Where Should a Utility Improve Tree Cutting to Reduce the Risk of Vegetation Coming into Contact with Power Lines?

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***Abstract*—Utility systems have come under attack from storms, trees, squirrels, fires, and firearms. 2018 was particularly bad for outages from wildfires in California. Fallen trees or tree limbs caused approximately 50% of the total minutes of service interruptions in 2017. In 2018, wildfires burned millions of acres. Regulators have struck back against utility companies, imposing tens of millions of dollars in fines related to wildfires. One issue is that the grid has many poles and wires that are vulnerable to falling trees and flying debris. To reduce the risk of wildfire and keep customers safe, electric utilities need to accelerate their vegetation-management work. The idea is to reduce vegetation below and near power lines that could act as fuel in a wildfire, as an added layer of protection, and to enhance defensible space. This study aimed to address the question, "Where should a utility improve tree cutting and trimming initiatives to foster operational excellence and reduce the risk of vegetation coming into contact with power lines?" To answer the research question, Insights for ArcGIS (a Geographic Information System) was used to build worksheets using a geographic information-systems-based application aimed at resolving current challenges faced by utilities to reduce the risk of power outages. A case study was developed to demonstrate the risk scenario that entails a utility company taking action and preparing for the unexpected. An artifact in Insights for ArcGIS was created using a design-science-research methodology. This research proposes an elegant, interesting, and novel solution to aid in vegetation management. The artifact demonstrates that GIS can play an integral role in the problem resolution.**

Keywords—power failure; GIS model; Design-Science-Research; vegetation management.

I. INTRODUCTION AND PROBLEM DEFINITION

The placement of a new automated distribution switch has long-term impacts on the reliability of the circuit in which it is installed [1]. Common placement strategies rely on manual processes and the inherited knowledge of the planning engineer regarding the configuration, past reliability performance, future load growth, planned distributed energy resources, and other protection-related schemes of the circuit being analyzed in order to select a new switch location [2]. Without optimization algorithms to account for the many operating parameters and outage scenarios, the planning engineer may select a less than optimal location. According to Jim Horstman, a utility-industry consultant, a less than optimal placement may lead to less-than-optimal reliability performance and adversely affect customer satisfaction.

The objective of this study was to provide instantiation of a Geographic Information Systems (GIS) model and an analysis framework developed in previous research by the authors of this manuscript. To instantiate is to create a real instance or a particular realization of an abstraction or a process [3]. Therefore, the solution offered in this paper could lead us to a GIS-based application prototype that identifies optimal grid location(s) that need inspection or infrastructure work, as well as detect regions where new components such as distribution switches may provide net benefits to the grid, considering the many operating parameters and outage scenarios.

The Environmental Systems Research Institute [4] defined GIS as a class of tools for seizing, storing, analyzing, and demonstrating data in relation to their positions on the Earth's surface. Analysts use GIS to view different objects' locations and study their relationships. Satellite and tabular data can be entered into GIS for a single map display. GIS applications include recognizing site locations, mapping topographies, and developing analytical models to forecast events [4].

Though predictive modeling has existed since the inception of statistics, the penetration of GIS fostered a new approach to forecasting and data analytics. Predictive modeling is a process to determine a mathematical relationship between two or more variables [5]. Future dependent variables can derive if their relationships to independent variables become known. Predictive modeling with GIS has been applied in various sectors such as public health [6] and public-works asset management [7]. GIS is not limited to any specific field; it is only restricted by the availability of geospatial data.

GIS is a catalyst for improving multiple facets of smart grids. For instance, Resch et al. [8] integrated GIS-based modeling into the energy system to address renewable-energy-infrastructure planning. Sultan and Bitar [9] used GIS to optimize the locations of a distributed energy resource such as solar panels. Similarly, Sultan et al. [10] investigated power-grid reliability incidents/power outages and their correlation with infrastructure age by using GIS-based modeling. Therefore, GIS enhances research inquiries in the smart-grid domain. Based on our previous research [9]-[10] we posit GIS can highlight the optimal locations for different components of the electric-power network including the new automated distribution switches. For this

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research study, we designed an artifact: a GIS-based solution that resolves current challenges faced by utilities to improve tree cutting and foster operational excellence. Section II presents the study design and methodology. Section III illustrates the design principle. Section IV describes deployment. In Section V, we discuss research evaluation. In Section VI, we offer conclusions.

