Doing more with more information: Changing healthcare planning with OLAP tools

Monica Chiarini Tremblay a,⁎,1, Robert Fuller a,2, Donald Berndt a, James Studnicki b

a Information Systems and Decision Sciences Department, College of Business Administration, 4202 Fowler Ave., CIS1040, University of South Florida, Tampa, FL 33620, USA
b College of Public Health, University of South Florida, Tampa, FL 33620, USA

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Abstract

On-line analytical processing (OLAP) is an example of a new breed of tools for decision support that give decision makers the flexibility to customize the selection, aggregation, and presentation of data. To understand the impact of this type of tool, we study an implementation of an OLAP interface on the CATCH data warehouse used by knowledge workers at a regional health planning agency in the State of Florida. The results of a qualitative field study show that after the OLAP implementation, these workers made use of the additional capabilities of OLAP (e.g., aggregation levels and intuitive data manipulation), thereby leveraging their individual abilities to enhance and expand on the tasks they performed for their community. Consequently, they were able to perform in more of a consultative role to their clients, and improved their reputation in the community they serve. This research adds a new dimension to prior research in data warehousing by focusing on the decision support capabilities of OLAP.

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1. Introduction

Previous research on decision support systems has focused on technologies that assist managers in making decisions. Many of these technologies can be considered “static” tools since the data presentation and analysis are predetermined by the designers of the technology and unlikely to change after implementation. Today, organizations are implementing a new breed of tool for decision support. These technologies are more malleable in that they allow decision makers to work with vast amounts of data and give them the ability to modify how and which data are presented and, to some degree, to select the methods used to analyze data. Unlike earlier technologies, a systems analyst or programmer does not completely predetermine the way a decision-maker can view or analyze data [4,16]. An example of such a technology is on-line analytical processing (OLAP). OLAP tools allow knowledge workers to manipulate and perform complex analyses over the data stored in a data warehouse.

Data warehouses contain a wealth of data, and tend to be quite complex in their architecture. Studies on the implementation of data warehouses [8,17,20,26] have
often investigated success factors for initial implementations of data warehouses. However, these studies usually do not consider the tools that are typically used to access and analyze the data stored in the data warehouse (such as on-line analytical processing, OLAP) – the tools used to report on the knowledge or “business intelligence” contained in the system. These enabling technologies allow users to mine and present data in a meaningful format [19] to extract benefit from data warehouses. Likewise, articles in the practitioner journals indicate that while companies may be successful in implementing multi-terabyte data warehouses, they are finding that it is difficult to translate this investment into useful business knowledge or positive business results [13]. Glassy acknowledges that some of the most elegantly designed data warehouses sit abandoned because the developers do not provide the correct end-user tool and they fail to engage and enable users. She identifies the need for tools that enable “user-centric” computing [10].

Unlike past research into data warehouses which generally do not consider the OLAP front-end, our focus in this study is to understand how OLAP functionality impacts the nature of the work (knowledge work) performed by health planners at a regional health planning agency in the State of Florida. These agencies are tasked with overseeing the Certificate of Need (CoN) program and developing their district health plan, as well as addressing issues relating to the un-served and under-served populations in their community. As part of their community healthcare assessments and healthcare needs planning, health planning agencies collect data from a variety of sources and employ various tools for data analysis and presentation purposes. Many of their tasks entail combining data from hardcopy reports provided by the State of Florida, web pages, and publications, which do not lend themselves to easy aggregation and analysis.

To examine the context in which health planning agency employees operate, and how this new technology impacts them, we use Task-Technology Fit Theory (TTF) as a framework to identify the relevant constructs in this context. TTF suggests that information systems will have a positive impact on performance when their functionality is appropriately matched to user characteristics and task requirements [11,12] (see Fig. 1). Therefore, with a better match between a task’s characteristics, the features of the technology, and the characteristics of the individuals involved, a higher level of performance should occur.

This study is unique in three ways: 1) it examines the implementation of an OLAP interface and underlying data warehousing technology within a health planning agency, the first implementation of its kind in the State of Florida, 2) it identifies the potential of these tools by examining their use in a real healthcare planning setting, and 3) analyzes at an individual level of analysis the impact of these tools. Past studies of similar implementations [8,17,20,26] do not make use of an individual level of analysis, but rather utilize an organization level of analysis. This perspective allows us to investigate at the individual level the impact of this technology on healthcare planning activities. Furthermore, this research adds a new dimension to prior research in data warehousing by exploring how OLAP technologies can contribute to the successful implementation of a data warehouse.

The paper continues as follows. First, we briefly examine prior research on data warehouses and in particular business intelligence tools such as OLAP, and their potential benefits. Next, we provide an overview of health planning agencies and illustrate one of the major functions they perform, the Certificate of Need. We also describe the healthcare data warehouse used in this study, the CATCH data warehouse. We outline our research methodology and report our findings based on a series of structured interviews conducted over a 1-year period. We utilize quotes from these interviews and screen shots from the OLAP interface to describe the

![Fig. 1. Task-technology fit (Goodhue [11]).](image-url)
nature of the work of health planners, the tasks they perform, both before and after the implementation of OLAP capabilities. We conclude with a discussion of the results, and implications for future research in this area.

