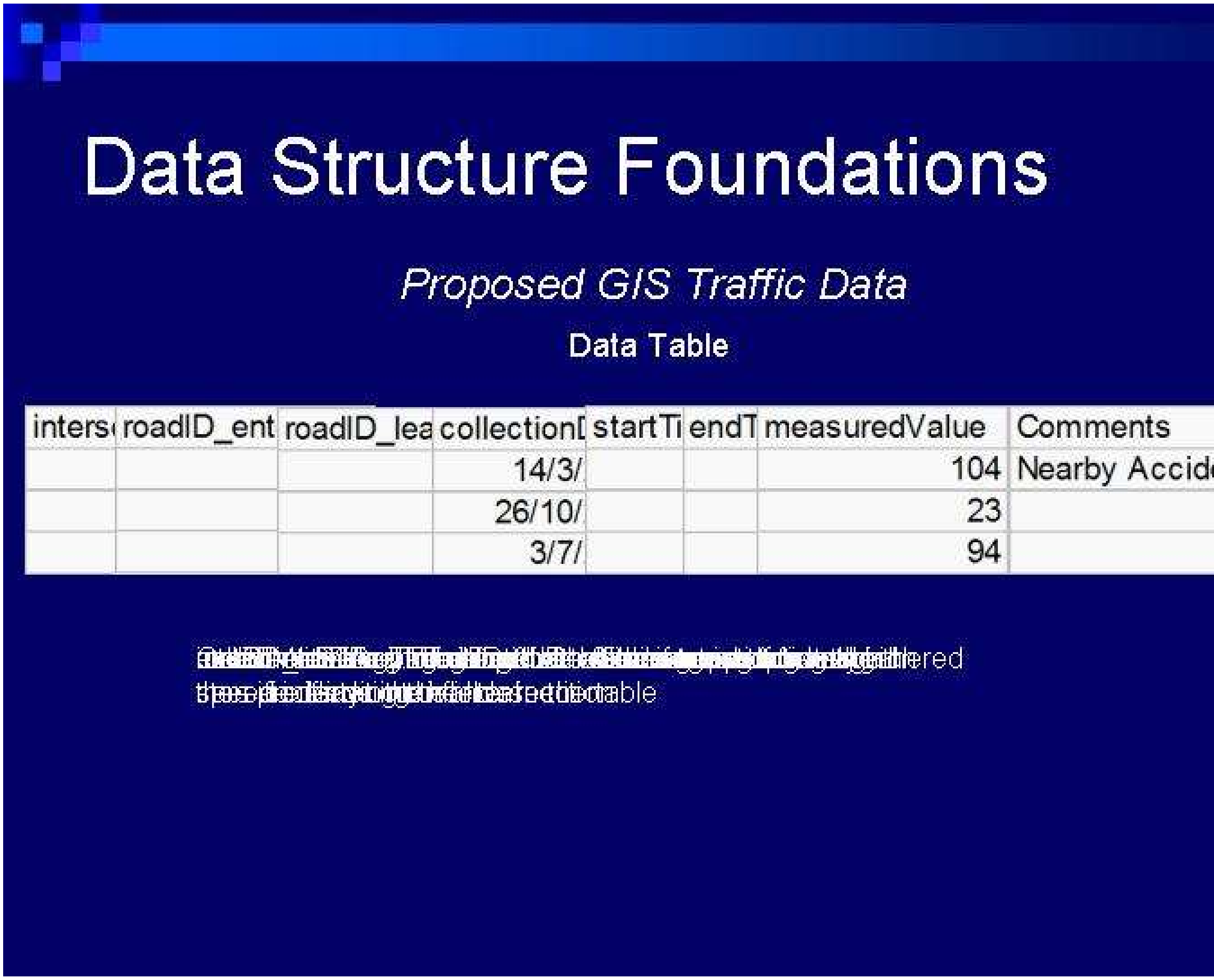

Data Structure Foundations
Current GIS Tree Data
GIS Object Data
Data Table
Info Tool
Central_Asset_id:
Species:
Primary_Measurement:
Site_Name:
Centroid_Easting:
Centroid_Northing:
167,411.00
List
Trees2
Central_Asset_Id
Species
Primary_Measurement
Site_Name
pendula
241952 Aesculus indica 1 Wilton Grove
241953 Aesculus indica 1 Wilton Grove
226215 mas 1 Abbey Recreation Gro
226216 Thuja plicata 1 Abbey Recreation Gro
Trees in this location