II. STUDY DESIGN AND METHODOLOGY

The artifact/solution uses a Design-Science-Research (DSR) methodology. Walls, Widmeyer, and El Sawy [11] conceived DSR and laid the foundations and arguments for DSR in behavior-centric information-systems research. March and Smith [12] elucidated DSR further by separating natural science from design science. A decade later, DSR was integrated into the fabric of information-systems research through several seminal publications [3][13]–[16].

Every DSR needs a design principle as guidance. Hence, for this study, we used the principle outlined in Peffers et al. [16]. The principle, collectively called DSR, was also used as a basis for another study [13]. Figure 1 depicts the DSR method.

III. DESIGN PRINCIPLE

The DSR method contains six activities. These activities interact sequentially. In addition, iteration through one or more activities is likely. The DSR method includes four possible entry points that indicate how a DSR project would start.

A. Possible Entry Points

Even though Peffers et al. [16] did not elucidate the four entry points—(1) problem-centered initiation, (2) objective-centered solution initiation, (3) design and development center initiation, and (4) client/context initiation—they did provide four case studies to demonstrate how each entry point works. Conceptually, researchers could start their research endeavors using any of the entry points, as long as the researchers defined all activities in the design science research method in their entirety.

This research entry point is classified as an objective-centered solution initiation. As noted above, our objective in this research was to reduce the risk of power outages by advancing tree cutting and trimming initiatives. Due to the rapidly changing nature of energy generation, new developments in the electric-power network, the incorporation of distributed energy resources into the grid, and circuit and equipment overloads, grid reliability research has been unable to keep pace. Power outages can be especially tragic in life-support systems in hospitals and nursing homes or systems in synchronization facilities such as airports, train stations, and traffic control. The economic cost of power interruptions to U.S. electricity consumers was $79 billion annually in damages and lost economic activity [17]. These facts highlight the need to investigate grid reliability, which is the objective of this research and the entry point to initiating an objective-centered solution.

B. Process Guiding Design

In conjunction with the design principle elucidated in the previous section, the research entailed using the process steps in Takeda, Veerkamp, and Yoshikawa's [18] design cycle to create an artifact/solution. This cycle has five simple steps: awareness of the problem, suggestion, development, evaluation, and conclusion. The Takeda et al. design cycle demonstrates how DSR was embraced as a research paradigm for information-systems research projects [13]. We used the three DSR cycles of relevance, design, and rigor [14] to perform each of the Takeda et al. process steps leading to the final prototype in this paper.

This study aimed to address the following question: "Where should a utility improve tree cutting and trimming-related initiatives to foster operational excellence and reduce

