

**Evaluating a Geographic Information System as a Decision Support Tool
for the Michigan Department of Transportation, Environmental Section**

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Abstract

The Michigan Department of Transportation (MDOT) Environmental Section has created a geographic information system (GIS) that organizes and displays large amounts of information from multiple disciplines to facilitate the review of transportation projects. These maps are dynamic and interactive, and allow different types of spatial information to be visualized simultaneously. Over 70 data layers representing statewide framework information and as well as specialized information specific to each specialist are organized into published map files that are viewed using ESRI's ArcReader software. Evaluating the effectiveness of the query interface as a tool for storing, retrieving, and analyzing information is an important but not often explored aspect of a GIS. This study evaluated the usability and effectiveness of the ArcReader maps as a decision support tool, and identified potential ways to improve the system. MDOT staff members found the maps to be a useful tool for their decision making process while reviewing transportation projects. For the majority of map users, the effort to review a job had decreased, the ability to visualize multiple pieces of information simultaneously improved the efficiency of the review process, and the time spent reviewing projects has decreased.

Introduction

For all transportation projects receiving federal dollars, the Michigan Department of Transportation (MDOT) is required to conduct an environmental review for social, economic, and environmental impacts under the National Environmental Policy Act (NEPA) of 1969. The NEPA aims to provide protection to agricultural land, aquifers, threatened and endangered species, recreational land, coastal zone, air quality, and cultural resources (historic and archaeological), among others. The NEPA also stresses public involvement, sustainable development, and a community impact assessment for all transportation projects.

The MDOT Environmental Section is responsible for conducting environmental reviews for all transportation projects. Previously, the Environmental Section was using a system that involved printing out or photocopying various sources of information (road maps, topographic maps, photographs, project plans, etc.), and assembling these pieces of information into a paper study packet. These study packets were a large collection of papers that had to be sorted through, could only be looked at by one person at a time, and could become lost or misplaced.

As each specialist reviewed a job using this study packet, they also used other sources of information specific to their discipline to aid in their reviews that were not available in the study packet. Often these other sources of information were outdated paper maps, scattered online resources, or information from project managers or colleagues in other departments. The use of these study packets for environmental reviews was inefficient and in some cases lacking the best available information.

The need for a more efficient project review method became necessary when new standards were outlined in an early clearance process that was to take effect in February 2009. A geographic information system (GIS) that could organize and display large amounts of information for multiple disciplines would aid in the new early clearance process and facilitate more efficient environmental reviews of transportation jobs. A GIS would allow for all of the information that was available in the paper study packet, along with additional data specific to the specialists' disciplines, to be available in one map. A GIS map would also be dynamic, interactive, and would allow the map users to visualize multiple pieces of information simultaneously. Data visualization is a powerful tool that allows you to explore data, and has the potential to transform the decision making process by allowing new questions to be asked about the data (Mirel, 1998).

To adopt a GIS, MDOT went through several phases including a user needs assessment, data collection, data storage, evaluating software options, and training of staff members. While creating the GIS interface, it was important to avoid overwhelming the decision makers with too much information, and help them to focus on the most relevant data (Speier and Morris, 2003; Mirel, 1998). The maps were created using ArcGIS 9.3 software from the Environmental Systems Research Institute, Inc. (ESRI). Over 70 data layers representing statewide framework information and as well as information specific to each specialist was organized into an ArcGIS map document. The ArcGIS 9.3 Publisher extension was used to publish map files that are viewable using ESRI's ArcReader software (Appendix A). Once MDOT staff became familiar with the maps it was important to evaluate how well they were meeting the users needs.

Evaluating the human-computer interaction (HCI) as well as the usability of the GIS can contribute to the improvement of the system being used, and can open up new ways of understanding what users need and expect from a GIS (Haklay and Tobon, 2003). The working definition for HCI describes it as "a discipline concerned with the design, evaluation, and

implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Haklay and Tobon, 2003). Haklay and Tobon (2003) state that for a (GIS) system to match the user’s requirements, the design and implementation should be influenced by, “the needs, capabilities, and preferences for the way users perform an activity within an environment”. For this approach to be effective it is necessary to have knowledge about the users and the work they need to accomplish so their tasks can be completed effectively and efficiently (Haklay and Tobon, 2003; Mirel, 1998).

The subjective mental workload (SMW) is defined as “the subjective experience of a decision maker and is influenced by a decision maker’s processing strategies, perceptions, and skill level” (Speier and Morris, 2003). The SMW can be examined by looking at performance, effort levels, the amount of time spent, and the level of frustration by users (Speier and Morris, 2003). Task performance can be affected by the SMW experienced by a user. Identifying aspects of the map that affect the SMW can help with identifying ways to change these aspects so that performance can be improved (Cao, et al., 2009). Evaluating the effectiveness of the query interface as a tool for storing, retrieving, and analyzing information is an important but not often explored aspect of a GIS (Speier and Morris, 2003). This study evaluated the usability and effectiveness of the ArcReader maps as a decision support tool, and identified potential ways to improve the system.

Methods

The MDOT is located at the State Transportation Building in Lansing, Michigan. There are 35 staff members within the MDOT Project Planning Division that are involved in the review of transportation projects for social, economic and environmental impacts. Most of these staff members are within the Environmental Section. Sixteen staff members qualified to participate in the study because they had been using the GIS. Data was collected from June 22-July 23, 2009.

