Maps as a technique for visualizing load-shedding schedules

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ABSTRACT
The South African electrical utility, Eskom, is faced with the problem of communicating information about the times and locations for rotational load-shedding. This paper challenges whether the current presentation format is an optimal communication medium. An alternative communication medium is proposed in the form of a map-based schedule. The value of maps as communication devices is determined by means of a qualitative study into the areas affecting the comprehension and construction of maps. Following from this a prototype map-based schedule is developed as a proof of concept in order to determine its feasibility as a communication medium and case studies are employed to qualitatively evaluate the effectiveness of maps as a technique for visualizing load-shedding schedules. It was found that maps present advantages over the current table-based schedule provided by Eskom. However it is also clear that the proposed solution is not a panacea for all potential tasks. While new spatial information is made available, a map-based approach results in the loss of significant temporal information. Maps and tables were found to fulfill complementary roles, leading to the recommendation that they be employed simultaneously as load-shedding schedule communication devices.

Categories and Subject Descriptors
[Interaction design]: Interaction design process and methods – *Interface design prototyping*;

[World Wide Web]: Web interfaces – *Mashups;*

[Applied Computing]: Computers in other domains – *Cartography;*

[Information systems applications]: Spatial-temporal systems – *Geographic information systems;*

Keywords
Load-shedding; maps; usability; schedules, South Africa

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1. INTRODUCTION
1.1 Background
South Africa is in the midst of an electricity crisis, with demand outstripping supply. Eskom, the country's main electrical utility provides almost 95 percent of electricity in South Africa, with the remainder supplied by independent power producers [37]. In January of 2015 the former CEO of Eskom, Tshediso Matona described the power system as: "extremely constrained and vulnerable" [31]. This state of affairs in South Africa has necessitated the introduction of scheduled, coordinated and rotational load-shedding at peak times in South Africa to protect the power system from a total, nationwide blackout [27].

In order to inform the public of the planned times when locations are affected by load-shedding Eskom has furnished municipalities and news agencies with schedules describing when specific locations are to be affected. Each municipality is divided into a number of zones with each zone being assigned various times to experience load-shedding. The schedules are designed around the days of the month and are divided into four stages reflecting the extent of the shortage in generation capacity in comparison to the demand for electricity, as indicated in Table1 [8]. One area is affected at a time during Stage 1, and four areas are affected at a time throughout Stage 4 load-shedding [10].

Table 1. Load-shedding Stages

Stage	Megawatts to be shed
1	1000 MW
2	2000 MW
3	3000 MW
4	4000 MW

Casting load-shedding schedules as communication devices allows for their analysis through the lens of information theory, specifically through Shannon and Weavers '*Theory of Communication*'. This theory proposes that information does not exist in isolation; it is dependent on an external entity to encode it as a message and transmit this message via a communication channel to other entities [40]. In this interpretation load-shedding schedules form the communication channel between Eskom and the public. Additionally the theory describes noise as an entity that acts on the communication channel, resulting in the transmitted information being misunderstood by the receiving entity [40]. For the case of load shedding schedules, noise occurs through inefficiencies in their design — increasing the cognitive load required to attain the desired information. A diagram applying Shannon and Weaver's theory of communication to load-shedding is provided in Figure 1.

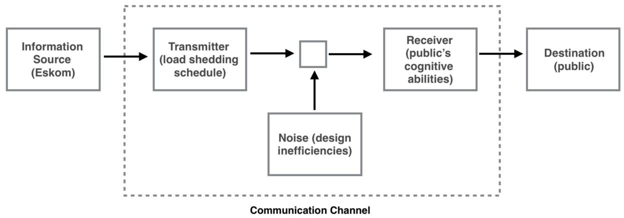

Figure 1. Shannon & Weaver's theory of communication applied to load shedding schedules [40]

1.2 Research Goals

Load-shedding information needs to be displayed in a manner that provides the highest level of usability, without compromising its ease of understanding or requiring a significant amount of cognitive effort on the part of the user. Schedules for electricity load-shedding are typically presented in a tabular format. This paper takes the position that this mechanism for presenting load-shedding schedule information is sub-optimal. Improvements in usability and ease of understanding can be achieved through altering the mechanism of display. Faster and more accurate decisions and interpretations can be made if information is presented in a manner that corresponds more accurately with the task at hand [43]. In response to this statement, this paper proposes that visualizing load-shedding schedule information in the form of a map will enhance their usability and ease of use.

Load-shedding presents an economic, social and personal burden to South Africans [2]. By improving the techniques through which load-shedding schedule information is made available to the public, people and organizations will be able to better organize their activities and to a degree mitigate some of the impact of load-shedding on their daily lives. This is especially the case for organizations such as logistics companies where accurate and simple information about many different locations is required in a timely manner. In light of this, the central aim of this paper is to investigate a technique for reducing the "noise" on the communication channel between Eskom and the public.

Certain media agencies have utilized the provided schedules to create maps to display load-shedding information. However, at the commencement of this study these solutions were not yet in existence. Moreover, little or no academic research exists exploring the theoretical rationale behind using maps as load-shedding schedule display techniques. By conducting research into the aspects surrounding the use of maps as techniques for displaying and locating information an improved understanding of their value will be able to be established.

In order to determine the value of maps as a visual display technique a qualitative study of the related literature was conducted. A secondary outcome of the literature review process was to establish guiding principles for the development of a load-shedding schedule using a mapping methodology. Owing to the fact that this schedule is based on guidelines established from academic research it is intended that it will be a significant improvement upon the existing tabular format as well as the proprietary map-based schedules created by certain news agencies. This schedule developed serves as a proof of concept. For this reason the scope of the schedules displayed is limited to one municipality's schedule; namely the City of Cape Town.