2. Data warehouses and OLAP

Data warehousing and on-line analytical processing (OLAP) [3] are fairly recent technological advances in the field of information systems for decision support. Data warehouse systems were built to assist business users in analyzing the vast amount of data that originate from heterogeneous data sources, especially operational transaction processing systems that record the day-to-day activities of most organizations [23]. OLAP interfaces not only integrate the functionality of earlier generations of data warehouse information technology but also go further and introduce spreadsheet-like multidimensional data views and graphical presentation capabilities [16]. OLAP interfaces provide a fairly simple, yet extremely flexible navigation and presentation environment that is capable of representing the structure of real world data typically stored in the form of multidimensional tables or data cubes.

A data cube implemented as a relational star schema has two kinds of entities: facts and dimensions. The set of dimensions consists of many categorical or textual attributes. For example, a customer dimension may contain a key, name, purchase profile, credit profile, address, salary level, home ownership information, along with possibly hundreds of other characteristics. The fact tables are populated with numeric attributes like dollars sold, units sold, costs, revenues, and any other attributes that can be summarized using mathematical operators. Dimensions usually have associated hierarchies that specify different aggregation levels [18]. Interesting patterns are often highlighted by analyses at well-chosen levels of aggregation. Dimensions also allow a user to ‘slice and dice’ a data cube to form customized data subsets for further analysis.

OLAP interface tools take advantage of the predictable structure of data cubes, designed with dimensions and facts, to provide a graphical query environment. Typically, these tools generate highly structured SQL queries, often using analytic query language extensions, which organize and aggregate a subset of data from the warehouse. OLAP users can navigate through a cube by either “drilling-down” (focusing on a lower level of granularity, e.g., dollars sold on a certain day of the week for a certain promotion) or “rolling up” (choosing a higher level of aggregation) [14]. Manipulation and presentation of such information is performed by end users through these multidimensional views and graphical displays which provide invaluable support for decision-making [16]. Although the data cube is a simple structure, the large numbers of alternatives, including many numeric facts, many dimensions that can be used to slice through the data, and many hierarchies or abstraction levels combine to form an immense universe of queries that can be explored via an OLAP interface.

3. Study context – health planning agencies

In the State of Florida, local health planning agencies were established as a network of non-profit agencies that conduct regional health planning and implementation activities. The Boards of Directors of these agencies are composed of healthcare providers, purchasers and nongovernmental consumers. Florida’s eleven health planning agencies (ranging in size from 1 county to 16 counties) develop district health plans containing data, analyses and recommendations that indicate the healthcare status and needs in the community for local health care facilities. Their recommendations are designed to improve access to healthcare, reduce disparities in health status, assist state and local governments in the development of sound and rational healthcare policies, and advocate on behalf of the underserved. Local health planning agencies also study the impact of various initiatives on the healthcare system, provide assistance to the public and private sectors, and create and disseminate materials designed to increase their communities’ understanding of healthcare issues [22].

3.1. Certificate of need

One of the important health planning agency functions is to provide detailed information for Certificate of Need (CoN) reviews. The Certificate of Need review process regulates entry and expansion of a variety of health services by state-licensed hospitals, nursing homes, and other organizations. The CoN program in Florida, as well as in other states, was originally created in response to federal health planning standards (see www.fdhc.state.fl.us/MCHQ/CON_FA). Furthermore, a state was required to have a CoN program in order to qualify for federal U.S. Public Health Service funds. The objective of CoN programs is to partially regulate the services offered by healthcare provider organizations in a specified area, making sure healthcare needs are met, but avoiding costly duplication of services.
The Certificate of Need program is one of the explicit mechanisms for directly influencing the allocation of services in a healthcare marketplace. The factors considered in a Certificate of Need review include: the history and current services of the applicant organization, the healthcare needs of the local population, resources available to the applicant organization, possible alternative approaches, and any impacts on local healthcare costs. Additionally, the CoN review process considers excess capacity that can lead to over-utilization. CoN reviews can identify the existence of excess surgical programs that could lead to more, possibly unnecessary, surgeries. Other objectives include the containment of healthcare costs, providing equal access to care, and fostering continual improvements in the quality of care. There is much a stake during the CoN review process, with stakeholders on both sides of the issues scrutinizing the work of fact-finding agencies such as the health planning agencies. Because of the data intensiveness, detailed analyses, and planning needed for CoN reviews, these types of activities are well-suited to the application of data warehousing and the analytic capabilities of OLAP interfaces.

### 3.2. The CATCH data warehouse

Since 1991, the College of Public Health at the University of South Florida has developed and enhanced a methodology for performing community health assessments – the Comprehensive Assessment for Tracking Community Health (CATCH). The CATCH methodology identifies both a rich collection of quantitative indicators and a framework for ranking healthcare problems to support policy formulation [16,17]. The CATCH methodology has been applied to more than two-dozen counties throughout Florida, as well as selected applications in other states, with great success. For each of the hundreds of healthcare indicators in the CATCH methodology, the selected county is compared to the state average and an average based on statistically selected peer counties in the state. All indicators that are worse than both the state average and the peer counties’ average are subjected to further analyses and prioritization. The final report provides a rank-ordered list of healthcare indicators that represent a profile of the communities’ most serious and challenging health problems. Originally, these CATCH reports were prepared by hand, a difficult and time-consuming task, spurring the development of an integrated, statewide healthcare data warehouse.