Participants were asked to anonymously fill out a paper survey form (Appendix B) asking questions about the data and functionality available in the ArcReader maps, as well as their feelings towards different aspects of using a GIS interface for reviewing transportation projects. Participants were also asked to answer 8 questions (Appendix C) in a confidential face-to-face interview. The interview questions were designed to identify how the ArcReader maps were being utilized by different users, which data layers were most important to their work, and what

data is still missing. A computer with an ArcReader map was available for the participant to refer to during the interview. Answers to the interview questions were recorded in writing by the researcher, except for two questions (#4 and #7) where the participant was asked to place checkmarks next to the data layers they use.

Results

Survey Results

Paper surveys were returned by 15 of the 16 consenting study participants. Survey responses were summarized and grouped by the age of participants to see how the responses varied within and between age groups. Of the 15 surveys, one participant was < 30 years old, four participants were 31-35 years old, three participants were 36-40 years old, two participants were 41-45 years old, four participants were 46 years old or older, and one participant did not mark their age range.

Spatial Ability - Participants were asked to select their experience level with using GIS prior to the implementation of the ArcReader maps at MDOT. Sixty seven percent of participants responded that they were ‘somewhat experienced’ or ‘experienced’ with GIS, while the remaining 33% responded that they had ‘little experience’ (Table 1). When asked to describe the GIS training they received, 20% of participants described it as ‘very satisfactory’ and the remaining 80% described it as ‘satisfactory’. When asked if they would like to receive more training, 7% of participants answered that they ‘strongly agree’, 47% said they ‘agree’, 33% said they ‘disagree’, and 13% said that they were ‘not sure’.

User Perceptions - When asked how they felt about *going to* a GIS-based review system, 93% of participants said that they were ‘excited’ or ‘somewhat excited’. A total of 93% of participants responded that they were ‘excited’ to ‘somewhat excited’ about *using* a GIS-based review system. Ninety three percent of participants were ‘excited’ to ‘somewhat excited’ when asked how they felt about the ArcReader maps after using them. Participants were asked if the ArcReader maps were meeting their expectations, and 87% responded that the maps were ‘very satisfactory’ or ‘satisfactory’, 6.5% responded ‘unsatisfactory’, and 6.5% responded ‘not sure’.

One participant (46+ age range) responded that they were ‘somewhat unexcited’ to go to a GIS-based review system, but changed their response to ‘somewhat excited’ after using the ArcReader maps. Another participant (unknown age range) responded that they were ‘somewhat excited’ to go to a GIS-based review system, but after using the ArcReader maps they became

‘somewhat unexcited’ about using a GIS-based review system. This participant also responded that they were ‘somewhat unexcited’ about the ArcReader maps after using them.

Subjective Mental Workload - Survey results revealed time spent on a single review had ‘greatly decreased’ or ‘decreased’ for 67% of participants, 27% saw ‘no change’, and 13% answered that the time spent ‘increased’ (Table 1). When choosing the answer that best described the amount of effort that was used to complete the review of a job using the ArcReader maps, 53.5% responded ‘very low effort’ or ‘low effort’, 13.5% responded ‘high effort’, and 33% were ‘not sure’ about the amount of effort they used. Participants were asked to describe the amount of effort used to complete a job review using the ArcReader maps as compared to the amount of effort used before using the ArcReader maps. Seventy three percent responded that their effort level ‘greatly decreased’ or ‘decreased’, 13.5% responded that their effort ‘increased’, and 13.5% responded that they were ‘not sure’ how their effort level before ArcReader compared to their effort level with ArcReader.

Two participants felt that the amount of time spent on a review had ‘increased’, the amount of effort they now had to use to review a job was ‘high’, and the effort compared to before ArcReader had ‘increased’ (Table 1). Both participants described themselves as having little experience with GIS. The difference between these two participants was their age range (31-35 and 41-45) and their frustration level. The participant in the 31-35 age range felt ‘little frustration’, while the 41-45 year old felt ‘frustrated’ while using the maps. In total, 80% of participants responded that they felt ‘no frustration’ or ‘little frustration’ when using the ArcReader maps, 7% felt ‘frustrated’, and 13% responded that they were ‘not sure’ how they felt.

Table 1. Responses by age group for survey questions 12, 24, 25, and 26 (Appendix B)

Responses	Age Ranges						Sum
	?	<30	31-35	36-40	41-45	46+	
Experience level with GIS							
Very experienced							0
Experienced						1 1	2
Somewhat experienced		1	1 1 1	1 1			8
Little experience	1			1	1 1		5
No experience							0
How has the amount of time spent changed							
Greatly decreased			1	1 1	1		5
Decreased		1	1	1		1	4
No change	1		1			1 1	4
Increased				1	1		2
Greatly increased							0
Describe the amount of effort to review a job using ArcReader							
Very low effort			1				2
Low effort			1 1	1 1		1 1	6
High effort				1	1		2
Very high effort							0
Not sure	1	1		1	1	1	5
Effort with ArcReader compared to effort before ArcReader							
Greatly decreased effort							1
Decreased effort	1	1	1 1 1	1 1	1	1 1	10
Increased effort				1	1		2
Greatly increased effort							0
Not sure				1		1	2
How do you feel when using ArcReader							
No frustration			1	1	1	1 1	5
Little frustration		1	1 1 1	1 1		1	7
Frustrated					1		1
Very frustrated							0
Not sure	1					1	2

The survey used two separate questions to ask about the participant’s ability to make decisions with the ArcReader maps. Sixty seven percent of the participants responded that their ability to make decisions about job reviews ‘greatly improved’ or ‘improved’, and 33% responded ‘not sure’. When asked if the ArcReader maps and the data they provide have improved their ability to make decisions, 67% said they ‘strongly agree’ or ‘agree’, 13% ‘disagree’, and 20% were ‘not sure’. When asked to describe the confidence level felt in their decision to clear or deny clearance of a job after using the ArcReader maps, 20% of participants responded that they felt ‘very confident’, 67% felt ‘confident’, and 13% were ‘not sure’.

