Individual Emergency Response and Recovery: a learning experience from Puerto Rico's encounter with Hurricane Maria

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Coastal Resilience Center Mentors:
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Mentors' Signatures Robert W. Whalin

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Abstract

Hurricanes are massive shows of nature's force. Destructive in short times, regenerative at longer ones, they provide ample opportunities to learn and study the interaction between human beings and their environment. Of particular interest in this work, is the activity of individual decision-making during and after a hurricane. To approach this area, we capitalized on the experience of the team members who faced Hurricane Maria's pass through Puerto Rico in 2017 as well as the guidance of our mentors of the Coastal Resilience Center. The original aim was to determine the series of decisions necessary to maximize survival during and after a hurricane in the presence of imperfect information. To approach this aim, the project was organized in three stages: (I) Survey and Statistical Analysis, (II) Model conceptualization, and (III) Prototype coding. From the first stage, it was learnt what the participants worried the most about at different points in time, what kind of decisions they made, and what kind of information they had at the moment. These findings were the basis to model decision making as an individual wellness monitoring mathematical model similar to those used in manufacturing plants for inventory control purposes. The model, designed in the second stage, was verified and validated to finally, in the third stage, take the form of a mobile device app named 'iWILL', which stands for Individual Wellness Inventory Level Log. Once a hurricane strikes, iWILL queries the individual every two hours to: register detrimental events, reflect the decrease in the person's wellness, and propose up to three restorative measures from which the user can choose. The app reflects the restorative effects in time, allowing the user to monitor wellness as a result of personal decision-making as well as review his/her response in perspective. In the future, it is expected that a more formal version of the app be made available to the public in hurricane-prone areas and a scaled-up version of the system be developed to aid emergency-management agencies

UPRM Summer Team: The background is a NOAA picture, the top pictures from the hurricane were taken by Frederick Gonzalez, and from left to right in the bottom, the headshots are from Verónica Díaz-Pacheco, Frederick González-Román, and Mauricio Cabrera-Ríos.

Individual Emergency Response and Recovery: a learning experience from Puerto Rico's encounter with Hurricane Maria

Introduction

In September 2017, Puerto Rico was visited in less than three weeks by two hurricanes, Irma and Maria. Both achieved category 5 before touching Puerto Rico. To this date, we are still living with the consequences, especially from the second one, Maria, which crossed the island diagonally as a Category 4 phenomenon in about 18 hours. Many aspects about hurricane Maria have been studied, analyzed, and –certainly- debated. Even the number of deaths attributed to it is still a matter of discussion that spans from tens of deaths to thousands of them. This project focuses on the decision-making carried out by individuals during and after the hurricane. Regardless of how people and institutions planned and prepared to face Maria, in the island we all went through the initial hit, the eerie calm of the eye of the hurricane, the second hit right after it, and the painful aftermath. At the individual level, we all had to deal with crises in our households or places of shelter, and we all had limited information to devise a course of action to try to survive. The task of making decisions to improve instantaneous wellness in the presence of imperfect information during and after a hurricane is what our team decided to study in this project. Such task is a pertinent process that requires clarity and effectiveness. It was envisioned that a mathematical model relating wellness to decision-making would provide both qualities when coded in an adequate framework.

Three stages were outlined for this work. In the first stage, a survey was designed and delivered to people who lived through the hurricane to understand their worries, decisions, and the information available to them during and after the hurricane. Descriptive statistics were the main tool to decide upon the necessary information to build a mathematical model in the second stage. In the selection of a model, simplicity and accuracy were the main criteria to represent wellness level as a measure to be maintained. These characteristics were found in models used to approach inventory control. After appropriate testing, verification, and validation phases, the model was then to be coded in a mobile app for user convenience during a third stage of the project. The three project stages are discussed in this report.