A data warehouse project was initiated in 1998 to automate much of the community assessment process, although the interpretation of the many health status indicators is still a matter of art. Today, the data warehouse integrates fine-grained event data such as vital statistics (birth and death records), hospital discharge data, and free-standing clinic data, along with several more detailed disease registries. The infrastructure also includes major healthcare coding systems, such as the International Classification of Disease (ICD), Common Procedure Terminology (CPT), and Diagnostic Related Group (DRG) coding systems to support analyses at varying levels of detail. In addition, population data from the census, economic data, and even commercial marketing data are added to the mix.

Early in 2000, the federal Health Resources and Services Administration (HRSA) awarded three consecutive 1-year grants to a consortium of health-related organizations within the health planning agency’s region to establish the Primary Care Access Network (PCAN). The PCAN established a series of coordinated activities in a multi-county area that were intended to provide access to primary care services, largely for the uninsured or underinsured, which would enable the medically indigent to receive important primary treatment and preventive services in defined “medical homes” and avoid inappropriate use of hospital emergency rooms for non-emergency situations. One important objective of the PCAN was to perform baseline assessments of the health status in its various constituent communities. PCAN contracted with the University of South Florida (USF), Center for Health Outcomes Research, to evaluate the progress of various PCAN activities and, subsequently, to perform two specific community health status assessments. Three reports, a special analysis and projection of the number of uninsured, their healthcare utilization, and healthcare costs, were undertaken.

These three major reports proved valuable to the health provider community, providing important objective documentation for multiple grant applications in the community. However, they also stimulated the need for more specific information than could be provided in the hardcopy reports, as extensive as they were. Furthermore, the health planning agency was designated to serve the role of information provider for health planning and evaluation purposes across the multi-county area. The health planning agency would play an important role in health assessments and various regulatory activities, such as Certificate of Need reviews.

Given these increased needs for data to serve a variety of planning and assessment purposes, the health planning agency and the developers of the CATCH data warehouse decided that the health planners would benefit enormously by having direct access into the data warehouse.
This would allow the planners to proactively respond to their many requests for information and to better meet their assessment and CoN review responsibilities, rather than relying on hardcopy periodic assessment reports. In this study, we observed the implementation and use of an OLAP interface on the CATCH data warehouse by agency health planners within a specific regional health planning agency in Florida. We follow with a description of how we studied this implementation and collected and coded the resulting data.

4. Research methodology

It has been noted by W. Whyte and K. Whyte [24] that behavior is best understood by studying it in its context. OLAP tools provide highly interactive and malleable interfaces whose effectiveness is linked to the tasks for which they are used, and to the characteristics of the individuals who use these tools. Additionally, individuals using this technology in the healthcare industry can have significant impact on the community which they serve. As a result, the context of use is important in understanding both how knowledge workers, such as health planners, can be aided by OLAP tools and the impact of the usage of these tools on the communities in which they serve. Yin [27] describes using qualitative research methods when you wish to investigate “a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Therefore, we chose a field study approach as an appropriate method to examine the use of the OLAP interface and underlying data warehouse by the health planning agency, given the few studies that have been carried out in this area [1].

A single research site was chosen since this was an initial attempt [25] to describe the impact of providing a malleable decision support tool such as OLAP to knowledge workers in the healthcare industry. The research is based on a 1-year field study conducted between October 2003 and October 2004. During this time period, knowledge workers at a Florida health planning agency were provided with access to a data warehouse in an iterative fashion, beginning with hardcopy reports and ending with direct access to data cubes through an OLAP interface that gave them the flexibility to select and customize the data presentation.

4.1. Data collection method

Multiple data collections methods were used in this study, including: interviews and direct observation, as well as documents, which were used to corroborate and augment evidence from our other sources [27]. We conducted three interviews with each of the four health council workers and recorded three different training sessions. The interviews were semi-structured, allowing for open-ended responses. The interviews were guided by the constructs from TTF and consisted of a set of questions regarding the individual’s previous work experience and training, their current job activities, the tools they used to perform their tasks prior to using the OLAP interface, their expectations of OLAP, their familiarity with OLAP-type tools (e.g., spreadsheets and pivot tables) and their preference for self-initiated data collection and aggregation.

The number of interviews to conduct was not determined a priori. Since the technology was implemented in stages, interviews were administered prior to initial implementation as well as after each implementation stage. Most interviews were conducted at the health council’s offices. During the interviews, participants were asked to illustrate examples of projects they were working on and their data collection and analysis techniques. Each time a data cube was implemented or expanded, telephone interviews were conducted. These interviews were open-ended discussions where the participants were asked whether access to the data warehouse through the OLAP interface was aiding them in their data collection and analysis efforts. The respondents were asked to cite particular examples where their work load was significantly reduced, increased or altered, and instances where they were able to perform tasks with the data that would not have been possible prior to the availability of the OLAP tool. Of particular interest were situations where they were able to provide data to their clients that made a significant impact on the communities they served. With the permission of the participants, these interviews were recorded and later transcribed and coded.

The researchers were also present during the training sessions held by the developer. These training sessions were also recorded and later coded. As noted above, the goal was to gain an understanding of how well the participants understood the technology and to capture their questions and concerns about the use of the OLAP interface capabilities in their work.