Query Interface - Data Display and Map Functionality - Participants were asked if they found it distracting to have the data layers for the other specialists in the map. Seventy four percent responded that they ‘strongly disagree’ or ‘disagree’ that the data layers are distracting, 6% ‘strongly agree’, and

20% were 'not sure'. The participant that strongly agreed that the data layers for the other specialists are distracting fell into the age range of 41 to 45 years old, and described themselves as having little experience with GIS. The speed/performance level that the ArcReader maps delivered information was 'very satisfactory' or 'satisfactory' to 86.5% of participants, and 'unsatisfactory' to 13.5%. Those that found the speed/performance level to be unsatisfactory fell into the age range of 31 to 35 years old.

Participants were asked how important it was to have the ability to print maps, create Adobe PDF files of maps, and to create markups on the maps. They were also asked how often they have performed these functions in the GIS (Table 2). The majority of participants (86%) felt that it was 'very important' or 'important' to be able to print maps, create Adobe PDF files of the maps, and to create markups on the maps. One participant did not mark an answer for this question as indicated by an asterisk (*) in the table. When asked how often they printed maps, created Adobe PDF files of maps, or created markups on maps in ArcReader, the majority of participants (80%) said that they 'sometimes', 'rarely', or 'never' perform these functions (Table 2).

Table 2. Importance vs. frequency of printing maps, creating Adobe PDFs, and creating markups on maps

	Age Ranges						Sum	
	?	<30	31-35	36-40	41-45	46+		
How important is it to be able to:								
Print maps								
Very important	1		1	1	1	1	1	8
Important		1	1	1		1	1	5
Unimportant								0
Very unimportant								0
Not sure				1				1
Create Adobe PDF files of the maps								
Very important	1	1	1	1	1	1	1	9
Important			1	1		1	1	4
Unimportant								0
Very unimportant								0
Not sure				1				1
Create markups on the maps								
Very important		1	1	1	1	1	1	8
Important	1			1		1		4
Unimportant			1					1
Very unimportant								0
Not sure				1				1
How often do you:								
Print maps								
Always								0
Frequently				1		1		2
Sometimes		1	1	1	1	1	1	7
Rarely					1		1	4
Never	1							2
Create Adobe PDF files of the maps								
Always								0
Frequently		1		1		1		3
Sometimes			1	1	1	1	1	6
Rarely					1		1	4
Never	1							2
Create markups on the maps								
Always								0
Frequently		1				1		2
Sometimes			1	1	1	1	1	6
Rarely					1		1	4
Never	1		1	1				3

* No response was given.

Participants were then asked if the GIS provided a decision-making environment in which they were able to display and analyze spatial data and its corresponding attribute information. Eighty six percent answered they ‘strongly agree’ or ‘agree’, 7% said they ‘disagree’, and 7% were ‘not sure’. Forty percent of participants responded that they ‘strongly agree’ that the GIS allowed them to visualize multiple pieces of information simultaneously, 53% responded that they ‘agree’, and 7% responded that they were ‘not sure’. When asked if being able to visualize multiple pieces of information simultaneously

allowed them to understand the relationships between the data, 20% of participants responded that they ‘strongly agree’, 73% ‘agree’, and 7% were ‘not sure’.

Data Quality and Usability - General data quality was ‘very satisfactory’ to 27% of participants and ‘satisfactory’ to the remaining 73%. When asked to describe the usability of the data, 80% responded that the data was ‘easy to use’, while the remaining 20% described it as ‘very easy to use’. Participants were asked to describe how well they understood the data, and 67% responded that it was ‘easy to understand’, 20% said that it was ‘very easy to understand’, 6.5% found it ‘hard to understand’, and 6.5% responded that they were ‘not sure’.

Interview Results

Face to face interviews were conducted with all 16 participants. When asked to describe the role the ArcReader maps play in their work, nine of the participants responded that they use the maps to see where potential impacts are in relation to the project limits so they can identify specific areas of concern. Six of the participants said that the ArcReader maps provided them with the project limits (give accurate beginning and ending mile points). Two participants responded that the ArcReader maps helped them orient themselves to the area, and three participants responded that they use the maps to get a general overview (of the project area) so they can know ahead of time about any potential issues. Three participants responded that the ArcReader maps allow them to turn on layers that are most relevant to their review. Two participants responded that the ArcReader maps are another tool that they can use for their work, which includes communicating with others. One participant responded that the ArcReader maps allow them, “to create attractive, colorful, and accurate maps that I can share electronically with MDOT project managers and other agency partners”.

Participants were then shown a list of the 77 available data layers in the ArcReader maps and asked to mark the ones they use (Table 4). Of the 77 data layers available in the ArcReader maps, sixteen of the layers are utilized by nine or more users. Five data layers were not used by any of the participants (source water protection areas, wellhead protection areas, management plans-Rabbit River, management plans-nested, management plans-base). Participants were also asked to name additional data layers that they would like to have added to the ArcReader maps (Table 5).