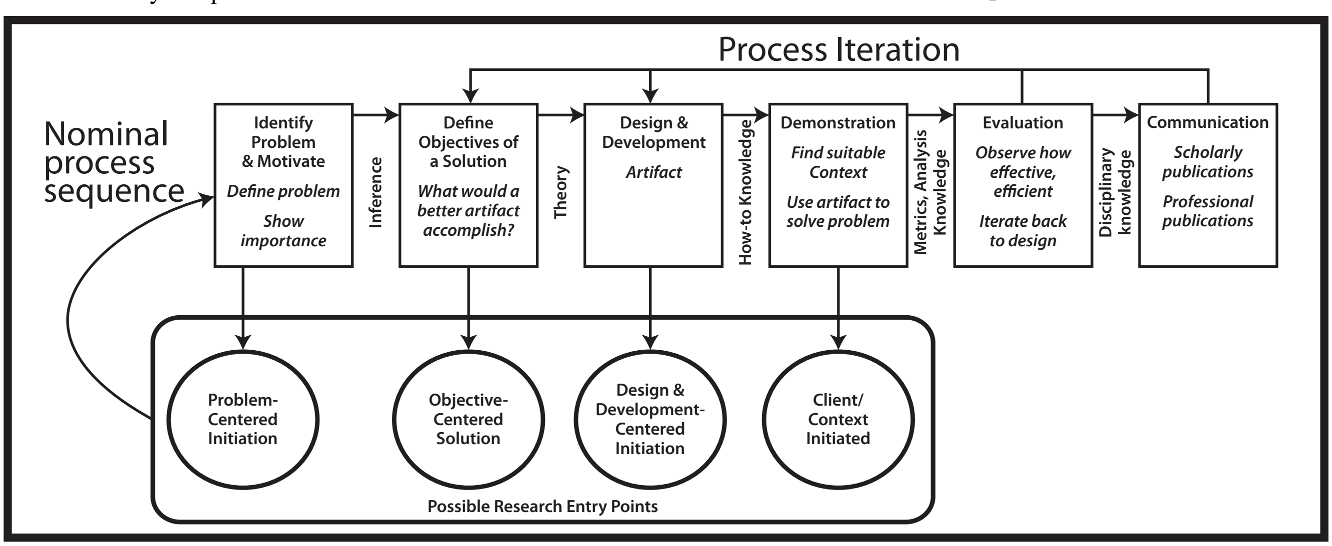

Figure 1. Design science research method [16].

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the risk of vegetation coming into contact with power lines?" To answer the research question, we propose a GIS-based application that would be an elegant, interesting, and novel solution to aid in vegetation management. This study illustrates how utilities can address current challenges to improve grid reliability. The artifact demonstrates that GIS can play an integral role in the problem resolution.

We used a scenario-based methodology to evaluate the proposed solution. We extracted case episodes of actual site use by users (described as scenarios) to define the objectives of the target application. The key strength of the scenario-based methodology is its ability to support investigation of phenomena such as power failures that are hard to research by more conventional means. Sugimura and Ishigaki [19] highlighted its potential, for example, to break down an extracted scenario into steps of actions and answer questions about the actions given as check items. To complete the evaluation, we elicited opinions from industry experts regarding the viability of the model. Getting expert feedback is helpful at this phase to see if the instantiation demonstrated the overall usefulness of the intervention.

IV. DEPLOYMENT

One of the newest technologies is Insights for ArcGIS, which is part of the new ArcGIS Enterprise family from the Environmental Systems Research Institute. Insights for ArcGIS can open doors for utilities to expand the use of asset-management data, for example, to support business-related decisions. Insights for ArcGIS has transformed how researchers traditionally performed spatial analysis [20]. It is a web-based, data-analytics application with the capability to work with interactive maps and charts at the same time.

In this research, we developed a case study to demonstrate the risk scenario/challenge that entails a utility company taking action and preparing for the unexpected.

A. Utilities Case Study/Vegetation Scenario

Utility systems have come under attack from storms, trees, squirrels, fires and firearms and 2018 was particularly bad for outages from wildfires in California. Regulators imposed tens of millions of dollars in fines against utility companies associated with wildfires, including $37 million for the 2007 Malibu fire; $14.4 million for the Witch, Rice and Guejito fires in the same year; and $8.3 million for the 2015 Butte Fire [21]. Many poles and wires in the grid are vulnerable to falling trees and flying debris.

Half of the total minutes of service interruptions in 2017 accrued from fallen trees or tree limbs [22, p. 14]. According to the National Interagency Fire Center, in 2018 more than 48,347 wildfires burned more than 7.3 million acres, as of late September [23]. Figure 2 shows some overall data on the total number of outages caused by weather/falling trees [24].

To reduce the risk of wildfire and keep customers safe, electric utilities need to accelerate their vegetation-management work. Utilities are already working to meet new state vegetation and fire-safety standards. In California, for instance, the new standards require a minimum clearance of 4 feet around power lines in high fire-threat areas with clearances of 12 feet or more at the time of trim to ensure compliance year round [25]. However, accelerated wildfire