Initially, the paper establishes the theoretical background underpinning factors affecting the usability and perception of maps and visual display techniques. Following this, the next section reports on the process of developing a proof of concept map-based schedule. Next, two cases studies are employed to evaluate the effectiveness of maps as techniques for visualizing load-shedding schedules. Subsequently, a discussion of the shortcomings of the proposed system as well as the potential for future research will be presented.

2. RESEARCH PARADIGM

As this research paper proposes the evaluation of the theoretical underpinnings for the value of maps as load-shedding schedule display techniques, as well as the development of a prototype map-based load-shedding schedule, it falls under the paradigm of design science research (DSR). DSR describes a subcategory of Information Systems (IS) research focusing on the design and evaluation of artifacts with the intention of providing solutions to real-world problems [26]. March and Smith [29] characterized the nature of the artifacts produced within this paradigm into four categories: constructs, models, methods and instantiations. This paper produces an instantiation as an artifact. An instantiation involves developing a working artifact as a solution to the proposed problem, demonstrating its feasibility for the required tasks [29].

3. RELATED LITERATURE

In order to establish the theoretical framework within which this research lies, this section aims to explore literature relevant to the subject of visualization, and information display in an online context. To this end, research into the areas of website usability, visual perception, the use of colour as a highlighting technique, information overload and mapping as a visualization technique is presented. In addition to forming the theoretical framework supporting this research, the literature reviewed is intended to aid in guiding the development of an artifact-depicting load-shedding schedules in a map format.

3.1 Website usability

Research conducted by Dillon and McKnight [12] articulates the idea that usability should form a fundamental component of web design. The key role of usability in website design has been attributed to the nature of how the web is used. Nielsen explains that usage of the web is particularly goal orientated [34].

According to Dumas and Redish [14], usability denotes the ability for people to use a product to accomplish their own tasks in a manner that is quick and easy. The International Standards Organization (ISO) has formalized this conceptualization, defining usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specific context" [22]. Additionally, Keevil [25] proposes that the ease with which people can locate, and more importantly, understand information on a web site should be incorporated into a definition of usability. Relating this conceptualization to website usability, Nielsen [34] outlined five key characteristics to be incorporated into web usability, namely: ease of navigation, clarity of interaction, ease of reading, organization of information and speed.

Lee and Kozar [28] provide an interpretation of the ISO standard for usability for the web context. Lee and Kozar [28] state that in the context of website usability effectiveness relates to the accuracy with which users achieve their goals. Efficiency is represented by the extent to which achieving the desired goal requires significant cognitive effort [28]. Finally Lee and Kozar [28] explain that satisfaction describes the comfort of a website to the users.

3.2 Visual Perception

Owing to the fact that individuals obtain a larger amount of information through visual means than through all other senses combined [47], visual perception plays a key role in how individuals receive and process information displayed on the web. For this reason, understanding the major concepts behind visual perception will allow for the psychological aspects affecting perceptions of usability and ease of use of load-shedding schedules to be incorporated into the research artifact.

The initial stage of visual perception occurs prior to the stage of conscious attention [47]. Cognitive models of information processing classify pre-attentive processing as the processing of external inputs in an automatic manner not under the control of the individual [1]. Pre-attentive processing is an essential concept to visualization because it allows for the rapid processing and understanding of visual stimuli, causing elements to stand out from their surrounds [47].

Highlighting and the use of colour are primary examples of techniques applying pre-attentive processing to attract the attention of the viewer. Traditionally highlighting contrasts a coloured zone intended to stand out from the rest of the content [47]. A commonly cited example illustrating this concept is the task of locating a red dot amongst a collection of blue dots. An example of this task is presented in Figure 2. The target dot has a visual property distinct from the rest of the dots. This unique property attracts the attention of the visual system and allows for it to be pre-attentively processed, causing it to stand out to the user [21].

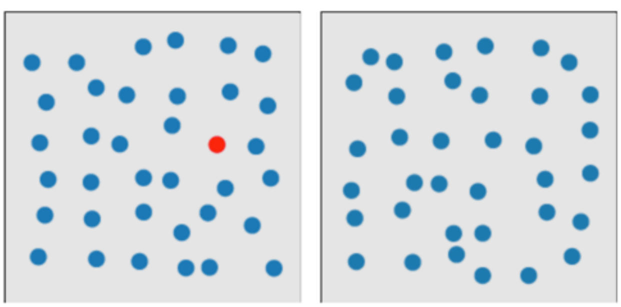

Figure 2. Locating a red dot amongst blue dots [21]

Differences occur in how humans process and store visual stimuli in working memory. Ware [47] supports the dual coding approach advocated for by Allan Paivo. This theory proposes two different psychological units for handling information: *imagens* for the mental representation of visual information and *logogens* for the mental representation of language information [36]. Dual coding is recognized and accepted as the mechanism for processing visual stimuli.

Images and words each present various advantages and disadvantages as far as visual perception is concerned. Information pertaining to spatial arrangements, location and detail is better conveyed in the format of an image, while text has an advantage for representing procedural information as well as logical conditions [47]. Likewise, Vessey [44] advocates for the theory of cognitive fit. Namely, spatial tasks require spatial information representation, such as maps; and symbolic tasks require symbolic representation such as tables. In addition to these differences, research conducted by Paivo & Csapo [35] indicates that when presented visually, nonverbal stimuli have a higher recall rate than verbal stimuli. However, the superiority of image recall in all instances has been challenged. Bower, Karlin and Dueck [7] propose that this superiority is only the case if the information conveyed by the image is meaningful to the viewer.