Table 4. Summary of number of users that utilized each data layer

Data Layer	# of users	Data Layer	# of users
All roads	15	Critical dune	3
Topographic maps	15	Archaeo deep site potential	3
Aerial photos	15	Archaeological sites	3
Trunkline	14	Private land	3
Railroad	13	County_Local land	3
City	13	Scenic Heritage Routes 09	2
Plat maps	13	Lead paint bridges	2
Township	12	Superfund sites	2
Village	12	Section 111	2
Natural rivers	11	Section 115	2
County	11	Section 201	2
Sections	10	Section 615	2
Town Range	10	LUST	2
5 year plan points	9	Public access recreation points	2
5 year plan lines	9	Snowmobile trails	2
Wild & Scenic rivers	9	Stream baseflow	2
Bridge	8	Watershed mgt plans	2
5 year plan polygons	8	Watersheds all	2
Natural tributaries	7	Biot_1985_clip	2
Lake polygons	7	Exploded buffers	2
Urban	7	High risk erosion areas	2
Federal land	7	Coastal barrier resources	2
Wetlands	7	Designated dune	2
Parks all polygons	6	Piping plover habitat units	2
Designated streams	6	Kirtland warbler units	2
Trout streams	6	Ecological reference areas	2
Hydro lines	6	Conservation land	2
State land	5	PA 116	2
Historic bridges	4	Circa 1800 LC	2
Landmark	4	Tribal lands (treaty boundaries)	2
Parks all points	4	Water intakes	1
Redbook sites	4	Environmental areas	1
CZM areas	4	Special management areas	1
Natural areas	4	Source water PA	0
State wildlife areas	4	Wellhead PA	0
Recreation trails	3	Mgt. plans Rabbit River	0
Recreation land	3	Mgt. plans nested	0
Drains	3	Mgt. plans base	0
Hines emerald	3		

Table 5. Additional data layers

- Census data (socio-economic data)
- All historic sites
- Birds eye view aerial photographs (Bing.com)
- Google street view (Google.com)
- MDOT photo log
- Soils
- Archaeological sites with attributes
- General Land Office historic plat maps
- Michigan Natural Features Inventory (MNFI) database
- PA 116 for the rest of the state
- Local zoning maps
- Local planning data
- Sufficiency data (Average Daily Travel, Level of Service)
- Warm and cold water stream classifications
- Bridge ID numbers
- Land and water conservation grand fund lands shapefile
- More complete parks data
- Wildlife layers (migratory bird information for bridges and culverts)
- National register sites
- Historic district boundaries

Participants were asked to give their feelings on the adequacy of the symbology (symbol color, shape, size, and contrast) in the ArcReader maps by choosing a multiple choice answer (Table 6) and then explaining their answer. The majority of map users found the symbology to be ‘adequate’ or ‘somewhat adequate’. Participants’ comments about the symbology were summarized and separated into pros and cons (Appendix D). Map users were asked how the ArcReader maps have affected their work, along with how things changed since they began using the ArcReader maps. Responses were summarized and then categorized into pros and cons (Appendix E).

Table 6. Adequacy of the symbology

Adequate	11
Somewhat adequate	4
Somewhat inadequate	0
Inadequate	0
Not sure	1

Discussion

This study identified the spatial ability, user perceptions, and data needs for the way they wish to perform activities within a GIS environment. The SMW is influenced by these factors and can be evaluated by looking at the map users’ effort levels, time spent, and frustration levels. Even though all of the participants within each age range had some level of experience using GIS, the majority of participants said that they would like to receive more training on how to use the maps. This could suggest

that as the map users become more familiar with the GIS that they want to learn more so they can utilize its full capabilities.

Thirteen interview participants commented that the ArcReader maps have made their work faster or more efficient, or has saved them time (Appendix E). Survey responses supported this, although two map users found the opposite to be true for them. The same two map users that said that the maps increase the amount of time it takes them to do their work also said that their effort levels were high. Experience level with GIS is the likely reason why these two map users felt that the time spent on a review and effort levels had increased. Speier and Morris (2003) state that, “given the graphical nature of many of these query interfaces, spatial ability may be an important individual skill that moderates one’s performance with visual tools”. The less familiar the environmental is, the longer it may take to adapt to the new system. It appeared that for some, getting used to the new system has been ‘tedious’ and has slowed down the process for them (Appendix E), which can lead to higher frustration levels. Hopefully as the system is improved upon and as the users get more experience navigating the maps the review process will be faster for everyone. For the majority of map users, the time spent, effort level, and frustration level do not seem to be major factors affecting their SMW.

Two separate questions asked the map users if the ArcReader maps improved their ability to make decisions, and both times survey participants responded that their ability to make decisions was improved, showing that the maps have been an effective decision making tool. The majority of map users also responded that the confidence level in their decision making was ‘very confident’ or ‘confident’, which suggests that having the data they need to do a thorough review of a project is facilitating their decision making process.

When the number of users of each data layer was tallied it revealed that over half of the 77 data layers are being used by three or more people, which indicated that these data layers provided useful information to the map users. The five data layers that are not currently being used by any of the study participants should be evaluated further to see if they have any value to the map users or if they should be removed from the maps. Removing the three unused tools (go to XY, swipe and export markup) could make the interface more user friendly by giving them fewer buttons to choose from. However, survey responses indicate that having the tools/ability to do certain functions (e.g. creating markups, exporting PDFs) within the ArcReader maps is quite important to map users, even if those tools are not often utilized (Table 2).

The survey revealed that most of the map users thought the symbology made it easy to distinguish between the different layers in the map (Table 6). But, when map users were asked to comment on the map symbology during the interviews, a number of areas needing improvement were identified (Appendix D). The circa 1800 land cover, archaeology deep site potential, and the 5 year plan are

shapefiles where the data is displayed using several colors to represent different categories of data. The circa 1800 land cover data symbology was said to be “overwhelming” and it is hard to distinguish between all of the colors. The archaeology deep site potential shapefile symbology uses three similar colors for the top three categories. These three colors can be adjusted to create more contrast. The 5 year plan shapefiles represent project locations using solid red points, lines, and polygons. When project locations change (e.g. the extent of the project increases) these features are symbolized using a red and black checkered line for line features, and a black circle with a red cross inside it for point features. During the interviews, one participant said that this symbology was “quite useful”, while another participant commented that this symbology didn’t stand out to them. Further evaluation of the 5 year plan symbology should be done to see if it is working for the majority of the maps users or if modifications should be made.