Top states for outages caused by weather/falling trees

2017 (1,159 total outages)	2016 (1,279 total outages)	2015 (1,069 total outages)	2014 (1,081 total outages)
1. California (124)	1. California (116)	1. California (96)	1. California (81)
2. Texas (65)	2. Texas (72)	2. Texas (72)	2. Texas (57)
3. New York (64)	3. Michigan (72)	3. Michigan (43)	3. Pennsylvania (52)
4. Michigan (56)	4. North Carolina (67)	4. Ohio (42)	4. Michigan (49)
5. Pennsylvania (47)	3. Ohio (67)	5. North Carolina (41)	5. Ohio (47)
6. Ohio (42)	5. New York (60)	6. Washington (35)	6. New York (44)
7. Massachusetts (38)	6. Pennsylvania (48)	7. New York (35)	7. North Carolina (41)
8. North Carolina (35)	7. Florida (46)	8. Pennsylvania (34)	8. Georgia (35)
9. Colorado (32)	8. Massachusetts (41)	9. Oklahoma (33)	9. Virginia (32)
9. Virginia (32)	9. Virginia (38)	10. Connecticut (33)	9. Wisconsin (32)

Figure 2. Eaton's Blackout Tracker [24].

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vegetation-management work is still needed to address overhanging branches or limbs. The idea is to reduce vegetation below and near power lines that could act as fuel in a wildfire, as an added layer of protection and to enhance defensible space. Thus, the challenge for an electric utility in this case is, "Where should a utility improve tree cutting and trimming-related initiatives to foster operational excellence and reduce the risk of vegetation coming into contact with power lines?"

B. *Insights for ArcGIS Solution*

We created an artifact in Insights for ArcGIS using DSR methodology. Insights for ArcGIS workbooks were developed to explore and discover trends and details in a utility company's data. The workbooks are templates that can be imported from a utility company's analytics models built in Insights for ArcGIS. Having the data in Insights for ArcGIS provides powerful analysis that can be shared.

In this research, we propose an elegant, interesting, and novel solution to aid in vegetation management, identifying optimal grid location(s) that need inspection or infrastructure work, and detecting regions where new components, such as distribution switches, may provide net benefits, considering the many operating parameters and outage scenarios. Because Insights is so easy to use, everyone at the electric utility, from personnel in the field to the chairman of the board, can take advantage of its capabilities. The following section describes one Insights worksheet we developed to demonstrate how the proposed solution might address the risk scenario/challenge examined in the previous section.

V. SOLUTION: ARCGIS INSIGHTS VEGETATION SCENARIO INVESTIGATION WORKSHEET

We selected the ArcGIS Insights tool to identify critical locations where a utility company needs to prune trees as an added layer of protection and to enhance defensible space. All relevant data were imported from the supervisory control and data acquisition/Outage-Management System/distribution-management system at a power utility into Insights for ArcGIS.

Page 1: Developed to investigate trees-related outages and the reported right-of-way events shown in Figure 3. This page allows utility personnel to answer the following questions.

1. What is the reported right-of-way event category contributing to the largest count of outage events?
2. What is the reported right-of-way event category contributing to the longest duration of outages?
3. What is the reported tree-related cause contributing to the largest count of customers' calls?

Page 2: Developed to investigate the relationship between tree-pruning time and outage events shown in Figure 4. This page allows utility personnel to answer the following questions.