3.3 Color

There are two key elements pertaining to the manner in which colour effects perceptions of web content usability. First colour impacts readability. Second, colour can affect users' emotional responses to a stimulus. Research shows that colour impacts on readability primarily through the mechanism of contrast [20]. A study conducted by Shieh and Lin [41] considered the effect of colour combinations on readability and visual identification. Their study confirmed the salience of contrast for affecting readability.

As has previously been explained the primary function colour can facilitate in visualizing information is that of attracting attention to particular objects. Extensive research has been conducted supporting the role of colour in improving performance in search tasks [15,18].

As indicated by Moczarny, de Villiers and van Biljon [32], emotion is a primary factor in determining user experience. Therefor it is important to understand the nature of elements that can effect emotion, in order to facilitate a greater user experience. A large amount of psychological research, independent of information technology and the web, has been conducted investigating the relationship between colors and emotions.

The wavelength of the colour has an impact on the autonomic nervous system [39]. Investigations into the autonomic nervous system indicate that longer wavelength colors such as reds and yellows provoke greater levels of autonomic arousal than shorter wavelength colors such as blues and purples [48]. Samara [39] explains that this outcome is due to the fact that longer wavelengths require more energy to process and thus raise arousal levels, while the opposite is true of short wavelength colors. However, context, culture and personal experience affect these results. For instance Jacobs and Suess [23] show results indicating that long wavelengths can increase levels of anxiety, resulting in a less desirable emotional state.

3.4 The Amount of Information

How do users respond to being confronted by a larger or smaller amount of information? The key concept surrounding this issue is information overload. Eppler and Mengis [16] propose that information overload occurs when an individual is expected to process or understand a greater amount of information than they wish to or are capable of processing at that instance. Consequences of information overload include increased levels of stress and anxiety [16], contributing to a decrease in the emotional arousal associated with the information source and therefor a reduction in the perceived user experience [32]. This indicates that users can be overwhelmed with more information than is necessary and that there is scope for improvements in usability if a smaller amount of information is displayed. This would increase the efficiency of the experience as well as the effectiveness and the emotional response associated with it.

Distinct from the information overload concept, is the reading behavior of users on the web. In an examination of web-reading habits conducted by Morkes and Nielsen [33], it was shown that 79% of users sampled scanned webpages rather than reading all of the provided information. This study indicates that when confronted with a large amount of information on the web, a majority of users choose to ignore most of it and skim through for information that attracts their attention. This implies that designing a system that reduces the amount of reading required should achieve improvements in the user experience.

3.5 Tables and Maps

Tables are a common and significant tool for visualizing data and information [30]. Marchese [30] explains that the compact organizational structure which facilitates comprehension of relationships among the data elements within a table accounts for their potency as visual display mediums. Wainer [46] outlines four functions of tables: exploration, storage, communication and illustration. Marchese [30] expands upon Wainer's rationale for tables and explains that the central purpose of both communicative and illustrative tables is to present data or information in a clean and clear way that supports the purposes of the designer.

Due to the fact that the structure of a table is two dimensional, the information that they contain may be represented in the form of a map [30]. Cartography, the science of drawing maps uses imagery to express information about spatial data [30]. The term map describes a graphic representation containing two-dimensional spatial data, symbolic representations of real-world entities as well as conveying information about real world spatial relations [5].

Maps integrate pictorial representation with symbolic representation [4]. Berendt, Rauh and Barkowsky [4] justify this statement explaining that maps are manifested as images containing spatial relations corresponding to real world spatial relations [4]. Similarly, symbolic map representation is due to symbols, pictures, overlays and text being used to annotate maps, in order to describe real world elements [4].

As Ware [47] stated, images are a superior medium for displaying spatial and location specific information. Additionally, key advantages of viewing maps as pictorial representations of the real world are created by the geometric properties of the two-dimensional planar space [5]. A further factor supporting the use of maps is the argument by Pavio and Csapo [35] that visual, nonverbal information has a greater recall rate.

When utilizing a map as an information display technique, the primary aspect of the information does not have to relate to land. Rather, as Celantano and Pittarello [9] explain, the map forms a background upon which relations between different pieces of information or the locations where an event occurs may be made perceptible to a viewer. Research by Skupin [42] justifies the use of spatial or geographic techniques because of their link with the cognitive processes linking space, reasoning and thought.

Load-shedding affects various areas of a municipality either simultaneously or consecutively. Visualizing these spatial relationships in the form of a table requires more cognitive effort [44]. However, maps can easily facilitate the visualization of these relationships. Comprehending relationships between constructs allows for the improvement of individual's mental models of an issue, allowing them to make better decisions [24]. Smelcer and Carmel [43] explain this improvement through maps' ability to represent relationships between geographic features as well as among objects depicted on the map.

3.5.1 Maps as Communication Devices

As previously stated load-shedding schedules can be cast as communication devices between Eskom and the public. Extending this metaphor to the proposed map-based load-shedding schedule system, the map communication model developed by Robinson [38] allows for the analysis of maps as communication devices. Crampton [11] explained the key principles established in the map communication model. First, a clear distinction between the cartographer and the user is established. Second, maps form an intermediary between the cartographer and the user. Third, information is communicated by the map to the user from the cartographer. Fourth, the design of maps should take into account the cognitive and psychophysical limitations of the users' abilities to comprehend and remember information conveyed by the map.