The majority of map users answered that they ‘strongly agreed’ or ‘agreed’ that all of the data they needed was in the ArcReader maps, but at the same time responded that they still use external information sources. This suggests that even though the map users said they have all of the information they need in the ArcReader maps, data gaps still exist for the majority of users. When the interview participants were asked to name additional data layers they would like to have added to the maps, only one person responded that they had no data to request which reaffirms that there is data missing from the maps for the majority of the map users. Of the twenty different data layers requested (Table 5), some are readily available, while others do not yet exist or it is unknown if they exist. Some data layers may only be available for portions of the state, for example, not every local government has local zoning or planning information available in a GIS format. Online resources, such as the historic plat maps from the General Land Office (GLO), can be made available in the maps through hyperlinks. Data layers that are available in shapefile format can easily be added to the maps in the same way as the existing data layers.

Since they began using the ArcReader maps, interview participants said that the data they need is now conveniently located in one place. Not all of the data they need is in the ArcReader maps, but now they have the ability to look at multiple layers simultaneously which they were not able to do with the paper study packets (Appendix E). Survey responses showed that the majority of map users did not find the data layers for the other specialists distracting, suggesting that the data is being presented in a way that works for most users. For those that did find the other specialists’ data layers distracting, perhaps as their spatial ability increases their level of distraction will decrease.

Drawbacks and limitations to using the ArcReader maps were also identified during the interviews. One participant commented that looking at projects with multiple locations “can be hard”. This is where additional training may be beneficial to remind the map users to use the bookmark tool which will zoom the map view to each project location automatically. Another participant was concerned

with how fast the maps refresh. Aerial photographs can be slow to load because they are accessed through an internet map server (IMS) at a remote location. Data stored on the local server is not being managed with a relational database management system (RDMS), and therefore data load times can be slower especially if multiple users are trying to access data at the same time.

Several positive outcomes of the ArcReader maps were identified by the map users during the interviews. One map user responded that they now use a lot less paper, which was one of the goals of the new process. With the GIS, multiple users can now look at project locations at the same time whereas before only one person at a time could be looking at a paper study packet. One map user commented that they “think (the GIS) is a very useful tool that will definitely streamline how we do environmental clearance”. Another map user commented that, “it really has sped up my reviews. It's one of the first things I look at now”. These comments show that the use of ArcReader has been a positive change that has proved to be an effective decision support tool.

Conclusion

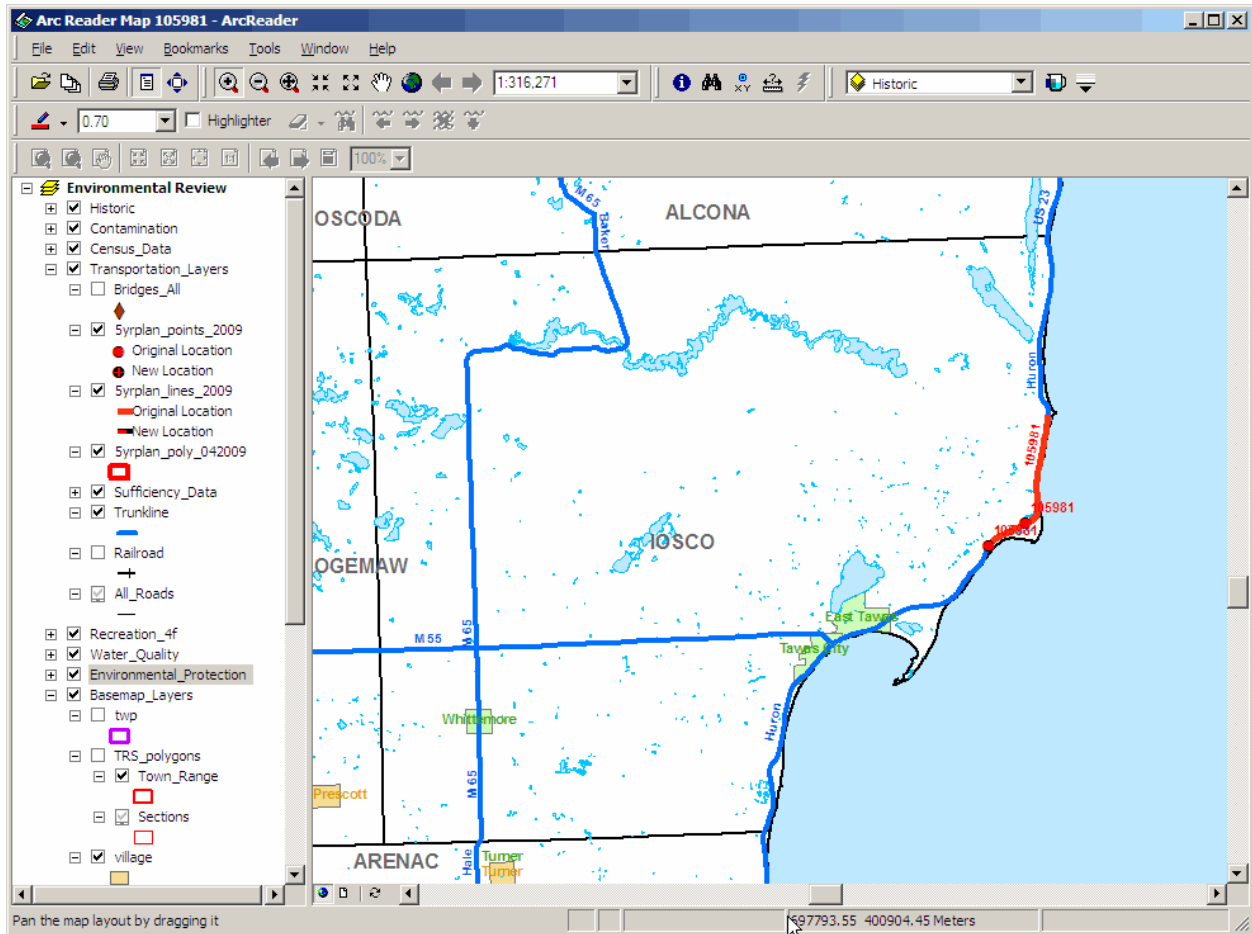
With the continually increasing amount of spatial data that is available, a GIS acts as a tool to allow the storage, retrieval, and querying of large amounts of data (Speier and Morris, 2003). Inexperienced GIS users can easily be overwhelmed by too much information. It is important to be aware of the spatial ability of your map users, how your map users need to be able to use the GIS for their work (Haklay and Tobon, 2003), and if the data they need is available. Each map user will see and interact with the query interface in their own way, so it is a continual challenge to create a map that will meet everyone’s needs. Evaluating the human-computer interaction and the usability of the GIS is important so that you can continually work to improve the GIS and therefore the subjective mental workload of the maps users.

