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City Resilience through Data Analytics: A Human-Centric Approach

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Abstract

Our cities are being redefined daily based on social, political and environmental factors. This creates substantial challenges for those that attempt to develop resilience strategies for cities. Resilience planning requires a set of assumptions often based on data; however, the dynamic nature of our growing urban environments has impeded our ability to rely on these suppositions. To account for the unpredictable ebb and flow of changes in our cities we have become heavily dependent on data modeling and analytics. The ability to collect and store data from a variety of systems in a cloud infrastructure has enabled the potential for resilience planning to be based on historical scenarios and societal context – prioritizing risks and issues based on multiple factors. As our infrastructure becomes "smarter" with the ability to capture more data and make decisions through machine learning algorithms, resilience plans may become less in touch with the citizens for whom the resilience strategies exist. Thusly, an emergent risk to the inhabitants of cities is the imbalance of qualitative versus quantitative feedback that is leveraged to develop and improve a city's resilience strategy.

Cities are living organisms that cannot be purely defined through machine data. A modern way to establish policies and plans for major urban centers is to leverage machine data collected through various "smart" technology programs. Such data-aggregation mechanisms feed into analytics tools that often fail to account for historical context or citizens' perspectives. Without leveraging this information, a resilience plan cannot be complete as it will not address the city as a system, but only a component thereof. This paper proposes a new model for developing a city's comprehensive resilience strategy that integrates machine data, historical

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context and societal effects. The risk of not pursuing a three-pronged model would be that future resilience strategies would lack a human-centric approach.

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1. Introduction

Imagine a city that can conform to your daily life and adjust itself to new parameters. Upon exiting the subway at 116th Street in New York City on a sweltering summer's day, the subway's occupancy sensor will notify the surrounding buildings that additional energy capacity could be required in the near future due to increased cooling demand. A signal would then be sent to the grid notifying it of the potential increase and adjust accordingly. When you leave, similar technology will notify the buildings that less energy is required, and the buildings' systems can make appropriate adjustments, in turn preserving comfort and decreasing waste.

This future city is enabled by the collection and processing of machine and sensor data on a massive scale. Such an interconnected, technology eco-system could theoretically be very helpful and desirable while developing a city resilience plan. A resilience plan can be defined as a framework developed to enable a robust and quick recovery to normal operations after an urban disruption. With the prevalence of the "Internet of Things" and big data analytics, an emergent issue for cities and their citizens is the imbalance of qualitative versus quantitative information that is leveraged to develop a city's resilience plan. Developing a resilience strategy based on machine data can result in a plan that is technology-centric and out of touch with the citizens for whom the resilience strategies exist. This paper will aim to demonstrate the inherent issues with relying primarily on technology-centric data to develop a resilience strategy and propose additional inputs for resilience plans including: A) historical data reflecting the causes of emergencies, and B) societal consequences reflecting the effects of past emergencies. The resilience strategy for power outages will be analyzed to illustrate the flaws of a machine-data driven approach to resilience planning.

1.1. Methodology

The principle method of analysis for this study will be to evaluate resilience planning using a People, Process and Technology framework. This methodology was popularized in the 1990's and early 2000's in the fields of business process management and operations research to evaluate the thoroughness of organizational technology problems and solutions [1]. City Resilience Strategy can be described using the People, Process and Technology framework as seen below in Figure 1. The paper will specifically investigate "People" and the resilience planning implications of our technology-focused society. While not explicitly investigated in this analysis, "Technology" and "Process" are discussed in context to frame the lack of human-centric resilience.