1. How many expected pruning staff hours are needed to eliminate vines-caused power outages?

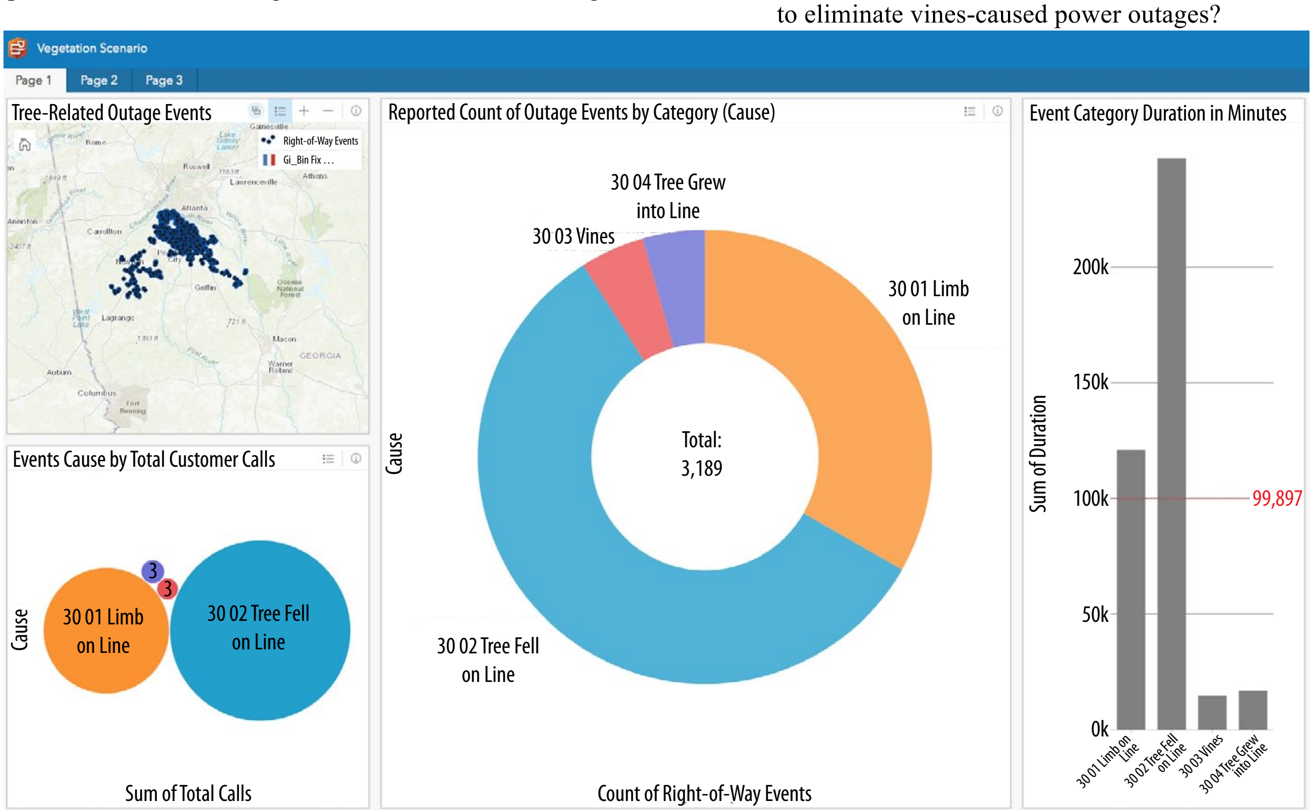

Figure 3. ArcGIS Insights Vegetation scenario investigation Worksheet Page 1

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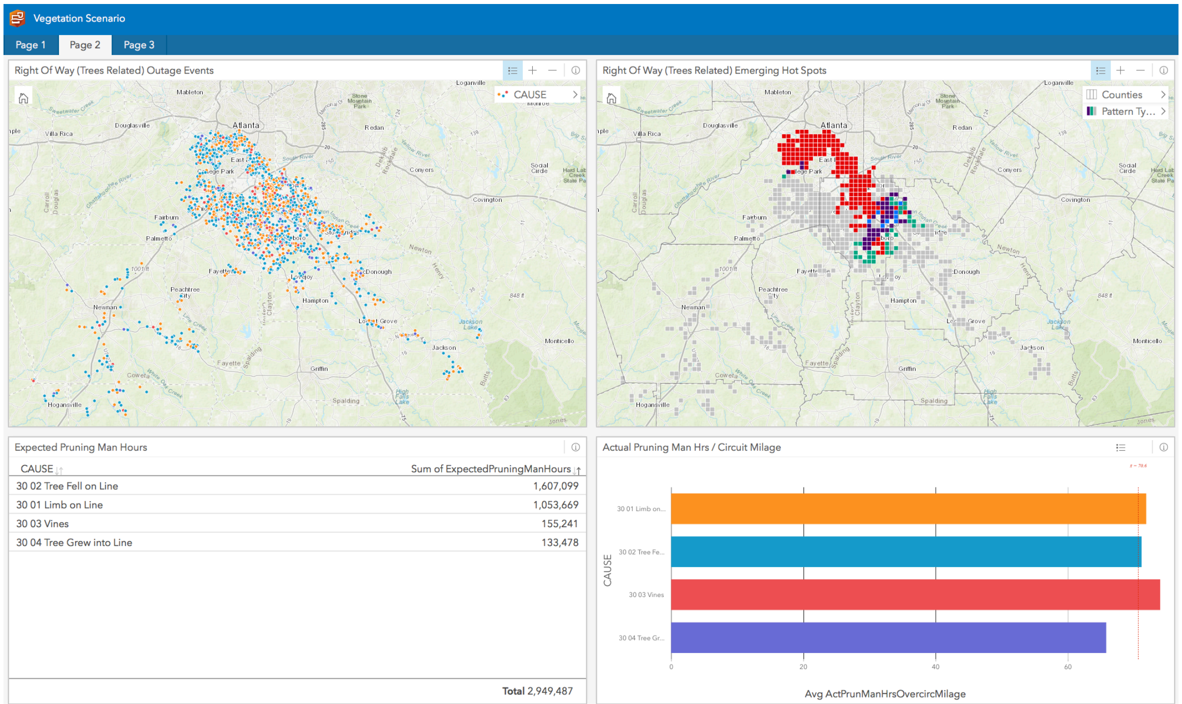