This evaluation of using GIS as a decision support tool at MDOT has demonstrated that people with different experience levels and different amounts of resistance to using GIS can find it to be a useful tool for improving their decision making process. For the majority of map users the effort to review a job decreased and the ability to visualize multiple pieces of information simultaneously improved the efficiency of the review process. Time spent reviewing projects decreased, and the process became more efficient. Adding additional data that the map users need will be important to improving the system. Working on displaying all of the data in a way that makes it accessible to multiple users is another important part of improving the usability of the system. It is also important to keep the map users involved in the process since they are the target audience (Haklay and Tobon, 2003). The map evaluation phase is an iterative process that should be employed so that you may stay in touch with the changing needs of the map users and continue to improve the GIS.

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Appendix A – The ArcReader Query Interface



Appendix B – Survey Questions

1. Please select your age

< 30 31-35 36-40 41-45 46+

2. Please rank your experience level with using Geographic Information Systems (GIS) prior to the implementation of the ArcReader maps

5-Very experienced 4-Experienced 3-Somewhat experienced 2- Little experience 1-No experience

3. Please select the answer that describes how you felt about going to a GIS-based review system

5-Excited 4-Somewhat excited 3-Somewhat unexcited 2- Unexcited 1-Not sure

4. Now that you have been using the ArcReader maps, how do you feel about using a GIS-based review system?

5-Excited 4-Somewhat excited 3-Somewhat unexcited 2- Unexcited 1-Not sure

5. Please select the answer that best describes how you feel about using the ArcReader maps

5-Excited 4-Somewhat excited 3-Somewhat unexcited 2- Unexcited 1-Not sure

6. All of the data that you need to complete your review of a job is available to you in the ArcReader maps

5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure

7. How often do you still use data/information sources from the old review process because they are not available in the ArcReader maps?

5-Never 4-Rarely 3-Sometimes 2- Frequently 1-Always

8. The quality of the data that is currently available in the ArcReader maps is generally

5-Very satisfactory 4-Satisfactory 3-Unsatisfactory 2-Very unsatisfactory 1-Not sure

9. Please select the answer that best describes the usability of the data in the ArcReader maps

5-Very easy to use 4-Easy to use 3-Hard to use 2-Very hard to use 1-Not sure

10. Please select the answer that best describes how well you understand the data in the ArcReader maps

5-Very easy to understand 4-Easy to understand 3-Hard to understand 2-Very hard to understand 1-Not sure

11. In the ArcReader maps, the symbology used to represent the data (symbol color, symbol shape, layer transparency) make it easy to distinguish between the different data sets

5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure

12. How has the amount of time you spend on a single review changed since you began using the ArcReader maps?

5-Greatly decreased 4-Decreased 3-No change 2-Increased 1-Greatly increased

13. Do you feel that your ability to make decisions about job reviews with the ArcReader maps has

5-Greatly improved 4-Improved 3-Worsened 2-Greatly worsened 1-Not sure

14. Describe the confidence level you feel in your decision to clear or deny clearance of a job after using the ArcReader maps

5-Very confident 4-Confident 3-Unconfident 2-Very unconfident 1-Not sure

15. Are the ArcReader maps meeting your expectations?

5-Very satisfactory 4-Satisfactory 3-Unsatisfactory 2-Very unsatisfactory 1-Not sure

16. When looking at the ArcReader maps, do you find that having the data layers for the other specialists is distracting?