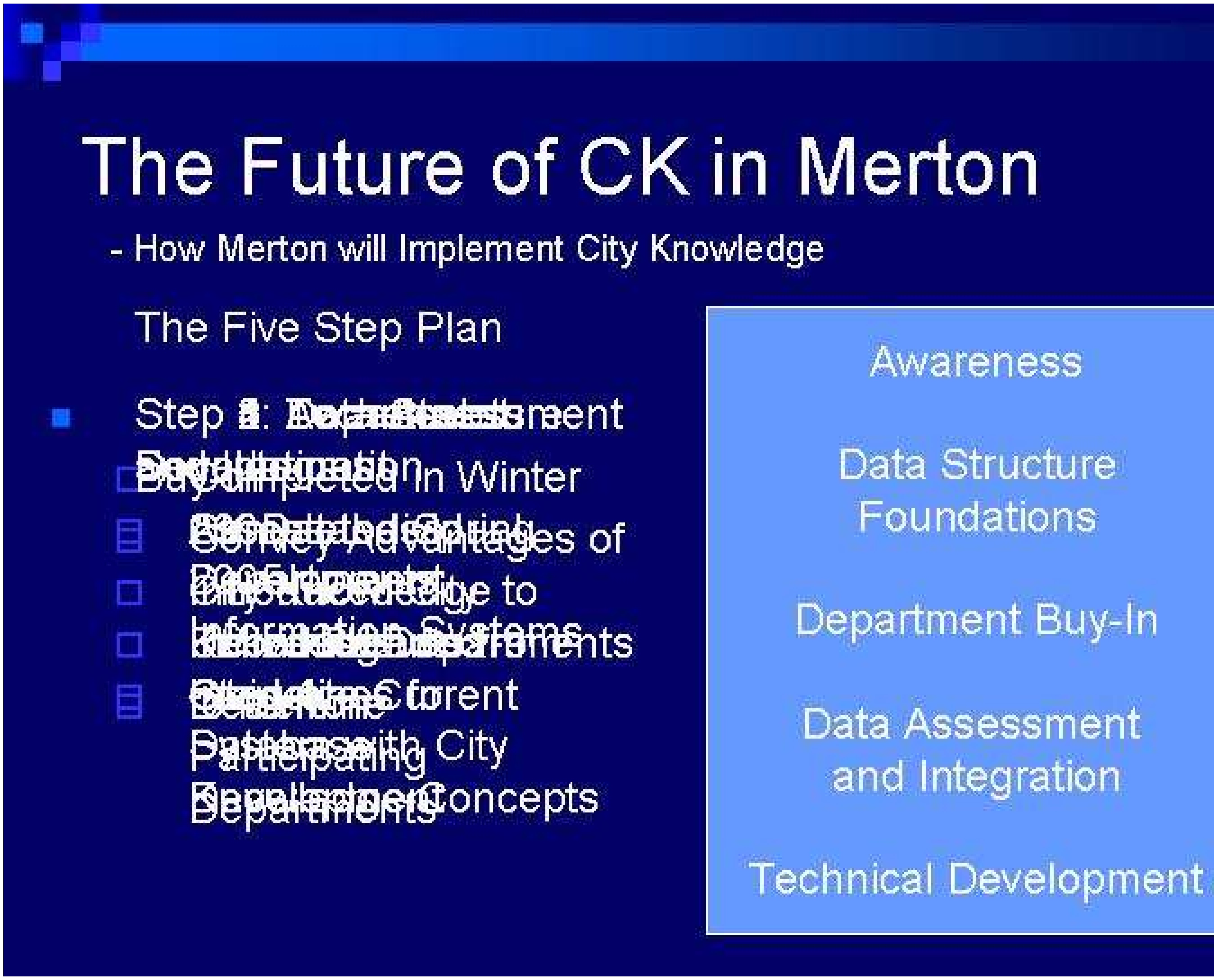
Data Structure Foundations

Current non-GIS Traffic Data

Sample Excel Spreadsheet

Site No: 27154012			Grid Reference: TQ50377,68681								
Site 12, Cranmer Road, Merton (L/C 12)											
Class Report FHWA		Sat 05-Jun-04				Channel: Northbound					
Time Begin	Total Vol.	Bin 1 Motorcycle	Bin 1 %	Bin 2 Cars	Bin 2 %	Bin 3 LGV	Bin 3 %	Bin 4 HGV	Bin 4 %	Bin 5 Buses	Bin 5 %
0:00	43	0	0	39	90.7	3	6.98	1	2.33	0	0
1:00	21	0	0	18	85.71	1	4.76	2	9.52	0	0
2:00	9	0	0	8	88.89	1	11.11	0	0	0	0
3:00	16	0	0	12	75	3	18.75	1	6.25	0	0
4:00	21	2	9.52	18	85.71	1	4.76	0	0	0	0
5:00	41	2	4.88	32	78.05	5	12.2	2	4.88	0	0
6:00	79	2	2.53	57	72.15	12	15.19	7	8.86	1	1.27
7:00	143	4	2.8	111	77.62	21	14.69	7	4.9	0	0
8:00	185	2	1.08	158	85.41	15	8.11	10	5.41	0	0
9:00	198	2	1.01	169	85.35	17	8.59	9	4.55	1	0.51
10:00	211	4	1.9	186	88.15	14	6.64	7	3.32	0	0
11:00	219	3	1.37	198	90.41	10	4.57	8	3.65	0	0
12:00	212	4	1.89	180	84.91	19	8.96	8	3.77	1	0.47


Data Structure Foundations
Proposed GIS Traffic Data
Data Table
inters roadID_ent roadID_lea collectionI startTi endT measuredValue Comments
14/3/ 104 Nearby Accid
26/10/ 23
3/7/ 94


The Future of CK in Merton
- How Merton will Implement City Knowledge
The Five Step Plan
Awareness
Data Structure Foundations
Department Buy-In
Data Assessment and Integration
Technical Development


Questions?