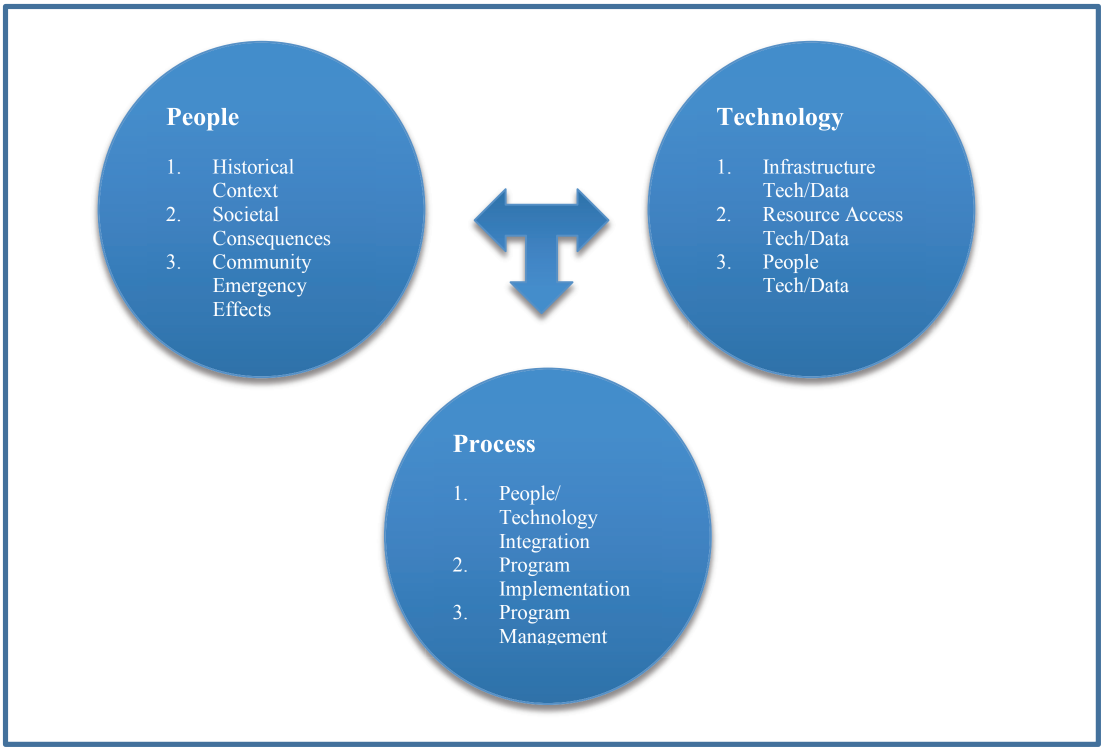

Fig 1. Principle Components of a City Resilience Strategy

2. The Emergency

On a day in a city when the alarm clock does not alarm; the juicer does not juice; and the lift does not lift, an urban emergency is taking place. This was the reality for 750,000 New Yorkers in 2012 amidst a major power outage that shut down midtown and lower Manhattan and parts of the boroughs [2]. Power outages have the distinction of causing approximately $80B USD (£48B GBP) in economic losses annually in the US alone [3]. Our modern city operations are heavily reliant on technology, which is almost entirely dependent on power. Without power, basic city operations such as vehicular transport can be brought to a standstill. A robust resilience strategy is needed concerning the electric grid in order to avoid potentially fatal consequences of this urban emergency.

2.1. Limitations of Machine Data for Resilience Planning

Today's modern grids are data-enabled smart grids which allow utilities to troubleshoot issues by providing visibility into real-time grid operations. Such "smart" systems capture unprecedented amounts of machine data, whose source could be anything from a security system to a generator. This data is stored and packaged in a digestible and easily accessible way for the appropriate parties to analyze. An example of this is Singapore's Smart City Test Bed program which processes and analyzes video data from a variety of sources to drive the city's security initiatives [4]. Using video analytics, the test bed helped the government predict real-time crowd behavior and respond accordingly by coordinating resources across government entities in the Marina Bay. The limitation to this approach is the lack of historical context of people's interactions and the societal consequences of any interventions. Persistent use of such analytics will result in a reliance on information that lacks context of city operations. The trend of leveraging point-in-time data to develop informed security plans will persist and the information might ultimately be used as inputs to future resilience plans. The emergent risk is an over-reliance on such technology-centric data to formulate a city's resilience strategy. There are limitations to relying on a purely technology-focused data set to formulate a power outage resilience plan.