5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure

17. **The speed/performance level at which the ArcReader maps deliver information to you could be described as**
5-Very satisfactory 4-Satisfactory 3-Unsatisfactory 2-Very unsatisfactory 1-Not sure
18. **The tools available in the ArcReader maps (zoom, pan, identify, find, etc.) allow you to explore the data and its attributes in all of the ways you would like to**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
19. **It is clear how the tools in the ArcReader maps (zoom, pan identify, find, etc.) can be used for exploring the data and its attributes**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
20. **In the ArcReader maps, how important is it to have the ability to:**
- print maps _____
- create Adobe pdf files of the maps _____
- create markups on the maps _____
5-Very important 4-Important 3-Unimportant 2-Very unimportant 1-Not sure
21. **From the ArcReader maps, how often have you:**
- printed maps _____
- created Adobe pdf files of the maps _____
- created markups on the maps _____
5-Always 4-Frequently 3-Sometimes 2-Rarely 1-Never
22. **The training you received on how to use the ArcReader maps was**
5-Very satisfactory 4-Satisfactory 3-Unsatisfactory 2-Very unsatisfactory 1-Not sure
23. **I would like to receive more training on how to use the ArcReader maps**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
24. **Please choose the answer which best describes how you feel when using the ArcReader maps**
5-No frustration 4-Little frustration 3-Frustrated 2-Very frustrated 1-Not sure
25. **Please choose the answer which best describes the amount of effort you must use to complete the review of a job using the ArcReader maps**
5-Very low effort 4-Low effort 3-High effort 2-Very high effort 1-Not sure
26. **Please choose the answer which best describes the amount of effort you must use to complete the review of a job using the ArcReader maps as compared to the amount of effort used before you had the ArcReader maps**
5-Greatly decreased effort 4-Decreased effort 3-Increased effort 2-Greatly increased effort 1-Not sure
27. **The ArcReader maps provide you with a decision-making environment in which you are able to display and analyze spatial data and its corresponding attribute information**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
28. **The ArcReader maps allow you to visualize multiple pieces of information simultaneously**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
29. **When you are able to visualize multiple pieces of information simultaneously in the ArcReader maps it allows you to understand the relationships between the data**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
30. **The ArcReader maps and the data they provide to you have improved your ability to make decisions**
5-Strongly agree 4-Agree 3-Disagree 2-Strongly disagree 1-Not sure
31. **Use the space below for additional comments**

Appendix C – Interview Questions

1. Briefly describe in a few sentences the role that the ArcReader maps play in your work.

2. Open an ArcReader map and show me which data layers you turn on first. Briefly describe why you are interested in those layers during the initial examination of a job location.

3. Place an X next to the data layers that you use in the ArcReader maps (even data layers that you have only used a few times)

HISTORIC

- Historic Bridges
- Landmark
- Scenic Heritage Routes 09

CONTAMINATION

- Lead Paint Bridges
- Superfund Sites
- Section 111 (Hazardous Waste)
- Section 115 (Solid Waste)
- Section 201 (Environmental Contamination)
- Section 615 (Hydrocarbon Contamination)
- LUST (Leaking Underground Storage Tanks)

TRANSPORTATION LAYERS

- Bridge
- 5 Year Plan Points
- 5 Year Plan Lines
- 5 Year Plan Polygons
- Trunkline
- Railroad
- All Roads

RECREATION 4F

- Parks All Points
- Public Access Recreation_pts
- Recreation Trails
- Snowmobile Trails
- Recreation Land
- Parks All Polygons

WATER QUALITY

- Water Intakes
- Designated Streams
- Trout Streams
- Wild & Scenic Rivers
- Natural Tributaries
- Drains
- Stream Baseflow
- Hydro Lines
- Natural Rivers
- Source Water PA (Protection Areas)
- Wellhead PA (Protection Areas)
- Lake Polygons
- Watershed Management Plans
- Mgt Plans Rabbit River
- Mgt Plans Nested
- Mgt Plans Base
- Watersheds All

ENVIRONMENTAL PROTECTION

- Species Data
 - Hines Emerald
 - Biot_1985_clip
 - Redbook Sites
 - Exploded Buffers
- DEQFWS Managed Areas
 - High Risk Erosion Areas
 - Environmental Areas
 - CZM Areas
 - Coastal Barrier Resources
 - Critical Dune
 - Designated Dune
- DNR Managed Areas
 - Piping Plover Habitat Units
 - Kirtland Warbler Units
 - Natural Areas
 - State Wildlife Areas
 - Ecological Reference Areas
 - Special Management Areas
 - Conservation Land

BASEMAP LAYERS

- Twp (township polygons)
- TRS Polygons (town, range section)
 - Sections
 - Town_Range
- Village
- City
- Urban
- County

ARCHAEOLOGY

- Archaeo Deep Site Potential
- Archaeological Sites

AGRICULTURE

- PA 116

LAND COVER

- Circa 1800 Land Cover

LAND OWNERSHIP

- Tribal Lands
- Private Land
- County_Local Land
- Federal Land
- State Land

- WETLANDS (Wetlands NWI 24K)
- TOPOGRAPHIC MAPS (Statewide Mosaic)
- AERIAL PHOTOS
- PLAT MAPS

4. Look at the symbology in the table of contents and in the map display area. Considering symbol color, symbol shape, symbol size, and how the symbols look against one another, do you judge the symbology to be:

Adequate Somewhat adequate Somewhat inadequate Inadequate Not sure

Explain your answer

5. Please name additional data layers that you would like to have added to the maps

6. Which tools do you frequently use in the ArcReader maps?

- | | |
|--|--|
| <input type="checkbox"/> Zoom In/Zoom Out (magnifying glass) | <input type="checkbox"/> Transparency |
| <input type="checkbox"/> Fixed Zoom In/Fixed Zoom Out | <input type="checkbox"/> Swipe |
| <input type="checkbox"/> Continuous Zoom/Pan | <input type="checkbox"/> Layout View Button |
| <input type="checkbox"/> Pan (white hand) | <input type="checkbox"/> Layout Tools (Zoom In/Out, Pan, etc.) |
| <input type="checkbox"/> Zoom to Full Extent (globe) | <input type="checkbox"/> Refresh Button |
| <input type="checkbox"/> Zoom to Previous Extent (blue arrows) | <input type="checkbox"/> Print |
| <input type="checkbox"/> Scale Bar Dropdown Menu | <input type="checkbox"/> Print to a .pdf file |
| <input type="checkbox"/> Identify | <input type="checkbox"/> Export Map (as a .bmp file) |
| <input type="checkbox"/> Find | <input type="checkbox"/> Full Screen View |
| <input type="checkbox"/> Go to XY | <input type="checkbox"/> Bookmarks |
| <input type="checkbox"/> Measure | <input type="checkbox"/> Markup Tools (Pen, Highlighter, Eraser) |
| <input type="checkbox"/> Layer Selection Dropdown Menu Bar | <input type="checkbox"/> Export Markup |

7. Describe how using the ArcReader maps have affected your work - how have things changed since you began using the ArcReader maps to review highway jobs?

8. Do you have any additional thoughts or comments?

Appendix D. Symbology pros and cons as identified by map users from interview question #4

Pros

All are contrasting or standard or colors I'd expect to see

Was confusing when we were figuring out project area color (was yellow, then blue), but now the red is ok (for the 5 year plan),

Red on the job number seems to be working

I like that it's red now (the 5 year plan)

Like having the county, township and TRS labels

The trunkline and rivers are both blue but once you zoom in you can tell them apart, not an issue, you can tell the difference

In general the features are colored how you'd expect in the field

Within water quality, the layers that would lay on top of each other are colored differently so you can tell them apart

Sometimes with so many layers you have to be careful, all seem to be working pretty good, pretty standard

I haven't had trouble telling one thing from another, if I do I just hit identify

Generally adequate to my needs

The hashmarked line to show where a job was extended is quite useful. Don't have to go back over the whole thing.

Cons

Roads won't always have the route name which can be frustrating.

When we have a carpool lot or new location, it's much more helpful to have a polygon instead of a point

Circa 1800 LC can be overwhelming, hard to distinguish colors

Archaeology Deep Site Potential - sometimes the top 3 colors are confusing

Sometimes still can't read road names with the aeriels on

Sometimes a layer sits over the top of something and covers it up/blocks what's underneath

TRS (labels) might be easier to see if it was a bold black

Would be nice to have names of all hydro_lines (not all labeled)

Some symbols could be different...when you have so many layers it's hard

The 5 year plan points and lines need to be clearer, the black and red points and lines don't stand out for me

There are a lot of very similar colors (Conservation Land, Village, Tribal Land are all orange), Land ownership and DNR Managed Areas are very similar colors, Natural Areas and City color are too similar

Open and closed LUST symbols could be larger

The parks aren't labeled so I'll have to search online to find out what it is

Appendix E. Pros and cons of how ArcReader has affected the map user's work/changes since using the ArcReader maps identified by map users from interview question #7

Pros	Cons
<u>Data Aggregation</u>	
Come to one location to find most of what I'm looking for	Still bring up quite a few tools manually, only halfway served through the GIS
One stop shop for majority of jobs Put multiple tools under the same platform	Not a one stop shop for all jobs but is for most
More convenient to be able to lay everything over each other vs. the paper, nice to have everything all together	
Nice to have topos and aerials together	
Don't have to recreate the map ourselves, having a map of the project area already highlighted helps us not have to gather information ourselves	
Better ability to visualize constraints	
Being able to look at multiple layers simultaneously adds to my perspective in evaluating cumulative impacts	
All in one view is nice	
A lot of information at people's fingertips, don't have to use multiple databases and other sources of information, don't have to call other agencies and have them look stuff up for you	
Gives a more complete look at a project in one step	
Gives specific spatial information for specific areas	
<u>Data Availability and Specificity</u>	
Limits mapped for you already, don't have to guess anymore	Still kind of dependent on Stacey (to make maps)
Feels like a more accurate project location	(The project location) seems slightly more accurate but there are still mistakes
Is probably a more thorough review	
More detailed	
It has made it easier to define the extent of the areas I need to study	
More information is provided	
Getting more information than from paper reviews	
<u>Affects on Time</u>	
Saves time not having to get a paper study packet	Not more effective but save a lot of time
In some ways faster	Some ways slower, going back and forth between aerials and topos takes longer
(While getting used to the system it) takes more time but is a better product especially when it goes outside the department	Initially taking more time as you get used to the system
More efficient, faster, getting same results faster	More tedious to find things, to capture images and save them, larger learning curve
Faster, more information quicker	It hasn't changed my work habits a lot yet because the data layers I need aren't there
Get it all done in half the time it used to (take)	

Has quickened the review a bit

Easier and quicker, they expedite the environmental clearance process

Faster reviews

More efficient

Speedier, more efficient

In the end it's much more efficient

Will expedite my preliminary reviews and help me decide if I need to conduct a field survey

They've sped up the process for an initial review

ArcReader Map vs. Paper Study Packet

No lost paperwork

Print a lot less paper

Less hard copy maps to shuffle through

Allows multiple users to see the information at once

Allows everyone to look at the maps at the same time

Now using new/up-to-date data

Dynamic mapping (3 map users gave this response)

Producing Maps

Will allow people to make more professional maps that can be shared

Can produce much more accurate and attractive maps

Communication

Help facilitate conversations with project managers

Made it simpler to communicate the information to the specialists

Miscellaneous

Easy to use

Some need to get used to the screen vs. paper