4.2. Data preparation and analysis

The interviews, training sessions and documents were coded using template analysis. This technique was selected because of its flexibility. Unlike a grounded theory approach [21], template analysis normally starts
with at least a few predefined codes which help guide analysis. The first step in template analysis is creating an initial template by exploring the interview scripts, academic literature, the researcher’s own personal experience, anecdotal and informal evidence, and other exploratory research [15]. The initial template was guided by the literature on TTF which identifies and defines our constructs of interest in this study: the tasks, technologies, individuals characteristics, level of fit, and subsequent outcomes [12]. Once the template was completed, the researchers listened to the taped interviews and worked through the provided documents, identifying sections that were relevant and annotating the appropriate codes from the initial template. The initial template was modified as needed. Several iterations of this step led to a final template. As recommended by King [15], coding was complete when all researchers agreed on all higher ordered codes and most lower order codes.

The final task is to present the researcher’s interpretation of the data. King [15] outlines three common approaches. The approach taken was to create an account structured around the main themes identified, drawing illustrative examples from each transcripts as required. As recommended by King [15], direct quotes from participants are included: short quotes to aid in the specific points of interpretation and longer passages of quotation to give a flavor of the original tasks.

5. Supporting healthcare planning

In this section we utilize the constructs from TTF to describe the work context prior to implementation and the level of fit after implementation. We begin by describing the health council planner’s characteristics prior to receiving access to OLAP technology (Fig. 2). We follow with a description of the changes after the implementation of the OLAP interface. To illustrate the context, we include quotes from the health council planners that were obtained during the interview process.

5.1. Individual characteristics

Workers at the health council (referred to as health planners) exhibit individual characteristics that one would expect to find in knowledge workers. Knowledge workers are defined as “employees who apply their own knowledge, acquired through experience and education, to develop new knowledge or apply existing knowledge” [9]. The characteristics identified from the interview data were skills, experience, autonomy, and creativity.

The individuals at the health council all have a significant level of skills. They have master’s degrees in health services administration and are supervised by an individual that recently received a Ph.D in Public Affairs. Their work requires that they have a good level of familiarity with word processors and spreadsheets, as well as some basic usage of queries to PC databases. According to a health planner, “the more (computer skills we have) the better”. The same health planner explained that it is imperative to have effective communication skills, “To talk to the person you are getting data for, to clarify not only what you are going to do for them, but what they are looking for”.

Often these health planners apply their own experience: “[With research for grants], I start at the beginning

Fig. 2. TTF before OLAP capability (adapted from Goodhue [11]).
and work my way through, and I know from work I have done before of a particular indicator that will work in that particular situation.” They refine their work processes so they can be most effective: “I keep notes on ways I collected data on previous projects because sometimes you need to go back because it may be such a unique thing they are asking for and you went through such a convoluted way to get the data and it’s hard to remember, so if I want to get this same data for this population, what did I do, how did I get this information? Sometimes I learn too, that I can skip some steps and still get to the same answer. So I waste less time to get to my answer.”

Their tasks are not predefined and they have autonomy in how they perform their work. From the interviews, a recurrent theme is that these workers enjoyed a challenge, and were not hesitant to change: “I never had something so complicated I gave up”. When describing her job, a health planner explained, “I don’t have any constraints. No one tells me how to do it, they just want it [data and analyses]. They identify a problem...Now we can go further and define it. The solution is more effective [because] I can further define the problem.” During discussion about ideal tool characteristics the health planners displayed their preference for autonomy, “I want this [tool] to be an area we have expertise in”, “[In response to developer who suggested a less flexible, but simpler web interface] No! We can do that. I’d rather have the flexibility.” When talking about the interface “I prefer to [be able to] manipulate [the data] so I can get what I need”.

5.2. Task characteristics

Understanding the characteristics of healthcare planning is important because task characteristics can account for up to 50% of the variance in performance. In general, the notion of task revolves around the activities or behaviors that individuals need to do to accomplish a goal. In this sense, task has been broadly defined as the actions carried out by individuals in turning inputs into outputs [11]. When considering the tasks performed by employees of the health council, it is apparent they fall into the category of knowledge work.

The principal activities of a task that is classified as knowledge work revolve around “the acquisition, creation, packaging, or application of knowledge” [5]. Acquisition entails the activities required to understand knowledge requirements, searching for the requirements, and then preparing the knowledge for transfer to a requester or user. Creation consists of the research activities and creative tasks that are performed to generate new knowledge. Packaging involves the preparation and assembly of knowledge for consumption by a requester or user. Finally, application consists of the activities that involve the use of existing knowledge in a situation. While the general activities are described in literature on knowledge work, the specific tasks performed by knowledge workers tend to vary greatly from task to task, such that there is little routine or repetition and a greater emphasis on creativity [5,9].

Prior to having direct access to the data warehouse through the OLAP interface, the tasks carried out by the health planners encompassed the characteristics described above, but fell predominately into two broad categories: knowledge acquisition and knowledge packaging. Their tasks often consisted of short-term research projects conducted on behalf of a diverse set of clients from direct healthcare providers to philanthropic foundations. As explained by a health planner: “The health planner [position] involves pulling together other community members and then planning a program or a process to fill a gap in the healthcare system”. Some of these tasks can be broadly categorized as knowledge acquisition, where the planners are mainly collecting data for their clients and carrying out some data analysis. A health planner described it as “pulling data and analyzing it to find out where there is a need, who it affects and how it affects them”. An example is when they were asked to investigate “what is happening to kids and kids health, how many kids are getting emergency care” for a task force on children’s health. Another example was a request from a senior resource alliance: “We want all you have on senior health care”. They also received many phone requests on physicians’ capacity, “how many practicing physicians (that are seeing patients) do we have in the area – (that is) very important to us – for malpractice and for health planning – for example there are abandoned plans to build an OB expansion because there are not enough physicians...there are many issues”.

