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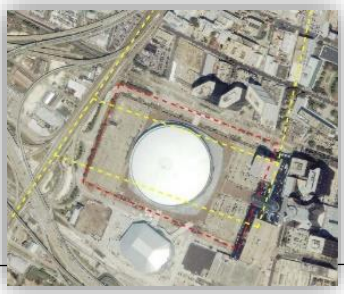
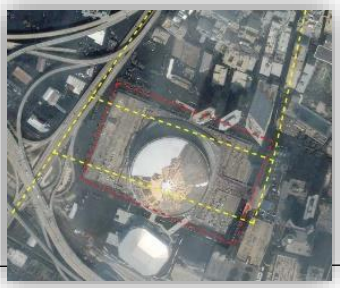
Introduction

Natural disasters are part of life and have occurred throughout human history. Between fires, hurricanes, earthquakes, volcano eruptions or floods, disasters have been well documented and, on many occasions, have also caused the complete eradication of entire cities and the deaths of thousands of victims.

Hurricane Katrina, a Category 5 Atlantic hurricane, caused over 1,800 deaths and $125 billion in damage in August 2005. More Than twenty-thousand people were sheltered in the New Orleans Dome without electricity for a week (crimes, such as rapes and murders were recorded within the shelter space), while the lack of utility maps hindered relief efforts. The hurricane left most of southern Louisiana without power, and the arena, which is in the central business district of New Orleans, was not spared. The air conditioning failed immediately, and a swampy heat filled the dome. An emergency generator kept some lights on but quickly failed.

Humans are getting better in preparing, predicting, and responding to such emergencies, however we are still unable to achieve immunity from their effects. Nature seems to have the upper hand at all times.

In recent years, dramatic weather patterns and global warming have increased the frequency of particular natural disasters such as hurricanes and large-scale fires with all the associated large scale economic damages associated in relief efforts of large Urbanized centers such as New Orleans, California, Puerto Rico etc.

> ***"On September 20, 2017, the third-strongest hurricane ever to hit the US hammered the island of Puerto Rico. … It took nearly a year for power to be fully restored on the island, and as of August 2019, about 30,000 people were still living in homes covered by tarps rather than solid roofs"***[1]

Furthermore, we have also seen a dramatic increase in sophisticated terrorist attacks on vital infrastructure such as airports, pipelines, fiber networks that target not only human lives, but attempt to cause economic collapses and psychological uncertainty.

These last situations should be addressed with extra care and expertise, but could also use the infrastructure described here as well.

Shelters and good weather prediction technologies have reduced the impact of such disasters on human lives however the impact of residential and utility infrastructure are causing major economic setbacks.

Power networks, telephone communication networks, along with all above-ground infrastructure suffers most of the impact of such disasters, and for this reason, new legislations and procedures are put in place to migrate these networks underground.

If not protected properly, utility networks and vital infrastructure can suffer major damages or complete destruction which makes for a lengthy process of emergency relief and reconstruction.

In other cases, utility networks are themselves the cause of large-scale fires such as the Californian fires have been proven to originate in faulty or poorly maintained Power Transmission infrastructure by PG&E.

[1] See "CNN News " https://www.cnn.com/2017/09/06/us/hurricane-irma-puerto-rico-florida/index.html

"PG&E, which had repeatedly failed to maintain a transmission line that broke from a nearly-100-year-old tower even though it cut through a forested and mountainous area known to experience strong winds, pleaded guilty to 84 counts of involuntary manslaughter and one count of illegally setting a fire. The company has agreed to pay a $3.5 million fine, as part of the criminal plea, the culmination of a two-year ordeal."[2]

2018 California Wildfires

Cost >$26.347 billion (2018 USD) (Costliest on record)
Buildings destroyed: 24,226
Deaths: 97 civilians and 6 firefighters killed
Non-fatal injuries: At least 80 totals

The network maintenance process ensures the proper functionality of the elements of utility networks during the performance in normal operations. However, one needs to ensure integrity performance on the network functionality that is required to support effective response to natural disasters.

For fighting a fire, one needs to ensure that fire hydrants are properly maintained and functional (which is usually done by the Fire Department). However, the integrity functionality depends on water supply being at a certain pressure during firefighting efforts, which is completely reliant on the water network (operated by the city).

Failure to properly maintain the power generators that supply water pressure in the network hinders the firefighting effectiveness. Further to that, if the fire itself completely damages the power generators, and there is no interoperability plan which will ensure alternative power supply, the result is disastrous.

