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A SOCIAL COST BASED DYNAMIC RESTORATION DECISION-MAKING MODELLING FRAMEWORK FOR POWER DISTRIBUTION SYSTEM

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ABSTRACT

Prioritizing restoration of critical facilities is important as delaying restoration may cause significant social distress. Few studies have investigated the social impact of power outages in these facilities and its influence on the restoration process. This study proposes a simulation modeling framework that investigates the dynamics of restoration decision-making based on the social impact of disrupted critical facilities. It was tested in a case study using storm-related power disruption and restoration data from a power utility company. Numerical results indicated that incorporating social impacts into decision-making significantly reduces social cost of power outage by almost 26.73% in the case study. Moreover, through simulation experiments, a cost-benefit analysis based on the restoration labor cost and reduction in social impacts under different resource allocation strategies was conducted and a tradeoff relationship was identified. The findings highlight the capability of the model in aiding decision-makers make informed decisions after a power outage.

1. RESEARCH BACKGROUND

Power system restoration is an extremely complicated process that requires detailed planning, technical expertise, and managerial efforts (Matisziw et al. 2010). When utility companies are facing large restoration needs with limited resource, it could be challenging to decide the optimal order of restoration. A few existing studies have investigated the impacts of different prioritization rules (e.g., nearest outage, largest number of customers) on power system restoration performance (Walsh et al. 2018). However, not every disrupted facility has the same level of impacts on quality of life. Some facilities may be more influential and if disrupted will cause more social distress to an impacted community. This social impact has to be carefully evaluated when planning for restoration so that the suffering of people can be minimized.

2. RESEARCH FRAMEWORK

This study proposes to adopt a social cost based approach to better allocate resources and prioritize tasks in power system restoration. In this study, the concept of willingness to pay (WTP) was used to quantify social cost for facility/service disruption caused by power outage. WTP is essentially the monetary amount a consumer would be willing to pay in order to avoid loss/disruption of service (Sullivan et al. 2018). For each disrupted critical facility, the service range (i.e., total consumers served) was first identified; which was later converted to equivalent WTP value for the respective disrupted facility based on its disruption time. Total social cost of outage was calculated as the sum of the WTP values of all the affected critical facilities. A simulation model that captures the dynamic activities of different power restoration system entities (e.g., *critical facility*, *utility pole*, *crew*, and *restoration manager*) as well as their interactions was developed to quantity the total social cost during the restoration process. Each entity has its unique attributes and behaviors, which were appropriately defined in the simulation model, created in AnyLogic 8.3.2. The restoration outcomes generated from the model include: *total restoration time*, *total social cost of outage* and *total restoration labor cost*.

3. CA SE STUDY RESULTS

A case study was conducted to test the simulation model based on a real-world storm-induced power outage and restoration event in New England, using data shared by a local power utility company. Monte-Carlo simulation experimentations were conducted to investigate the potential benefits of restoration decisions based on considering social cost of outage. Results demonstrated the benefits of taking social impacts into consideration of restoration decision making. For example, when compared with the *first-come-first-served* restoration strategy where social impact was not used for restoration prioritization, the average total social cost of outage decreased by almost 26.73% when the restoration activities were prioritized based on social impacts. This experiment showed that utility poles that serve more critical facilities should be prioritized as delaying their restoration have far negative consequences in a disrupted region. Another set of experiments investigated the impacts of assigning more crews for restoration. Two alternative resource allocation strategies were created where the number of crews were gradually increased compared to the base case. Results showed that average labor cost increased by almost 102.67% and 188.57%, respectively due to allotting more crews for restoration; whereas average restoration time decreased by almost 28.87% and 46.36%, respectively. In addition, the total social cost of outage decreased by almost 96.15% and 321.78%, respectively. This set of experiment showed that although higher labor cost is required, assigning more crews for restoration has significant social benefits.

4. RSEARCH CONTRIBUTIONS

The proposed framework makes both theoretical and practical contributions that could increase restoration efficiency and minimize community sufferings. This study proposed an innovative modelling framework that is capable of investigating the social impact of power outages during the dynamic restoration process. The effects of incorporating social impact into restoration decision making could be quantified using the proposed modelling framework. From a practical perspective, the proposed framework and model could help decision-makers make better restoration decisions by evaluating different restoration strategies based on social impacts. The model has the potential to be adopted and tested in future studies with expanded list of entity types to identify novel restoration strategies for improving power system resilience. The proposed framework has some limitations. First, only the direct impacts to residential homes due to power outage and associated service disruptions were considered. Power outage in business entities and associated economic impacts were not directly considered. Second, WTP were treated as deterministic in this study. In reality, WTP of the same service could be different in different communities based on different socio-economic conditions. In future work, different socio-economic factors and real time monitoring of public opinion would be considered to capture the real social impacts.

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