Some of their tasks can be categorized as knowledge packaging. They often receive requests from specialty groups, requesting “everything that is happening with the X population, broken down by country of origin, because there are disparities by that”. Another good example of knowledge packaging is a particular request for the Ryan-White Title 1 (funding to support health and social services for low-income and un- or underinsured persons living with HIV/AIDS and their families) where they need to compare epidemiology versus utilization data: “All of that data comes to me and I analyze it, chart it, and prepare presentations for their
committee meetings. In addition, they have asked for us to come up for the population that has AIDS whose needs are not met.”

5.3. Technology available to health planners

Technology is defined as the tools used by individuals to carry out tasks [12]. Technology can influence performance outcomes to the degree that it is appropriately designed for the task and used by the individual [6]. The primary difficulty in examining technology to support knowledge work is the fact that “The abstract and unstructured inputs to and outputs from knowledge work processes make the application of technology more difficult” [5].

Prior to the availability of OLAP and data warehousing technologies, the health council workers used several data sources of aggregated data. In particular they used hard copy reports printed from the CATCH data warehouse, census bureau data, and data available from the Florida Health Department, as well as reports provided by a local university. These sources of data were similar in that they had a fixed format: they were static, structured, and contained a fixed level of aggregation. For example, the reports provided by the CATCH data warehouse were helpful for the health council workers (as previously described), but limited in their flexibility. Fig. 3 shows an example page from a CATCH data warehouse generated report.

This particular report outlines avoidable hospitalization events due to Asthma attacks. It compares one county with similar counties across several years. This data is helpful; however, it cannot be easily manipulated. For example, it is not possible to compare this indicator across races, or socioeconomic status. Therefore, these health planners had sufficient tools and data available to them, but the lack of flexibility did not allow them to fully leverage their skills and experience.

In summary, we would expect that to the degree that the technology supports the nature of the knowledge work performed by the health planning agency, and provides flexibility to support the manner in which the agency’s employees wish to approach and perform their tasks, higher performance would result [2,7]. Although

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Fig. 3. A page from a CATCH hardcopy report.
the health planners were productive and successful, it was evident that due to the limitations inherent in the data and tools (e.g., hardcopy CATCH reports, static sources of information, limited integration between the sources of data and the tools needed for analysis), these health council planners could not fully leverage their individual characteristics and abilities. Therefore, any technology applied in the context of the health council must be able to support tasks that require data to be accumulated from diverse sources while providing the user with the ability to utilize autonomy and creativity in how they manipulate, analyze, and present data. We follow with a discussion of how the characteristics of the tasks, individuals and technology evolved after the introduction of an OLAP tool.

6. Introducing OLAP functionality

The health planning agency being studied has used the CATCH methodology in the past and the associated initial hardcopy reports from the CATCH data warehouse have certainly had an impact throughout Florida. However, the implementation being studied in this paper marks the first time that true OLAP data warehouse access has been available.

We expected that although the health council had technology that supported them in serving their clients, the introduction of a flexible OLAP data warehouse interface would help them to improve their performance by allowing them to better leverage their experience, skills, creativity and autonomy. A tool that is flexible in its ability to combine, manipulate, and present the data should assist the health council knowledge workers in further defining and refining tasks, as well as supporting various methods of exploring, analyzing and presenting information.

We use quotes from interview scripts, as well as example OLAP queries, to explain and highlight these emerging characteristics (Fig. 4). We begin by introducing the new capabilities this technology gave to the health planners and how this allowed them to utilize skills and expand their tasks and outcomes.

6.1. Flexible analysis and presentation

One of the characteristics that typify OLAP tools and data warehouse technologies is the capability to provide data at many levels of granularity for multiple perspectives. Fig. 5 depicts an OLAP worksheet that provides county level data for various cancer mortality indicators. This ability to traverse hierarchies, selecting appropriate levels of abstraction across multiple dimensions, is a key capability that makes OLAP tools a natural fit for the tasks facing health planners as well as other knowledge workers. Even at standard levels, such as county health status indicators, the OLAP interface provides advantages over previous hardcopy or spreadsheet reports. First, the current hardcopy reports have grown to upward of 700 pages,
making it difficult to justify new tables and multiple levels of abstraction. Using online access, any number of tables can be delivered at a wide range of granularities. In addition, there is no limit on the number of new health status indicators that can be introduced, so the development of data cubes is ongoing, driven both by the suggestions of the health planners and the developers. Another critical dimension is time and much longer-term trends can be presented in an interactive fashion. In this case, the most useful benefit of OLAP access to the CATCH data warehouse might be the finer grained perspectives, such as zip code level analyses, that can be provided (as shown in subsequent sections).

A good example of how a finer grained perspective was useful was a particular request for the number of licensed physicians by one of the data analysts. According to the health planners, “what they really want to know [is] how many physicians are practicing? You have to talk to them and have discussions on how it’s going to be used, what you are really looking for and there was no way to find out.” In this particular case, the health planners were able to change the focus from a simplistic perspective based solely on licensure data to an aggregated analysis using the hospital discharge data, ambulatory care data, and licensure data. Physician licensure data provides a snapshot in time with no information on actual practice patterns. By linking the data sets, the health planners were able to explore trend information across a wide variety of procedure or diagnostic categories. For example, Fig. 6 shows a query requesting the number of unique physicians performing orthopedic surgery in the community of interest, along with the raw numbers and case load. In this case, the planners were able to identify that there is growth in both the number of doctors and the average case load, probably due to a variety of factors such as population growth.