4. DEVELOPING A LOAD-SHEDDING SCHEDULE MAP

This section aims to explain the process of development of the load-shedding schedule map artifact. Three key areas will be presented. Firstly, the key principles identified in the literature will be synthesized. Secondly, the technological background for the development of the artifact will be discussed. Subsequently, the development process will be reported on.

4.1 Key principals identified

Synthesizing the research findings several key principles have emerged which need to be adhered to in order to extract all of the advantages available through using a map format for displaying load-shedding schedules.

From the research into visual perception highlighting and the use of color emerged as a key feature necessary to be incorporated into the artifact. The effect of the wavelength of colors on the autonomic nervous system indicates that the load-shedding schedule map can be enhanced by carefully selecting the colors for particular elements. Longer wavelength colors (red, orange, yellow) were selected to represent the areas currently, next and subsequently to be load shed respectively. The remaining areas are indicated using various hues of green, which possesses a neutral wavelength.

Due to the format of maps, as well as the findings of the research into information overload on the web the load-shedding schedule map only displays information about one load-shedding severity stage at a single time. This reduces the amount of information people have to handle; simplifying the process of determining where and when is affected by load-shedding.

4.2 Background and Technologies

Because of the ubiquity of Google Maps (www.googlemaps.com) as an online mapping service it was chosen to form the core of the load-shedding schedule map. Google Maps is a geographically empowered web 2.0 service [19] launched in 2005 displaying geographic information in various formats. Additionally, Google provides the Google Maps API to facilitate the development of web mashups for Google Maps [3]. This API allows for the Google base data to be combined with spatially referenced data from other sources in order to create custom applications displayed through the Google Maps interface [19].

The Google Maps API presents a collection of JavaScript classes for interacting with various elements of a map service [19]. The load-shedding schedule map required the creation of colored overlays representing each zone within the City of Cape Town. In order to facilitate this, vector shapes were created as polygon objects displayed on the map.

4.3 Development process

This section aims to briefly describe the process of developing the prototype map-based load-shedding schedule. First, the requirements are established. Second, the chosen technology stack is explained. Third, development of the mechanism for retrieving the data from Eskom is described. Following this, the logic for determining the current zone is explained. The penultimate section explains the process of converting the PDF document describing the zones into the required format for Google Maps. Finally the link between the schedules determining the current stage and the map is described.

4.3.1 Requirements

1. Accurate and reliable information on the current load-shedding stage retrieved from Eskom.
2. Represent the zones accurately as overlays on a Google Map of the City of Cape Town.
3. Indicate the correct zone currently being load-shed based on the time of the day and the day of the month, corresponding to the schedules provided.
4. Display the information in a manner allowing for quick, easy, visual querying by users.

4.3.2 Technology Stack

The web application framework Django [13], built in Python was used to create the website housing the load-shedding schedule map. The choice to implement this prototype within the framework created by Django was dictated due to the larger context within which this current research exists. This context includes the full-scale development of multiple display techniques in order to conduct user-based research into the effectiveness of various schedules. This framework is responsible for handling the necessary settings, HTML and CSS as well as the logic involved in determining the current stage and location to be indicated on the map. The map itself is generated using the Google Maps API in JavaScript. The overlays indicating the various regions as well as the logic for highlighting the required zones are handled in JavaScript.

4.3.3 Retrieving data from Eskom and storing schedules

The first stage in developing the load-shedding schedule map involved programmatically storing the schedules. Inspection of the schedules for each stage provided by the city of Cape Town [8] revealed the pattern for how load-shedding is distributed amongst the zones. This pattern was then used to generate lists for each load-shedding stage containing the zone number for each zone.

The second step required retrieving the current load-shedding status from Eskom. In order to do this the python httplib2 model is used to transmit a HTTP request to the address displayed below. In response to this request the current load-shedding stage is returned.

```
http://loadshedding.eskom.co.za/LoadShedding
/GetStatus?
```

4.3.4 Determining the current zone

The next stage of development required creating the logic to determine which stages were required to be highlighted in the map. In order to do this, two functions were created. The first function took the current load-shedding stage, the corresponding schedule list, the date and the current time as parameters. Based on the current load-shedding stage the second function was called receiving the corresponding list, the date as well as the time. The time and the date were used to determine the index for the current zone being shed from the stage list. The current zone or list of zones if the stage was greater than one was then returned to the first function, handling the separation for stages two, three and four.

4.3.5 Creating the map

In order to create the polygons for the overlay on the map the coordinates for each load-shedding zone were required to be extracted from the PDF map provided by the City of Cape Town. This PDF map was imported into vector graphics editing software. Each zone was then defined as a vector group. This file was then exported as a scalable vector graphic (SVG) allowing for the coordinates for each vector group stored as XML to be parsed and thereby converted from SVG viewport relative coordinates in to real world coordinates.

Figure 3. Creating the vector groups for each zone in Inkscape vector software

It emerged that the simplest method for conducting this translation was to employ a 3x3 transformation matrix of the form indicated in equation one as outlined in the W3C SVG specification [45].

$$\begin{bmatrix} a & c & e \\ b & d & f \\ 0 & 0 & 1 \end{bmatrix} \tag{1}$$

Equation two illustrates the process of converting the SVG based coordinates to geographic coordinates.

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = M \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{2}$$

Where M represents the current transformation matrix (CTM), defining the mapping from the SVG viewport to the geographic coordinate system. The SVG coordinate matrix is multiplied by the CTM in order to derive the final geographic coordinates.