A good example of the above situation was observed during the Attica (Mati) wildfires in Greece in 2018, which caused 102 deaths and the complete destruction of the Mati area. These fires are well documented in the legal investigation proceeding as Europe's deadliest forest fire in more than a century.[3]

[2] See "The New York Times " https://www.nytimes.com/2019/12/03/business/energy-environment/pge-camp-fire-report.html

[3] See "NBC News " https://www.nbcnews.com/news/world/death-toll-greek-wildfire-reaches-91-village-grieves-n895631

Some of the findings of the route-cause analysis of the aftermath of the fire as stated in the legal proceedings are listed below:

- *Fire hydrants had failed to function, as they were out of service.*
- *Fire caused the electricity network to fail and there were no alternative plans to maintain the electricity feed and pressure on the water network.*
- *Mismanagement of mobile resources; additional firefighting vehicles were in the area but were never engaged. No regional resources were implemented due to lack of centralized coordination.*
- *There were drastically inaccurate estimates for the speed and directions of expansion of the fire.*
- *Numerous separate communication protocols among the responders and no centralized communication channel causing chaos and miscommunications.*
- *There was lack of ongoing (real-time) areal overview.*
- *Total absence of high-level crisis management authorities.*
- *Technical problems and weather conditions prevented four regional planes to operate.*
- *There was poor traffic management strategy and no evacuation plan.*
- *Lack of zoning and proper municipal planning prevented access to the sea for numerous victims.*

Finally, in the aftermath of the fire in Mati, there was very poor organization of government relief efforts to the families of the victims, who they rely totally on volunteers.

All the above situations make it imperative for firefighters and Emergency Response teams to include Utility Network members in planning, to ensure proper emergency utility procedures and the safety of the firefighting teams.

One has also to consider the fact that a disaster can caused peripheral network damages. This is often the case with explosions/fires in urban environments related to gas utility network and house gas services, as a result of earthquakes.

In summary, one requires to include state of the art **Emergency Response Center(s)** for coordination of the response teams while a **Command Center** will oversee the population evacuation and relief efforts, coordination with additional emergency Responders from other regions or even countries, Utility network restoration, debris removal and managing other resources such as the army etc.

It is essential for all utility networks to be properly mapped and properly maintained, while proper technologies and systems can provide access to all required data. This will improve effectiveness and communications among all responder teams and the citizens on an ongoing basis.

An Integrated Approach for Emergency Response and Relief Operations

A Smart City model for Emergency Response should ideally include many of the following processes and procedures, technologies, and training to effectively address natural disasters.

A NETWORK DAMAGE PREVENTION/ ASSET MANAGEMENT/ INTEGRITY SYSTEM

It has been proven time after time that utility networks such as gas pipelines, transmission powerlines and critical infrastructure such as military installation, refineries, storage of fuel, etc. can be the cause of major disasters, (see Lebanon port explosion) can become the cause of major disasters, while at the same time they are so vital and necessary for provision of public services in normal life. Networks need to be property mapped along with all the network assets with full and detail plan for the proper maintenance of the networks in order to secure proper functionality and avoid disasters.

During the wildfires of 2016 in Fort McMurray, Alberta, Canada, INTUS crews were first responders right behind the Firefighters ensuring Safety and Damage Prevention.

During emergency crisis such as an earthquake, the natural gas network malfunction with explosions and major fires as often noticed (see Boston case).[4] Malfunctioned High-power transmission lines have been assigned the blame for most of the major fires in California.

Further to that, proper integrity and maintenance procedures to ensure the working of fire hydrants and other similar critical assets must be emergency ready and properly calibrated. A sustainable irreparability plan (what if plan) must be present at all times for all networks (*see Mati for example, where the power distribution network collapsed due to fire, resulting to terribly low water pressure while the fire was on*).

A full-scale "**IoT network of sensors"** for critical emergency response infrastructure units + ***"Mobile Asset Management"*** + ***"Integrity Management"*** systems for readiness assurance and early emergency alerting.

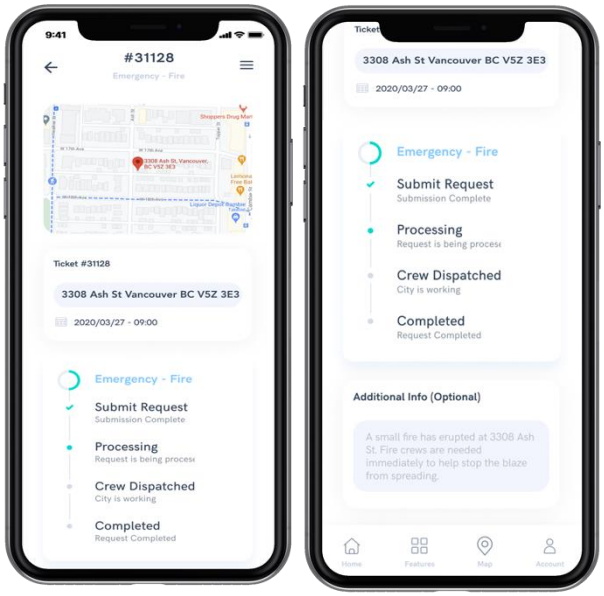
Other integral factors in Emergency Response operations are the proper maintenance and management of all critical mobile assets that firefighters and other emergency responders will utilize in crisis situations. This requires a proper **Mobile Asset Maintenance and Asset Management** System that offers a common two-way communications platform for responders. This, in addition to geolocation capabilities, allows for the coordination of operations, provides dynamic monitoring of the mobile field crews of all responders (firefighters, city crews, ambulances, police, etc.).