The health planners indicated although they were satisfied with the additional capabilities that OLAP tool provided them, there were some difficulties. Their primary complaint is they occasionally have to use other tools for data manipulation, e.g. EXCEL. They understand, however, that it is not always possible to combine certain data: “Because we are always benchmarking our county against other counties, against the state, or against other communities it is a little bit difficult when you want to look at all three without going from workbook to workbook and not all the workbooks are in the same order. Because of the ways they are calculated, not all indicators are calculated for the county, the state, or the peer groups. But when I want to look across the board for one indicator it’s a lot of work, just busy work. You have to copy and paste, line up all the indicators”.

6.2. Interpretation and judgment

The added flexibility provided by the OLAP tool allowed the health planners to leverage their individual skills while allowing them to exercise some new skills, in particular: interpretation and judgment. Interpretation became a large part of their work: “In the past I just exported it [acquired data]. Now, the knowledge of the people out there is not the same as ours, so I interpret, and they can use it”. “I now have the capability of digging deeper into the data than what they ask for, and provide that information back to them.”

The requests from their clients are sometimes ambiguous, and the health planners are now able to
“cross-examine” their clients in order to interpret what they actually need. “That is another problem that comes up, people may ask for something, but they are not asking for what they really want.” As health planner explained: “I talk to the requestor and I ask what is it going to be used for, is it for a grant, because that really helps you to help them, understand exactly what it is they are looking for. Sometimes they don’t know!” “They have some pre-conceived picture in their head of what this is going to look like, but there are limitations. Trying to communicate this has been a real challenge”.

Interpreting the clients’ needs and the data available has required the health planners to exercise more individual judgment than previously required: “This is the first time that we have to be really careful to make sure how we are interpreting that data.” Recounting an example of this a health planner stated: “… someone wants breast cancer indicators. They want to know maybe how bad the breast cancer in a county is and what zip code is the worst. Because a lot of people that want the data don’t know necessarily or understand how to interpret the data once you give the numbers. So you have to go in and interpret it so they don’t misinterpret it once you give them the numbers.”

They also express some frustration with their own level of expertise. They make several references to needing more training: “I don’t have the experience to go in and see if you can do a query it’s a little bit time consuming for me. Working with it, I have developed what I think it’s the quickest process for me and you know it gets better each time. I have discussed it with the developer, he is thinking about what he can do”.

According to the developer, they have the most flexibility possible with the data cubes that had been designed thus far. Their insistence on further training illustrates that the users were learning how to use the tool quickly and moving beyond its original capabilities. It is also becoming indispensable for their work. The developers comment that “it is really time to redesign and develop new data cube components in light of the current experiences.”

6.3. Additional task characteristics

The flexibility and availability of the OLAP interface allowed health planners to accomplish new tasks which can be broadly categorized as: knowledge application and knowledge creation. In early interviews, they anticipated that the OLAP interface would aid them by more efficiently getting the right data from the warehouse: “They have asked for us to come up with the population that has AIDS whose needs are not met. Currently we have no way to come up with that information, because we do not have access to the hospital inpatient data. I can’t do my job; I can come up with some sort of convoluted educated guess. But if I had access to the [detailed] data, I could come up with a number that was more accurate.”

Knowledge application became possible because of the rollup and drill down capabilities which made it much easier for them to find data for planning purposes: “For example, if they identified a problem with cardiovascular disease, I can now go into the three different communities we have designed and I can look at which community, in the socioeconomic class, and
see if it is in the higher or in the lower. Before we had a rate for the whole county, but now we can go and further define that. That makes planning a lot easier because you are actually planning to solve the problem where it is. The solution is more effective. You can further define the problem.”

Knowledge creation also emerges as indicated by one of the health planners in this example: “[There is a] Health Initiatives group. There are 10 health indicators needed. There are two groups: barriers to care and health [status] indicators. For barriers to care I had to research how long it takes for them to get into some sort of temporary housing, what percentage of the population speak a language other then English, the unemployment rate for that particular population in that particular county, the percentage below poverty level, the percent of uninsured (this is all county specific, by race or ethnicity). Same is true for health indicators; I had to find cancer rates, infant mortality rates, asthma rates, obesity rates, diabetes rates, STD/HIV/AIDS rates, low birth weight rates, depression rates, rate of respiratory infections, chronic liver disease rates. What makes it difficult is that I don’t know what their goal is.”

Fig. 7 depicts an analysis based on communities compiled by the health planners, in this case based on Hispanic population. The rate and trend information for chronic heart disease are shown for various Hispanic concentrations. These synthetic communities are composed of non-contiguous zip codes that highlight issues across racial composition, income levels, or other criteria selected by the health planners. Multiple perspectives are supported through different community definitions, based on factors such as income, poverty, or age distribution. The different community groupings were defined by the health planners and implemented in the data warehouse to provide additional OLAP aggregation opportunities.

6.4. Consulting and reputation

Although it is difficult to measure impact on the community at such an early stage (many of the health-related projects run several years), it was apparent that the OLAP interface to the CATCH data warehouse had made a difference in the effectiveness of these workers as well as what role they played as health planners. When asked how they would feel about not having OLAP capability: “We can’t do without it now. We use them for almost everything we do. It would be really hard to go back without it. Before, we had just one mediocre source of data.”