This process involves mapping the coordinates from the SVG viewport to the longitudinal and latitudinal coordinate system. In order to facilitate this process and create the new coordinate space, three points were required to be manually matched with corresponding longitude and latitude points. These equivalent locations were then used to carry out the matrix transformation.

The next stage in developing the map involved initializing a new Google Maps object to be displayed on the website upon the page being loaded. Creating the overlay for each zone required the initialization of a new polygon object containing the corresponding latitude and longitude coordinates for its' points. On completion of the initialization of each polygon, they are all assigned to the map object, along with their respective zone label.

4.3.6 Combining live load-shedding information with the map

Communication needed to be achieved between the Python system retrieving the current load-shedding stage and the zones affected. The HTML page containing the element populated by the Google Maps object receives a variable from the Django context referencing the zone number of the zones for which the map should indicate current load-shedding. The JavaScript function creating the map and the polygons is cast as an anonymous function, taking these variables as arguments. Each zone polygon retrieves its' color value from an array storing the available colors. The variables indicating the zones to be highlighted are then employed to alter the selected color for the zones currently being load shed. As previously explained, the load-shedding schedule map displays the currently affected area in red, the next area to be affected in orange and the area following that in yellow. The remaining areas are depicted in various hues of green.

The Google Maps API presents 18 options for the initial zoom level of the map. Each level hides or shows specific information [6]. For the load-shedding schedule map an initial zoom level of 11 was specified. This allows for a high level overview of how load-shedding will be affecting the City of Cape Town over the following six hours. This initial view can be observed in Figure 3. The functionality inherent in Google Maps allows for users to zoom in displaying a greater level of detail. Because of the vector nature of the polygon overlays, all information is preserved at higher zoom levels. A lower level example can be observed in Figure 5.

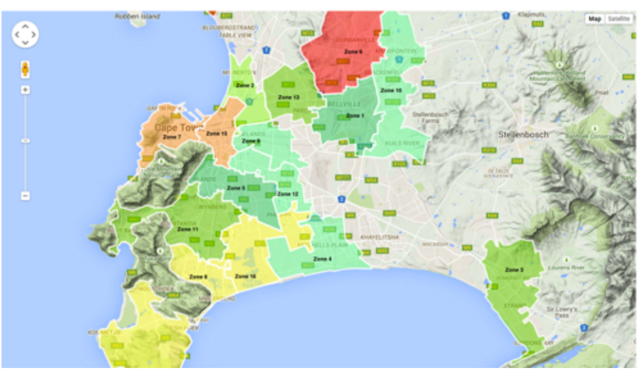

Figure 4. High-level view of Cape Town load-shedding map overlays

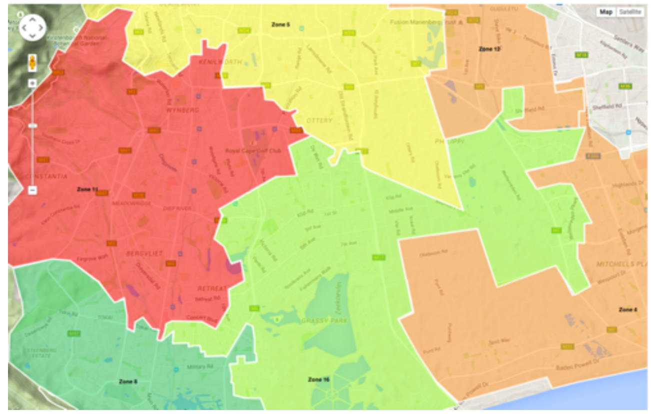

Figure 5. Zoomed, lower level view of Cape Town load-shedding map overlays

5. CASE STUDIES

Two hypothetical case studies are proposed as a means to qualitatively evaluate the effectiveness of load-shedding schedules. The first case study provides a run through of a potential use case for a table-based load-shedding schedule. The second case study provides an illustration of the advantages inherent in a map-based load-shedding schedule.

5.1 Case Study One

The problem posed in this case study is that of locating the load-shedding information for a particular location for every day of a particular month. This problem is considered to be a common use case for load-shedding schedules. Organizations and individuals will wish to be able to take the potential times and locations for load-shedding into account when they plan their future activities.

When using a table-based load-shedding schedule as indicated in Figure 7, a user is confronted with tables for each stage of load-shedding organized by the date and the time. In order for a user to determine when their location is to be load shed they need to look up their zone number in the key provided. Following this they are required to locate their zone number in the table and check at which times they are affected for each date. The process of determining the dates and times for which their area is affected by load-shedding then needs to be carried out for each stage of load-shedding as well as for any additional areas for which the user seeks information about.

This case makes it clear that many steps are involved in order to acquire this information, requiring a significant amount of cognitive effort. A static table-based display technique as shown in figure five carries no information about the current stage of load-shedding. To gain this knowledge users would first have to locate this at a separate location. Dynamic table-based schedules have been employed by several news agencies as a solution to this issue [17].