[4] See "CBC News " https://www.cbc.ca/news/world/boston-house-fires-gas-explosions-1.4823049

Lack of coordination and dynamic oversight of operations can endanger the emergency responders who can be trapped in direction changing fire fronts and unpredictable field conditions. In this regard, the use of drones can become a viable assistance tool.

A SMART APP PLATFORM

Operating on all smart phones and androids that provides two-way communication, push alerts, evacuation instructions to citizens, and the ability for citizens to send field information to the emergency response center. In addition to providing the real-time geolocation of citizens via mobile app activation, it should also include geolocation services whereby a citizen can submit a geolocated request for assistance. Using this geolocated information, the emergency response center has the ability to visualize the extent of any emergency in real-time.



A WORK-ORDER AND REQUEST MANAGEMENT SYSTEM

Interconnected with the Smart Apps platform in two directions that registers citizen requests and converts them to immediate work orders to responders and volunteers.

This management system is the system that provides warnings and alerts to citizens via the Smart Apps platform. In addition to the notifications sent to citizens the system should include a CRM center for direct communications with citizens.

The citizen requests gathered through these communications are automatically translated into work orders—according to the nature of the request—and dispatched accordingly to emergency responders and city crews that will assist in addressing the situation (firefighting, flood control, coordination of volunteers, police, etc.).

Additional work orders of operational nature are to be created by officers of the First Responding Teams (Fire Fighters, Police, Ambulance and Hospitals, Army etc.).

The performance of first responders in addressing such situations is secured and monitored using Geolocated Mobile Asset Technology for all responder's vehicles, which provides the real-time geolocations of responders and **two-way communications within a centralized environment.**

AN EMERGENCY RESPONSE CENTER

- Operated from all three levels of authorities: Firefighting, Police, City management and Ambulances, coordinates participation of volunteers and additional regional forces via a centralized interoperable environment.
- Usage of Drones for visual operations overview with geolocation capabilities.
- Dynamic monitoring of Municipal Field crews and First Responders performance of instructed tasks (tickets) generated from the Work Order management system or originating from Citizen Smart App requests for assistance or directly via the CRM Center
- Enables real time Geolocation of Emergency Responders and mapping on GIS maps of incident occurrences.
- Completion reports and feedback from field crews dynamically

CRISIS COMMAND CENTER

It is to be operated by the highest members of civic protection, the mayor, political authorities and provides real time overview of the crisis management forces (no matter the crisis nature). It has direct field overview of the emergency expansion with capabilities of modeling and prediction of a fire wave for example, in association with weather conditions (wind) and provides dynamic modification of the relief efforts. It takes critical decisions about citizens evacuations and protection of critical infrastructure such as airports, refineries, pipelines, etc.

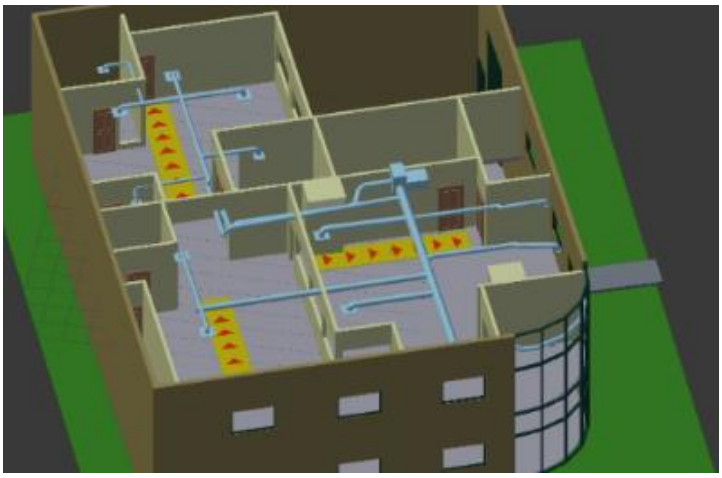
It has the responsibility of coordination the relief efforts for citizens and damaged areas by restoring utilities such as electrical and telecom cables dynamically provide lodging and feeding facilities to the victims of the disaster and mobilizing the army, separate and in parallel with emergency responders.