Figure 4. ArcGIS Insights Vegetation scenario investigation Worksheet Pages 2

2. How many pruning staff hours are needed to eliminate which category of right-of-way events?
3. Based on actual pruning staff hours, which category of right-of-way events needs the greatest number of pruning staff hours, on average, to be eliminated?
4. In which counties do you see the consecutive emerging power outage hot spots associated with trees?

Page 3: Developed to investigate tree-related outages optimized and emerging hot spots shown in Figure 5. This page allows utility personnel to answer the following questions.

1. In which counties do you mainly see tree-related outages optimized hot spots?
2. In which counties do you mainly see tree-related outages sporadic emerging hot spots?
3. How many sporadic emerging hot spots do you see?
4. What pattern type of emerging hot spots do you mainly see in the optimized hot spots locations of outages?
5. How many consecutive emerging power-outage hot spots are associated with trees?
6. If you were to send crews (a limited resource) to prune trees, does this map guide you with respect to where you need vegetation management most?

VI. EVALUATION

The proposed solution in this paper brings forth an important contribution to help practitioners identify the optimal location(s) for the placement of smart-grid interventions while considering many operating parameters, outage scenarios, and potential benefits. The GIS model presented in this study can advance smart-grid reliability by, for example, elucidating the root cause of power failure, defining a solution for a blackout through data, or implementing the solution with continuous monitoring and management.

This study illustrated how Insights for ArcGIS, a GIS-based solution, can be used to perform quick analysis, produce illustrative maps and charts, and share that information with managerial staff on the utility side. Because Insights for ArcGIS is able to record workflows, utility personnel will be able to rerun analysis monthly, whenever inspection budgets become available or whenever a storm is expected to hit the service area.

According to utility industry consultant Horstman, the solution offered here provides useful insights. However, Horstman pointed out that it still needs work because the terms used to describe hot spots, for example, are statistician’s terms, not layperson’s terms. Horstman commented that utilities are becoming more “analytical” and beginning to understand the value of this research.

Doug Dorr, a research program manager at Electric Power Research Institute, confirmed the potential of this application offered by the prototype. According to the program manager,

> “ArcGIS Insights worksheets are very easy to use and understand. Other layers like where the lines run and where the customers are located would be an additional useful integration consideration. Utilities would need to do some customization in order to make it truly