Developing a technology-centric, machine data driven resilience plan has the potential to result in numerous issues. Firstly, a resilience plan developed based on machine data would likely be biased towards the upkeep of technology infrastructure. For example, in such a plan, if the grid fails and electricity is lost the inclination would be to immediately ameliorate and fortify the component of the network that is broken. The issue with such an approach is that while a substation failure might be the cause of the black-out, the emergency for the city is not necessarily the failure, but all the compounded effects from the failure. A technology-centric issue management approach does not provide visibility into the emergencies that are caused by the power outage which might need immediate attention. A simple but poignant example is the consequences of the failed traffic signals during an outage where the immediate requirement should be to preempt an emergency (traffic accident). A machine data focused resilience plan might not address this immediate need considering it is external to the grid. Developing a technology-centric resilience strategy might lead to a lack of emphasis on such societal consequences.

Currently, cities are looking to microgrids to fortify their energy infrastructure; however, this is not a comprehensive resilience strategy for a city. With a machine data-centric view of resilience, a microgrid would be the solution to curtail outages – however it fails to address broader issues a city could experience amidst such an emergency. By nature, microgrids are small and the geography they cover tends to be limited. If an outage occurs across a city and a microgrid preserves power in Neighborhood A, the neighborhood next door, Neighborhood B, will not necessarily have power which could result in societal consequences on Neighborhood A. The city's resilience strategy must be comprehensive– solving for individual vulnerabilities in a grid will not solve a system problem that defies microgrid boundaries. For this reason, resilience plans require inputs inclusive of, but also beyond machine data.

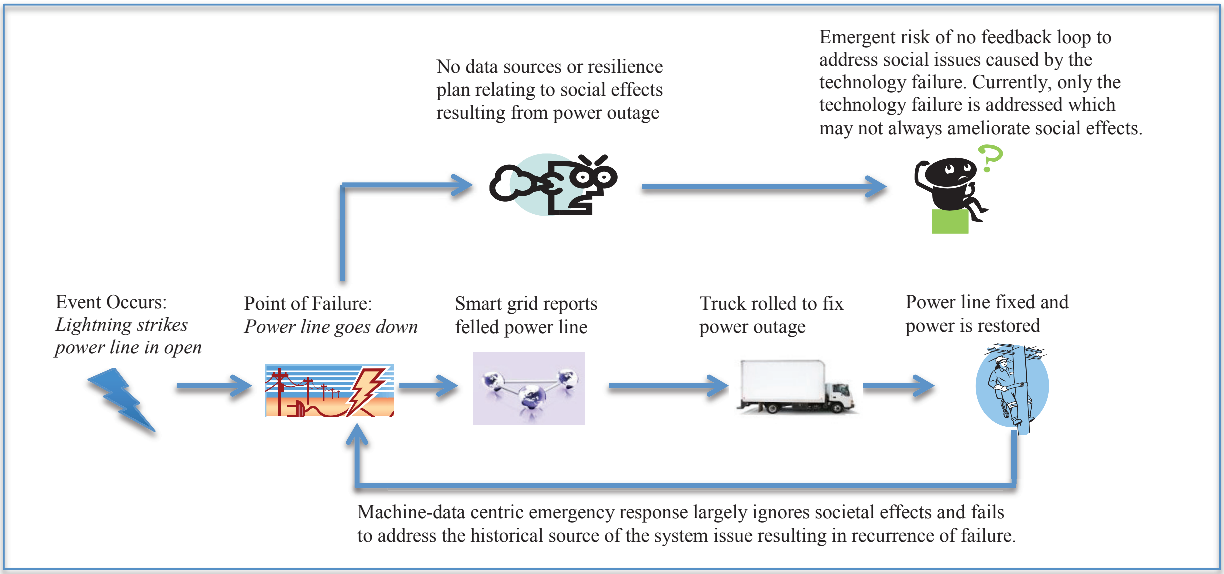

Fig 2. Emergent Risk of Machine Data Centric Resilience Approach

3. Proposed Inputs for a Comprehensive Resilience Strategy

As visible in the microgrid example above, machine data fails to provide a comprehensive perspective and solution for resilience planning. Technology-centric data provides "point in time" visibility and illustrates recent and real-time events – essentially a snapshot of the present. When a city develops an energy resilience strategy, a comprehensive perspective is needed that reflects on a long-term view, capturing the cause and effects of an outage. This drives the need for historical context and societal consequences to be included into a city's resilience strategy.