- Real time Overview of Relief efforts (Volunteering, Military, Anti-terrorism)

- Disaster Modeling (fire front motion) based on weather conditions
- Citizens Evacuation Activities
- Decision on critical Infrastructure (Airports, Refineries, Pipelines)
- Real time Overview of all Mobile Field Operations
- Temporary Restoration of Utilities with portable Units
- Provision of add-on crews for reinstating Telecommunications
- Dynamic Construction of anti-flooding, anti-fire protection provisions

RESPONDERS FIELD TECHNOLOGIES:

- **Buildings Modeling Information** (BIM) and **Augmented Reality** (AR) for emergency response in buildings, airports, and large commercial centers. This technology allows for quick repairs and utility restorations, the identification of employee concentration areas, and the identification of safety exits as well as health and safety procedures. It also provides shutdown procedures for utilities such as gas and power in order protect responders from dangerous infrastructure.



- Sophisticated hand-held devices that enable first response crews to monitor the conditions of vital infrastructure and access utility GIS maps in real-time to check for shutdowns and to ensure their own safety. The same devices will enable two-way communication with the Emergency Response Center receiving Work Orders and Instruction for Citizen assistance and provide dynamic field reporting on efficiencies and conditions to the Center.

Findings and Results

The process of carrying out an emergency response to natural disasters in urban environments is extremely challenging. This is because it involves critical and time-dependent decision-making in regard to human lives as well as valuable public infrastructure and private assets. For a successful response, the factors that must be considered are not only weather, assets, and first responders, but also those that are not immediately evident such as utilities networks and critical infrastructure machinery. Though considerations for utilities networks and critical Infrastructure machinery are not readily associated with emergency response, they are nonetheless critical for ensuring the efficiency and efficacy of first response and relief efforts.

Illuminating this point is the fact that earthquakes are often followed by large fires that occur due to gas pipeline explosions. In such situations it is often the case that homes will blow up due to open gas valves. The wildfires in Fort McMurray, Alberta that lasted

from 2016-2017 showed that firefighters are not typically trained in operations surrounding gas services, and that utility employees are not often available in such critical emergencies. In addition to first responders not being trained in the process of shutting such valves, there are also no reliable gas infrastructure maps that include assets. The lack of adequate maps would make it difficult to locate gas valves even if firefighters were familiar with gas utilities.

During such large fires we have also seen segments of the Power Grid failing to generate the needed power to manage sufficient pressure on the water grid, which is required for firefighting. As was exemplified during the 2018 Attica, Greece wildfires, the additional failure and destruction of power pumps and compressors can also hinder firefighting operations.

In the recent past we have seen relief efforts be hindered by the lack of underground maps of the electrician network in the New Orleans Dome that was used as a shelter for tens of thousands of people, which rendered impossible the provision of electricity and air conditioning during the Hurricane Katrina relief efforts.

Such instances make it clear that properly mapped utility networks can act as a preventative measure for both the creation of disasters (such as pipeline leaks and explosions), as well as for peripheral damages and the escalation of damages from natural disasters. In this sense, it is evident that considerations for utilities services and machinery are integral to any successful emergency response. This conclusion has driven emergency responders to utilize Utilities Damage Prevention Centers—which provide digital maps of underground utility networks—in collaborative efforts during their operations.

A complete emergency response system, with imbedded Technology/Services solutions as previously described, can provide an operational framework in Emergency Response efforts coordination along with all the Damage prevention and Utility maintenance plan and activities that will assist and provide a more effective Crisis Management in cases of Natural Disasters, Terrorist Attacks, and industrial accidents.

Part of the solution is the transfer of all Electric networks underground in order to protect them from natural disasters and secure vital services. Natural Gas and Telecommunication networks should follow up in a co-trenching model.

Such a plan would be costly at first, but it would undoubtedly reduce the cost of utility maintenance and restoration to damages dramatically. It would dramatically affect the cost of utility operations and reduce the cost of services to consumers.

Conclusions

Recent advances in technology along with proper planning, well tested processed and coordinated efforts can provide dramatic impovement to emergency response and relief operations in natural disasters and terrorist attacks.

Technologies such as Augmented Reality, Wireless Communications, Smart Apps and Command Center Infrastructure enriched by IoT (*Internet of Things*) sensors and full GIS capabilities for Utility Infrastructure and Vital Infrastructure (refineries, airports, military installations, etc.) will revolusionize Emergency Response.

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