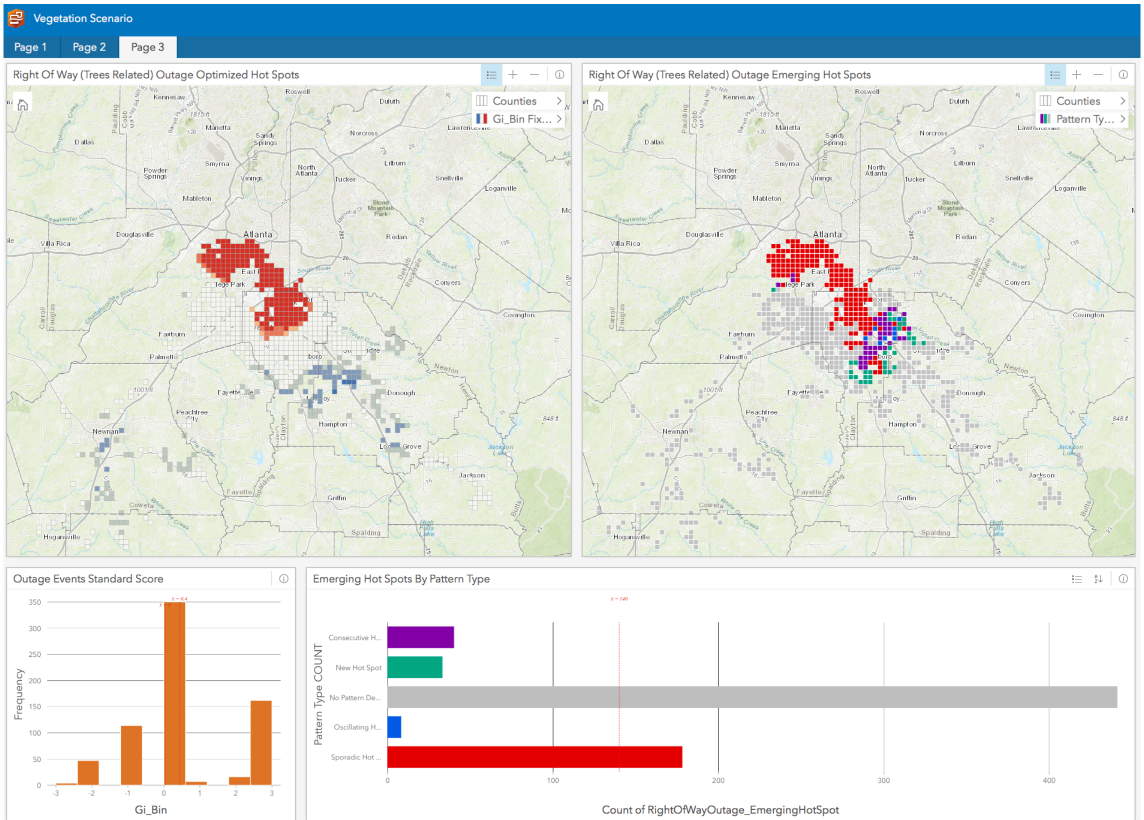

Figure 5. ArcGIS Insights storm scenario investigation Worksheet Page 3

actionable. Visual analytics and the ability to look at data over time is critically important. I really like the hot spots concepts."

VII. CONCLUSION

This study aimed to answer the question, "Where should a utility improve tree cutting and trimming-related initiatives to foster operational excellence and reduce the risk of vegetation coming into contact with power lines?" To answer the research question, we used Insights for ArcGIS to build worksheets using a GIS-based application aimed at resolving current challenges faced by utilities to reduce the risk of power outages. We developed a case study to demonstrate the risk scenario that entails a utility company taking action and preparing for the unexpected. We created an artifact in Insights for ArcGIS using a DSR methodology. This research proposes an elegant, interesting, and novel solution to aid in vegetation management. The artifact demonstrates that GIS can play an integral role in problem resolution.

REFERENCES

[1] A. Abiri-Jahromi, M. Fotuhi-Firuzabad, M. Parvania, and M. Mosleh, "Optimized sectionalizing switch placement strategy in distribution systems," IEEE Trans Power Del, vol. 27, no. 1, pp. 362–370, 2012.

[2] Electric Power Research Institute. "EPRI data analytics case: Optimal placement of automated distribution switches," [retrieved: September, 2017] http://smartgrid.epri.com/doc/DMD-Use-Cases/Optimal Placement of Automated Distribution Switches - Short Version.pdf 2017

[3] A. Hevner, S. March, J. Park, S. Ram, "Design science in information systems research," Manag. Inf. Syst. Q., vol. 28, no. 1, pp. 75–105, 2004.

[4] ESRI Environmental Systems Research Institute. Understanding GIS--The Arc/Info Method [retrieved November, 2015] http://www.ciesin.columbia.edu/docs/005-331/005-331.html, 1992.

[5] D. Dickey, "Introduction to predictive modeling with examples" in SAS Global Forum Proceedings [retrieved October, 2015] http://support.sas.com/resources/papers/proceedings12/337-2012.pdf, 2012.