3.1. Proposed Input: Historical Context

To construct a comprehensive resilience strategy for outage scenarios, historical events should be considered. Historical data points can be leveraged to understand future episodes and how to best drive city resilience. Without using historical information to develop a resilience plan, substantial knowledge of potential causes and effects of an outage will be wasted. An example of this could include historical scenarios where outages have affected hospitals. A machine data-driven approach to an energy resilience strategy would not provide insight into how hospitals should operate during an outage. Past lessons learnt from outages such as when Hurricane Sandy hit NYC in 2012 resulting in backup generator failures and subsequent evacuations at NYU Langone Hospital could provide insight to developing a robust hospital resilience strategy. During this scenario, Langone medical practitioners "downloaded a telephony app onto their phones and used it to send urgent text messages"; a strategy that can be cited and recommended in future resilience plans for hospitals in the event that mass communication systems are down [5]. Such historical information could also be leveraged as inputs to how other critical facilities and infrastructure operate during outages. Other contextual information could include variables such as weather data, load information and even the political state of a city.

The benefits to having historical, contextual data are manifold. Historical data can provide insight to pre-existing vulnerabilities and elucidate substantial intelligence on how best to manage emergency situations. A form of historical data that can be easily leveraged and is especially useful is weather information – especially considering weather often is a cause of grid issues. Considering the more frequent storm systems countries are experiencing with our evolving climate, historical models will be essential to understanding future impacts. Patterns can be further established indicating grid vulnerabilities due to regional geography or natural elements that could ultimately impact power flow. Historical information could even enable customized resilience strategies based on regional scenarios. Beyond weather, contextual data could include historical events that might have an impact on the grid or other correlations that can be used to understand the grid's flexibility to various scenarios.

Historical data can also be used to determine the cause of an outage. This could be accomplished by using outage and time of use data to analyze the chain of energy events that preceded an outage and understand the potential causes of the situation. For instance, on a small scale, a substation might fail which could result in an atypical load required of another generator causing it to overload as well. Such network effects will result in the potential collapse of the system. All of this historical information can be used to model future events and their impacts on the grid. Planning models can help to avert future issues and also enable virtual testing of scenario-based emergency plans on the models to determine the system's reaction.

3.2. Proposed Input: Societal Consequences and Emergency Effects

Historical grid data could be useful to understand the technology faults that might lead to an outage; however, perhaps more useful for the development of a resilience plan is the societal context that could be used to understand social effects of the outage. Among the greatest concerns with a machine data-centric approach to resilience is the lack of visibility of the after-effects of the emergency – particularly from a societal perspective. An issue that is found in the grid might readily be fixed, however the outage likely spurred other emergencies which are difficult to manage due to the complex nature of their genesis. Machine data points will provide visibility to singular issues across the system, but may lack the ability to provide situational context. Situational context is essential to understanding the potential for recurrence and economic repercussions of the domino effects of the outage. Cities are built for people, and societal data is not captured in a smart grid data set.

Resilience plans should be built around understanding potential consequences to communities and not solely built around the technology. Effects of outages such as accidents, economic losses, riots, displaced citizens or even deaths are not captured in machine data. By capturing consequential information and incorporating this into a resilience plan, recovery can be expedited and customized for a scenario. This information is admittedly not captured easily. One potential way to capture these consequences is to link the machine-generated time of emergency data with news feeds and media metadata. Such news feeds could be either from traditional media or social media. By collecting and categorizing this information, social consequences to outages can be analyzed to determine how to craft appropriate resilience plans. While a machine data-centric resilience plan might itemize how to fix and fortify machines, a resilience plan that is comprehensive would recommend policies leveraged to avert societal consequences that might have occurred as domino effects from past emergencies.