STAGE 1

DAYS OF THE MONTH		1st / 17th	2nd / 18th	3rd / 19th	4th / 20th	5th / 21st	6th / 22nd	7th / 23rd	8th / 24th	9th / 25th	10th / 26th	11th / 27th	12th / 28th	13th / 29th	14th / 30th	15th / 31st	16th
TIME FROM	TIME TO																
0:00	2:30	1	13	9	5	2	14	10	6	3	15	11	7	4	16	12	8
2:00	4:30	2	14	10	6	3	15	11	7	4	16	12	8	5	1	13	9
4:00	6:30	3	15	11	7	4	16	12	8	5	1	13	9	6	2	14	10
6:00	8:30	4	16	12	8	5	1	13	9	6	2	14	10	7	3	15	11
8:00	10:30	5	1	13	9	6	2	14	10	7	3	15	11	8	4	16	12
10:00	12:30	6	2	14	10	7	3	15	11	8	4	16	12	9	5	1	13
12:00	14:30	7	3	15	11	8	4	16	12	9	5	1	13	10	6	2	14
14:00	16:30	8	4	16	12	9	5	1	13	10	6	2	14	11	7	3	15
16:00	18:30	9	5	1	13	10	6	2	14	11	7	3	15	12	8	4	16
18:00	20:30	10	6	2	14	11	7	3	15	12	8	4	16	13	9	5	1
20:00	22:30	11	7	3	15	12	8	4	16	13	9	5	1	14	10	6	2
22:00	0:30	12	8	4	16	13	9	5	1	14	10	6	2	15	11	7	3

Figure 7. Table-based load-shedding schedule supplied by the City of Cape Town [10]

If this same user used a map-based load-shedding schedule as illustrated in Figure 4, they would immediately be made aware of the areas currently experiencing load-shedding as well as the following two locations to experience this. Additionally, they would be able to locate their desired locations with minimal cognitive effort and be able to determine if they fall within the set of upcoming locations. However the map provides no information about load-shedding for any other days of the month other than the current day. In fact, it only provides information about the next six hours from any given time. The map fails in fulfilling the user's desire for information about load-shedding for the entire month.

However, the case study does exemplify the value of table-based load-shedding schedules. The user can acquire time and date information about load-shedding for many different areas. Additionally, the table easily facilitates the display and location of load-shedding information for the entire month, allowing users to take load-shedding into account when planning future activities days or weeks in advance.

5.2 Case Study Two

The second case study poses the problem of an individual or organization wishing to plan their daily activities in different locations around the city. The assumption inherent in this case study is that individuals and organizations conduct their business in many different locations within the city, seldom remaining in one location throughout a single day.

If a user with this particular problem chooses to make use of a table-based load-shedding schedule they are required to know or lookup the zone number for each zone they are planning to visit. This task is complicated due the fact that the load-shedding zones do not directly match existing suburb boundaries. Following the location of all of the zone numbers for all of the required areas the user then has to conduct the standard table lookup process as explained in case study one, for each of the desired zones and load-shedding stages.

When using a map-based load-shedding schedule to solve the problem posed in this case study, the user is immediately made aware of which zones are currently being load shed. Additionally, the map indicates the zones next to be load shed. In this way, the information displayed for the user is reduced to just the information that they need to fulfill their current task. The benefit provide by a map-based solution to the problem posed in this case study is the ability for the user to visualize the path of load-shedding through the city. Additionally, the user is no longer required to determine which zone particular locations fall under. This information is made clear through the map overlays.

6. DISCUSSION

6.1 The Value of Maps

The primary hypothesis advanced by this paper is that maps provide an improved method for displaying and communicating load-shedding schedule information to the public. The research examined has revealed several aspects strengthening the stated position. The manner in which load-shedding schedule information is presented needs to correspond to both the way in which people intend to gather this information as well as the use they have for this knowledge. This statement is supported by Smelcer and Carmel's research [43].

A map format has the advantage of allowing people to visualize the pattern in which load-shedding will affect their municipality, allowing them to plan their activities better. However, the amount of information capable of being displayed in a visually pleasing manner simultaneously in a map format is limited. For this reason, displaying load-shedding schedule information on a map achieves a compromise between displaying all load-shedding information as it is in the table-based schedules, and a smaller subset of the information in an easier to understand manner.

Research into cognitive and psychological issues underpinning visual perception revealed further strengths of the map-based approach. Maps allow for the use of colour as a technique for highlighting. This can enhance the speed with which individuals can query schedules through preattentive processing. The use of colour can also be used to attempt to positively affect users' autonomic nervous system by wisely considering the colors in which particular zones are shown.

Load-shedding information is fundamentally a spatial concept with an associated time dimension. Research has shown that spatial information is better comprehended in the form of images or maps (Ware, 2004). Furthermore, depicting spatial information such as load-shedding locations in a map format makes information more easily accessible to the natural human cognitive processes of understanding and sensemaking [42].

6.2 The Effectiveness of the Artifact as an Information System

The artifact created serves as a proof of concept illustrating the applicability of maps as load-shedding schedule display devices. The use of Google Maps as a base simplified the development through the use of the Google Maps API. Because the map-based schedule created incorporates the ideas synthesized from the research, it is believed that it should achieve a greater level of usability and ease of understanding for the public. However, it has not been empirically confirmed whether this assertion holds true.

The case studies employed in this paper serve as a qualitative means for evaluating map-based load-shedding schedules. Case study one identified several key shortcomings in using maps for load-shedding schedules. The hypothetical user was unable to solve their problem using a map-based solution. This implies that maps are not a panacea for all load-shedding use cases. Nevertheless, the first case study confirmed the previously stated assertion regarding problems inherent in table-based schedules.