It was articulated by the health planners that, as they were able to acquire more data through the OLAP interface, their roles began to change. Rather than data collectors, they began acting more as consultants: “This is the first time we have to be really careful to make sure how we are interpreting that data. I used to give them data straight, but now I can actually go in and say this is what we found, but when you look at this, and you look at this, you know it kind of changes your focus. I am now a better resource. I have to maintain an unbiased position, I can’t lobby for a certain position, but I can certainly have a discussion. Before somebody asked and I gave it to them, but now I have more information so I can enlighten them, but then it’s their decision to take those things into account and go forward. We have the capability of digging deeper into the data than what they ask for and provide that information back to them.” These deeper analyses often include drill downs to community or even zip code level data. For instance, the low birth weight mentioned above can be viewed by zip code to pinpoint areas for intervention. Fig. 8 provides an example query that shows a zip code perspective on low birth weight for a specific county.

In one particular case where the health planners acted as consultants, they were able to indicate areas with
special needs: “You can’t just put a mobile mammogram in X or Y, because those people have insurance, they go to their physicians. But you can see that [a particular area] has 3 times the rate then another zip code, then you know you can put one there. Whereas if you only had county data you can put all the units you want if it’s not in the right place... Before, we would have had to rely on what people in the community said. But when you go for a grant you can’t just say we think there is a problem here. They always want hard data. [In the grant] they were able to substantiate rates were high in that zip code. So they could bring mammograms to the right people in the right zip code. People who really needed it.”

In one case they used the OLAP tool to define a more appropriate level of granularity for a client: “one person wanted to do some kind of special oncology care for women: basically breast cancer, or cervical cancer. She asked for late stage cervical cancer by zip code. Unfortunately, we don’t have that. Because the cervical cancer rates are really pretty low, that once you break them down to zip codes the numbers are useless. They are too low to be significant, so if you have ‘1’ in a zip code you really can’t use it. I was able to give it to her [the data] by county, and by zip code for other cancers, but not for late stage cervical cancer.” This analysis was approached by defining communities within the county as outlined above.

The tool allowed them to give more detailed information. For example “we were looking at schizophrenia, it has quadrupled in 3 or 4 years. What is causing this? Is it that more people are presenting themselves? We know already that there are limited mental health facilities; we have a real shortage here. So it’s not like there are more facilities being able to handle more clients. Was it a change in insurance?” Changes in reimbursement policies, coding practices, or even the underlying coding system itself can affect the healthcare utilization picture.

OLAP capabilities allowed them to provide data to substantiate other findings: “The health foundation did this qualitative health assessment. It was a 135 question survey, they over sampled in areas where they did not have info on.” They found that alcohol related motor vehicle mortality was enormous. “The CATCH [data warehouse] helped us see where it was astronomical. Was it at a particular age, socioeconomic [category], or zip code (maybe there is an intersection)?” Based on the information they could explore potential causes and design an intervention.

The impact to the community was described by the health planners using the reaction of the groups they served: “People are really happy with the data; they keep returning and asking for more.” In a recent annual meeting, it was noted that the Health council had been really instrumental. In particular, community clients were satisfied with quick turn around and the fact that the health council actually had what they were looking for. “They could pull the data themselves, but I can pull all chronic diseases across zip code – before I had to do each indicator – now I can do comparisons, benchmarking.”

They continue to receive constant positive feedback from their clients. A measure of their improving reputation is the amount of requests for data that they receive and that has been on the rise. Overall the health planners feel that they are being more effective: “It’s quicker, its more effective more efficient, gives a better picture.” They had a high level of trust on the data, although before disseminating it they always made sure they understood it: “I have to really understand the data before I give it out, not that it’s wrong, it’s just a different perspective. Like for example if I were to give out that information about schizophrenia I would have to understand it, I can’t just say, oh yeah schizophrenia is rampant in Orlando, I have to substantiate that, I have to find out why. You have to be really careful because this is all new and no one has ever had this before.”
Sometimes they still go to alternate data sources when the data looks suspect: “Not that I mistrust it, but sometimes there are goofy things with the data. For example, for some reason for the year 2000 the rates were just double what they were for the previous 2 years and the following 2 years. What caused this, are you sure it’s right, because as soon as I go and present this data they are going to ask what happened in 2000? Why is his like that? We were not able to find out why—it was correct—maybe for that year they were counted differently, maybe due to some piece of legislation.”

7. Conclusions and future work

The results of this field study illustrate how this type of technology has the potential to make strong contributions to performance, especially in the assessment and review of healthcare planning. The examples provided demonstrate how the availability of more data in an integrated data warehouse, combined with a flexible OLAP interface, allowed this agency to become more effective in serving the community.

This study provided an exceptional opportunity to study knowledge workers in a real life context. The health planners display the characteristics outlined by the literature on knowledge work [23]. They are all highly skilled individuals with advanced degrees and a superior skill set, whose tasks are complex and often require creativity in coming to a solution. Often these health planners apply their own experience and constantly refine their processes so as to improve their effectiveness.