[6] A. Idowu, N. Okoronkwo, R. Adagunodo, "Spatial predictive model for malaria in Nigeria," J Health Informatics Dev. Ctries. [retrieved October, 2015] http://www.jhidc.org/index.php/jhidc/article/view/34, 2009

[7] D. Totman, Model Predictions: GIS Helps Public Works Manage Assets, retrieved October 19, 2015, from http://americancityandcounty.com/gis-amp-gps/model-predictions-gis-helps-public-works-manage-assets, 2013.

[8] B. Resch et al. "GIS-based planning and modeling for renewable energy: Challenges and future research avenues," ISPRS Int. J. Geo-Inf., vol. 3, no. 2, pp. 662–692, 2014.

[9] V. Sultan and H. Bitar, “Geographic decision support systems to optimize the placement of distributed energy resources,” Proc. 22nd AMCIS, San Diego, CA, 2016.
[10] V. Sultan, A. Alzahrani, H. Bitar, N. Alharbi, “Is California’s aging infrastructure the principal contributor to the recent trend of power outage?” Proc. 22nd Annual Cal. GIS Conf., Anaheim, 2016.
[11] J. G. Walls, G. R. Widmeyer, O. A. El Sawy, “Building an information system design theory for vigilant EIS,” Inf. Syst. Res., vol. 3, no. 1, pp. 36–59, 1992
[12] S. T. March and G. F. Smith, “Design and natural science research on information technology,” Decis. Support Syst., vol. 15, no. 4, pp. 251–266, 1995.
[13] S. Gregor A. R. and Hevner, “Positioning and presenting design science research for maximum impact,” Manag. Inf. Syst. Q, vol. 37, no. 2, pp. 337–356, 2013.
[14] A. Hevner, “A three-cycle view of design science research,” Scand. J. Inform. Syst., vol. 19, no. 2, pp. 87–92, 2007.
[15] A. R. Hevner and S. Chatterjee, Design Science Research in Information Systems [retrieved September 2018] from http://link.springer.com/chapter/10.1007/978-1-4419-5653-8_2, 2010.
[16] K. Peffers, T. Tuunanen, M. A. Rothenberger, S. Chatterjee, “A design science research methodology for information systems research,” J. Manag. Inform. Syst., vol. 24, no. 3, pp. 45–77, 2007.
[17] K. LaCommare and J. Eto, J. Understanding the Cost of Power Interruptions to U.S. Electricity Consumers, Berkeley, CA: Lawrence Berkeley National Laboratory, 2004.
[18] H. Takeda, P. Veerkamp, H. Yoshikawa, “Modeling design process,” AI Magazine, vol. 11, no. 4, pp. 37–48, 1990.
[19] V. S. S. V. M. Sugimura and V. K. Ishigaki, “New web-usability evaluation method: Scenario-based walkthrough,” FUJITSU Sci. Tech. J., vol. 41, no. 1, pp. 105–114, 2005.
[20] ESRI Environmental Systems Research Institute, Insights for ArcGIS [retrieved September 2018] http://doc.arcgis.com/en/insights/, 2018.
[21] California Public Utility Commission, Electric and Fire Related Fines [retrieved September 2018] from http://cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Safety/Electric_and_Fire_Related_Fines.pdf, no date.
[22] Pennsylvania Public Utility Commission, Pennsylvania Electric Reliability Report 2017 [retrieved September 2018] http://www.puc.pa.gov/General/publications_reports/pdf/Electric_Service_Reliability2017.pdf, July 2018.
[23] National Interagency Fire Center, Year-to-Date Statistics, [retrieved September, 2018] https://www.nifc.gov/fireInfo/nfn.htm, September 2018
[24] Eaton’s Blackout Tracker, Power Outage Annual Report, [retrieved July, 2018] https://switchon.eaton.com/blackout-tracker, 2017.
[25] State Board of Forestry and Fire Protection, 2018 Strategic Fire Plan for California [retrieved September 2018] http://cdfdata.fire.ca.gov/pub/fireplan/fpupload/fpppdf1614.pdf, August 2018.

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