The problem posed in the second case study revealed the value of a map as a means for deriving load-shedding location information. This problem required a more spatially orientated solution as opposed to the problem in the first case study, which required a temporally orientated solution. The hypothetical user in the second case study was able to simply gain knowledge about the trajectory of load-shedding over the course of the day with a minimal amount of cognitive effort. The case studies revealed situations where maps provide value, as well as when a table is a useful tool. For this reason, it is recommended that maps and table-based schedules can serve as complementary means in which load-shedding information can be communicated to the public. Subsequent to the research conducted in this paper a map-table hybrid has emerged on the market, developed by EWN viewable at: http://ewn.co.za/assets/loadshedding/capetown.html. This solution combines maps and tables in a single solution. However the use of colour as a highlighting device is not optimized. Additionally, the value of a map in reducing the amount of information displayed is lost when it is combined with a table displaying the same information in a different format.

6.3 Scope for Future Research

The findings presented in this paper serves as a point of departure for researching alternative methods for displaying load-shedding schedule information. There exists a wide scope for future research to be conducted into the value of maps as load-shedding schedules. Due to time constraints present during the research process no quantitative testing into the effectiveness of the artifact could be conducted. In order to empirically determine the effectiveness of maps as a load-shedding scheduling technique quantitative, user-based studies need to be conducted. Similarly no prior quantitative empirical research was uncovered comparing methods for visualizing load-shedding information. The focus of this paper fell on the value of the artifact for individuals. Further research is required to extend this and determine the value of the proposed solution for companies.

7. CONCLUSION

This research paper set out to establish the value of maps as a technique for visualizing load-shedding schedules in Cape Town. Through a qualitative analysis of factors affecting the interpretation, understanding and construction of maps it was determined that if designed correctly, maps can enhance the display of load-shedding schedules. Case studies were conducted to evaluate these finding. The case studies revealed that while maps certainly present many advantages for the display of load-shedding schedules there are many problems and issues for which they do not present a solution. It is recommended that maps and table-based schedules can serve as complementary communication devices, working in tandem to reduce the noise between Eskom and the public.

The feasibility of a map-based schedule was demonstrated through the development of a prototype map-based schedule employing the techniques uncovered in the qualitative study. Due to constraints upon the research both the evaluation of maps in general as well as the evaluation of the prototype was restricted to two hypothetical case studies. This provides the opportunity for quantitative studies empirically assessing a map-based solution.

As previously noted, load-shedding presents a significant impact upon individuals and the society of South Africa [2]. This underscores the importance of research into methods for reducing the impact of load-shedding on the daily lives of South Africans. The research presented in this paper provides theoretical motivations for the value of an alternative manner of communication for Eskom. While this knowledge will not reduce the amount of load-shedding experienced in South Africa. It can lead to the creation of improved schedules allowing people to better control how they are affected by load-shedding – ultimately improving their daily lives.

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9. REFERENCES

[1] Atienza, M., Cantero, J. L., & Escera, C. (2001). Auditory information processing during human sleep as revealed by event-related brain potentials. *Clinical neurophysiology*, *112*(11), 2031-2045.

[2] Altman, M., Davies, R., Mather, A., Fleming, D., & Harris, H. (2008). The impact of electricity price increases and rationing on the South African economy: final report to the National Electricity Response Team (NERT) *Economic Impact Task Team.*

[3] Barr, R. (2008). Google and GI science: Revolution, evolution or wild goose? *London: Centre for Advanced Spatial Analysis Seminar,* University College London 30th January 2008.

[4] Berendt, B., Rauh, R., & Barkowsky, T. (1997). Spatial Thinking with Geographic Maps: An Empirical Study. In *Herausforderungen an die Wissensorganisation (ISKO Tagung)* (pp. 63-74).

[5] Berendt, B., Barkowsky, T., Freksa, C., & Kelter, S. (1998). *Spatial representation with aspect maps*. In C. Freksa, C. Habel, & K. F. Wender (Eds.), Spatial cognition - An interdisciplinary approach to representing and processing spatial knowledge. Berlin: Springer.

[6] Bildirici, I. O., & Ulugtekin, N. N. (2010). Web mapping with Google maps mashups: overlaying geodata. In A special joint symposium of ISPRS technical commission IV & AutoCarto in conjunction with ASPRS/CaGIS 2010 fall specialty conference, Orlando, FL (pp. 15-19).

[7] Bower, G. H., Karlin, M. B., & Dueck, A. (1975). Comprehension and memory for pictures. *Memory & Cognition*, *3*(2), 216-220.

[8] *Cape Town load Shedding Schedule* [Online] Retrieved June 19, 2015: https://www.capetown.gov.za/en/electricity/LS2015/EG2014_02_Schedule.pdf

[9] Celentano, A., & Pittarello, F. (2012). From real to metaphoric maps: Cartography as a visual language for organizing and sharing knowledge. *Journal of Visual Languages & Computing*, *23*(2), 63-77.

[10] City of Cape Town (2015). *Load shedding schedules.* [Online] Retrieved May 18, 2015: http://www.capetown.gov.za/en/electricity/Pages/LoadShedding.aspx

[11] Crampton, J. W. (2001). Maps as social constructions: power, communication and visualization. *Progress in Human Geography*, *25*(2), 235-252.

[12] Dillon, A., & McKnight, C. (1995). Never mind the theory, feel the data: Observations on the methodological problems of user interface design. In *Designing user interfaces for hypermedia* (pp. 117-125). Springer Berlin Heidelberg.

[13] Django Project. [Online] Retrieved June 21, 2015: https://www.djangoproject.com/

[14] Dumas, J., & Redish, J. (1994). *A practical guide to usability testing*. Norwood, NJ: Ablex Publishing.