Several ideas emerged from observing the health planners interact with this malleable business intelligence technology. We observed that their individual and task characteristics evolved, as did the outcomes. As their level of expertise with the OLAP tool increased, their job roles began to change. Rather than data collectors, they began performing more as consultants. Before the implementation of this decision support system, their job consisted of finding data and providing it to their customers. Using the OLAP interface, they began providing their users with highly detailed data, along with interpretations and descriptions. They also used individual judgment to advise their clients which data they really needed. The health planners were no longer only acquiring and packaging knowledge, but creating and applying it as well. As a result, their reputation among their peers and clients increased, escalating the requests for data from this particular health council. Although we have not had time to collect exact data, in a recent conversation with the supervisor of this group, we were told that the council now has a full time employee whose main responsibility is prioritizing and selecting data requests for the group.

It is important to note that because this study is conducted within a single health council, generalization of the results to other organizational settings is limited. However, this implementation has aroused the interests of other health councils in the State of Florida, as well as in other states. These additional sites can be used to further validate and refine our study [25]. While we would like to think these results are generalizable to any knowledge worker context, given the nature and unique context of healthcare planning, our results are likely most generalizable to that context. Additional research in different contexts would help determine the degree that these changes occur in other environments.

Our purpose was to study the impact of the implementation of OLAP access to a data warehouse within a regional health planning agency in the State of Florida. Specifically, we were interested in the degree that this particular technology fit the nature of the knowledge work performed by the health planning agency, and whether it provided the flexibility to support the manner in which the agency’s employees approached and performed their tasks. Thus, a qualitative approach was preferred to a statistical generalization. Because of our approach, other potential limitations are the biases and preconceptions that the researchers had when interpreting the data. In order to minimize this possibility, interviews scripts were generated a priori using Task-Technology Fit Theory (TTF) as our framework. A template was created to code the interviews and multiple raters were used to corroborate patterns and findings in the data. However, additional research in this area is necessary to corroborate our findings.

7.1. Implications for research and practice

In this research we did not utilize TTF as an instrument with which to measure constructs, but rather, to guide us in understanding the changes that business intelligence technology such as OLAP can bring about, and whether it can improve the outcomes for those who use it. We believe a main contribution of this work is the identification of the new individual, task and the outcome characteristics that emerged during this study. These characteristics suggest new conceptualizations of the TTF constructs that may be more applicable in the domain of flexible decision support technologies such as OLAP. While TTF has offered significant explanatory power, an expansion on the TTF constructs may be more
The results of this research also identify implications for practitioners in this area. Through the course of this research, we observed a high level of engagement between the knowledge workers and the developers of the OLAP interface. From the beginning, this was a joint development effort, and one that is still ongoing. In fact, from the first training session, the users expressed interest in being directly involved in the development of the tool. The developers created data cubes that were often guided by requests from the health planners. For example, one of their first requests was to have the ability to track health indicators against other states and the ability to benchmark against regions that are similar in other states. They were not intimidated by the complexity of the tool, in fact the developers suggested “If what you did was mostly routine, we can build a web interface that is simple to use but not with much flexibility”. The user is a complex tool: “I am glad about that, I don’t want any old Joe to come in and be able to use this, I would like this to be an area we have expertise in.” They have developed a good relationship with the developers. This was important, since development was essentially ongoing. “I can pick up at any time and call the developers and say OK, what’s the deal with this, or what does this mean, or, is this really OK.”

Communication with the developers was frequent, and the developers were very accommodating in rolling out more cubes or views as requested by the health planners. Yet, sometimes the health planners expressed some frustration with their level of expertise, highlighting the importance of the correct balance of training and the timing the introduction of new functionality. Practitioners in this area must acknowledge the higher levels of interaction between users and developers that should exist for these tools to be successful. Furthermore, a high degree of interactive planning between users and developers would be helpful, to balance the delivery of new capability with training on that capability. We observed the OLAP implementation to be a highly interactive dialog between user and developer, which certainly had a positive impact on the successful implementation (to this point) of this tool.

In conclusion, we found that on-line analytical processing (OLAP) is a powerful tool that can support knowledge workers in healthcare planning. The results of this field study show that the additional capabilities of OLAP supported the tasks and leveraged the skills of healthcare planners to generate positive outcomes on the level of service (and services) that they could provide to their community. We observed that this type of technology has the potential to make strong contributions to outcomes and performance, especially in the data-intensive environment of healthcare planning assessment and review.

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References


Monica Chiariini Tremblay is a Doctoral Candidate at the University of South Florida. She received an MS in Information Systems degree from the University of South Florida and a BS degree in Industrial and Systems Engineering from the University of Florida. Prior to pursuing her PhD, Ms Tremblay worked as a systems analyst. Her research interests include decision support systems, data warehousing, knowledge discovery, data and text mining.

Robert M. Fuller is an Assistant Professor in the Information Systems and Decision Sciences Department in the College of Business Administration at the University of South Florida. His research interests include decision support systems, collaborative technologies, and computer-mediated communication. Dr. Fuller received his PhD in Management Information Systems from the Kelley School of Business at Indiana University.

Donald J. Berndt is an Associate Professor in the Information Systems and Decision Sciences Department in the College of Business Administration at the University of South Florida. His research interests include data warehousing, knowledge discovery, data mining, and health informatics. Dr. Berndt received his PhD in Information Systems from the Stern School of Business at New York University.

James Studnicki is a Professor of Health Policy and Management at the University of South Florida College of Public Health. His research interests include measuring the health status of communities, evaluating alternative treatment outcomes, and studying the influence of managed care penetration on the utilization and quality of health services. Dr. Studnicki received a ScD from Johns Hopkins University.