Other opportunities for social context to be used in developing a resilience plan include understanding the reaction of communities to past emergency responses, associated consequences and resilience plans. Developing a framework for a feedback loop capturing the success or failures of other resilience strategies can be instrumental to the future success of planning for such events. The reaction of communities to past emergency responses and resilience plans can potentially be captured by matching targeted social media data to the time period after an urban emergency. A more proactive approach could be to hold public forums at defined periods after an emergency to collect feedback and use as input to develop future comprehensive resilience strategies. Such feedback would be impossible to incorporate with a machine-data centric resilience plan.

4. Implications

Integrating social and historic data into a technology centric resilience approach will have diverse implications socially, economically and politically. Social implications might include a more customized resilience strategy on a community level. Neighborhoods respond to emergency scenarios in different ways and technology centric data would likely fail to capture these nuances. The historical and social information captured on a neighborhood-by-neighborhood basis can be used to identify a community signature which would inform the type of resilience plan needed – blanket resilience strategies across a city would become obsolete. A community's signature would include insight to community operations and connectedness. Research indicates that those with close community ties and neighborhoods are more likely to survive a disaster [6]. Visibility to this factor and others embedded in the community's signature can help to identify and then encourage at-risk neighborhoods to take action and improve their resilience prior to a disaster.

Associated with the social effects, the economic implication of leveraging social and historical context will be improved budgeting of recovery funds. Increased context of past emergencies and increased visibility to cost of effective strategies used for recovery will improve the ability to manage emergency funds. Additionally, funds can be appropriated for communities based on their social signatures. Having a better understanding of city risks will inherently improve the ability to financially prepare for resilience.

Political implications of a comprehensive resilience approach will include the potential for revising policy that governs city entities during an emergency. With increased context, political entities will have improved governance visibility and have insight to potential repercussions of planned emergency interventions. Overall, by providing both quantitative and qualitative data points, cities and their encompassing communities can further customize their resilience strategies to enable a stronger and faster recovery.

5. Discussion

The challenges discussed for future resilience strategies might seem heavily data and policy centric, eschewing matters of the built environment; however, the resilience planning data issues have direct implications on future city design strategies. Prior to our modern, data-driven era, city design was organic in nature. Master plans were not heavily analyzed for environmental footprint impact, or for transportation efficiency – but were more of an art that was not concerned with zoning and policy. As a result, many of our older, established cities such as New York City or London were not designed with a wealth of data tools to foster a city of efficiency such as modern hubs like Singapore. Today, with a wealth of data at our disposal from technology, social media, and historical context, new cities can be designed for efficiency, but also for safety and resilience.

Designing cities for safety and resilience has historically been difficult due to the variability in definition of resilience and security across cultures and communities. However, the future holds potential to analyze social and historical risk data from a number of sources on both community and cultural levels to evaluate risk hotspots emerging within a city. This would enable planners to identify risk patterns and correlations within the built environment, which could potentially elucidate design strategies associated with risk. Understanding patterns in the placement of infrastructural elements that could foster risk can be avoided while developing plans for new cities. For example, if social data patterns indicate that there is a great deal of theft when tourist districts are located near low-income housing, the adjacent placement of these districts should be noted and avoided for future city plans.

Leveraging the social data elements discussed throughout this paper for future resilience strategies and for urban planning will have a substantial impact on both design and urban form. Today, city design falls short by not incorporating human-centric resilience components into its planning. By learning from social risk and resilience patterns in existing cities, inherent resilient design could be achieved for the next generation of cities to come.

6. Conclusion

Imagine a future where cities and technology evolve symbiotically; in turn, increasing the amount and quality of readily available data. This data will likely enable increased visibility to city operations which could improve our ability to design cities and manage urban emergencies. With a plethora of data and analytic capabilities available, cities and their citizens must be aware of the emergent risk associated with an over reliance on machine data rather than social and historical information. While machine data could be useful to develop a city's resilience strategy, this paper has demonstrated that limitations exist to a technology-centric approach. By leveraging qualitative and quantitative inputs including historical context, machine data and societal consequences, our future cities can avoid the risks associated with a technology-centric resilience strategy thereby ensuring the resilience strategy is built for whom the city exists – its citizens.

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