[15] Egeth, H. E., Virzi, R. A., & Garbart, H. (1984). Searching for conjunctively defined targets. *Journal of Experimental Psychology: Human Perception and Performance*, *10*(1), 32.

[16] Eppler, M. J., & Mengis, J. (2004). The concept of information overload: A review of literature from organization science, accounting, marketing, MIS, and related disciplines. *The information society*, *20*(5), 325-344.

[17] Eye Witness News (2015). *Load shedding.* [Online] Retrieved June 21, 2015: http://ewn.co.za/assets/loadshedding/capetown.html

[18] Friedman-Hill, S., & Wolfe, J. M. (1995). Second-order parallel processing: visual search for the odd item in a subset. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(3), 531.

[19] Gibin, M., Singleton, A., Milton, R., Mateos, P., & Longley, P. (2008). An exploratory cartographic visualisation of London through the Google Maps API. *Applied Spatial Analysis and Policy*, *1*(2), 85-97.

[20] Hall, R. H., & Hanna, P. (2004). The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention. *Behaviour & information technology*, *23*(3), 183-195.

[21] Healey, C. G., & Enns, J. T. (2012). Attention and visual memory in visualization and computer graphics. *Visualization and Computer Graphics, IEEE Transactions on*, *18*(7), 1170-1188.

[22] ISO9241-11. 1998. Ergonomic requirements for office work with visual display terminals (VDTs)—Part 11: Guidance on usability. International Organisation for Standardization.

[23] Jacobs, K. W., & Suess, J. F. (1975). Effects of four psychological primary colors on anxiety state. *Perceptual and motor skills*, *41*(1), 207-210

[24] Keen, P. G. (1981). Value analysis: justifying decision support systems. *MIS Quarterly*, 1-15.

[25] Keevil, B. (1998): Measuring the usability index of your Web site. In: *CHI '98, Conference Proceedings on Human factors in Computing Systems*. (pp. 271-277). New York, NY: ACM Press.

[26] Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489-504.

[27] Larson, A. (2015). Power Shortages Challenge Eskom, Force Load Shedding in South Africa. *Power*, 159(3), 12-14.

[28] Lee, Y., & Kozar, K. A. (2012). Understanding of website usability: Specifying and measuring constructs and their relationships. *Decision Support Systems*,*52*(2), 450-463.

[29] March, S.T. & Smith, G. 1995. Design and Natural Science Research on Information Technology, *Decision Support Systems*. 15(4): 251-266.

[30] Marchese, F. T. (2013). Periodicity, visualization, and design. *Foundations of Chemistry*, *15*(1), 31-55.

[31] Matona, T. (2015). *Eskom media presentation: 15 January 2015* [Online] Retrieved May 18, 2015: http://www.eskom.co.za/news/Documents/20150115CE_SystemStatusPresent.pdf

[32] Moczarny, I. M., De Villiers, M. R., & Van Biljon, J. A. (2012, October). How can usability contribute to user experience?: a study in the domain of e-commerce. In *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference* (pp. 216-225). ACM.

[33] Morkes, J., & Nielsen, J. (1998). Applying writing guidelines to Web pages. In *CHI 98 Cconference Summary on Human Factors in Computing Systems* (pp. 321-322). ACM.

[34] Nielsen, J. (2000). *Designing Web Usability: The Practice of Simplicity*. Indianapolis, IN: New Riders Publishing.

[35] Paivio, A., & Csapo, K. (1973). Picture superiority in free recall: Imagery or dual coding?. *Cognitive psychology*, *5*(2), 176-206.

[36] Paivio, A. (1990). *Mental representations*. Oxford University Press.

[37] REEEP. (2013). Energy Profile South Africa. [Online] Retrieved May 18, 2015: http://www.reegle.info/countries/south-africa-energy-profile/ZA

[38] Robinson, A. H., & Petchenik, B. B. (1975). The map as a communication system. *The Cartographic Journal*, *12*(1), 7-15.

[39] Samara, T. 2014. Design Elements, 2nd edition: Understanding the rules and knowing when to break them – updated and expanded. New York: Rockport Publishers

[40] Shannon, C. E. (1948), A Mathematical Theory of Communication. *Bell System Technical*

[41] Shieh, K. K., & Lin, C. C. (2000). Effects of screen type, ambient illumination, and color combination on VDT visual performance and subjective preference.*International Journal of Industrial Ergonomics*, *26*(5), 527-536.

[42] Skupin, A. (1998). *Organizing and visualizing hypermedia information spaces.* (Doctoral Thesis) State University of New York at Buffalo, Buffalo

[43] Smelcer, J. B., & Carmel, E. (1997). The effectiveness of different representations for managerial problem solving: comparing tables and maps.*Decision Sciences*, *28*(2), 391-420.

[44] Vessey, I. (1991). Cognitive fit: A theory-based analysis of the graphs versus tables literature. *Decision Sciences*, *22*(2), 219-240.

[45] W3 SVG Specification (2011). *Coordinate Systems, Transformations and Units* [Online] Retrieved June 19, 2015: http://www.w3.org/TR/SVG/coords.html#InterfaceSVGMatrix

[46] Wainer, H. (1997). Improving tabular displays, with NAEP tables as examples and inspirations. *Journal of Educational and Behavioral Statistics*, *22*(1), 1-30.

[47] Ware, C. (2004). *Information Visualization:* perception for design (second edition). San Francisco: Morgan Kaufmann Publishers.

[48] Wilson, G. D. (1966). Arousal properties of red versus green. *Perceptual and motor skills*, *23*(3), 947-94