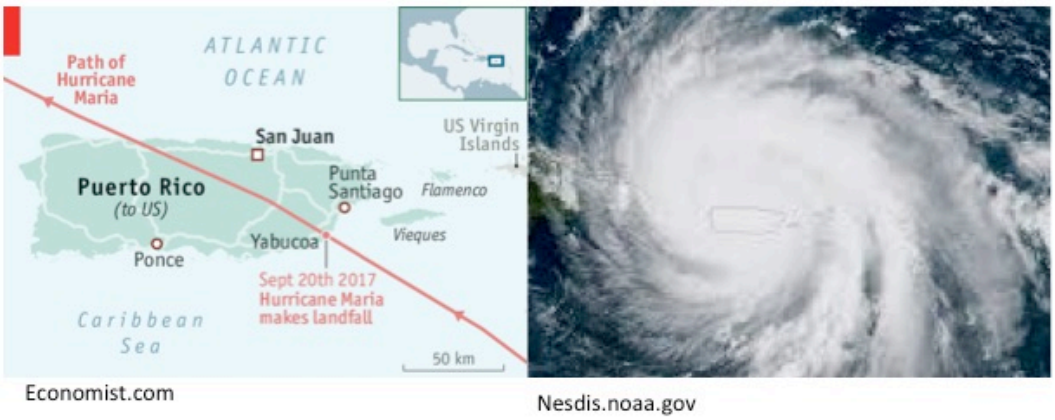


Figure 1. Hurricane María's path and size compared to the island

Team

Dr. Thomas W. Richardson and Dr. Robert W. Whalin, from the Coastal Resilience Center (CRC), were the mentors of this project. Dr. Mauricio Cabrera Ríos, lead the U. of Puerto Rico at Mayaguez (UPRM) team's technical work. Graduate student Ms. Verónica Díaz-Pacheco and undergraduate student Mr. Frederick Y. González-Román formed the UPRM team. Finally, in order to ensure the pertinence of the proposed approach, Dr. Clara E. Isaza and her student Johany D. Negrón –both from the Public Health Program of Ponce Health Sciences University (PHSU)- actively participated and contributed to this work.

Stage I, Survey and Statistical Analysis

The *Individual Emergency Response and Recovery Questionnaire* was a (preliminary) survey aimed to collect information about the experience of individuals who lived through Hurricane María in Puerto Rico on September 20th, 2017. It was intended for individual's sentiment to be described in several points in time, so that the survey was divided in 5 sections: socio-demographic Information, first hour of María, first eight hours of María, the day after María, and one week after María. In addition to picturing this initial data, we wanted to assess if any relationships linking individual uncertainty – wellbeing –, to his decisions and/or immediate circumstances existed or not. In an attempt to assess the power of any potential relationship using analytical tools, a Pearson correlation coefficient was calculated for all variables. Using these correlation results, it was possible to uncover several potential relationships as described next.

Summary of Findings from Stage I

The levels of worry of respondents seemed to be composed by a significant amount of their worry about relatives and family. The levels of worry also seemed to be dependent on the age group, in the sense that older individuals reported lower levels of worry than younger ones. Both of these results seem to be congruent with studies in relevant literature about the composition of wellness indices (Warner, 2013).

The overall worry of respondents lowered as time passed, which could represent to a certain degree the ability of adaptation of individuals after the crisis. The worry about utilities and communications seem to play a proportional role on overall worry levels -wellbeing-, and there might also be a regional aspect to the worry about utilities.

Additional interesting findings include:

- Worry for certain categories seemed to be lower when the amount of people with whom individuals reported to be sheltered was higher. This was true for all cases, except for vehicles and money.
- Worry about communications and utilities seem to have a regional aspect to them, which could be analyzed more in depth with timing the progression of restoration of services by region, for example the Southwest region did not report to be as worried about communications as the electricity service never stopped for some of the individuals from this region. These worries also did not lower across the time span under consideration.
- Worry about studies and future play a large proportion of the total worry reported by younger individuals.

Stage II, Model Development

In the first stage of this project, a preliminary questionnaire was designed to gauge three aspects of people in Puerto Rico regarding their experience during and after Hurricane Maria: (i) what they worried about, (ii) the kinds of decisions they made, and (iii) the amount of informal information they received.

What can be learned from the descriptive statistics summarized in our previous report - with a limited number of responses- is that individuals worried mostly about friends and relatives, utilities, communications, and plans for the future, pretty much in that order. This order was, in fact, very consistent with respect to time. There is a noticeable difference between worry levels during and after the event, and the levels of worry decreased with time. In addition, different age groups seem to worry about different things and there seems to be an effect of spending the hurricane with more people in terms of what worries people more, and to what extent.

In terms of decisions, people seem to pay more attention to the news, their health, their belongings, and their needs as time progressed. And finally, the level of informal information (rumors) increased with time. In particular, rumors about the destruction of the Leeward Islands and about flooding in the main island of Puerto Rico were prevalent.

It is undeniable that, a larger sample, better representation across age and geographical groups, as well as a revised questionnaire are important to arrive to strong conclusions in the future. However, with the information at hand it was possible to marshal an initial model to aid in the decision-making of individuals during and after a hurricane. The second stage of the project entailed creating such model.

An important realization at this point was that individual wellness could be seen as an inventory to be maximized. In this sense, an inventory level is akin to a wellness level. This wellness level will be impacted negatively by detrimental events (e.g. losing a window in your place of shelter) and can be increased through the effect of restorative actions resulting from effective decision-making (e.g. covering the hole left by the missing window with cardboard and tape/rope). The parallel between both situations is illustrated and explained in Figures 2, 3, and 4 below.

It was envisioned that a wellness monitoring system would query the individual periodically -say for instance every two hours- to reflect the individual's current wellness level and to register detrimental events that had occurred since the last time of query. The user would enter these events and the system will provide simple solutions aimed to help mitigate the detrimental effects and restore the wellness level in the near future. This system could run as a mobile app capable to work both online and offline as a tool for decision-making during and after a hurricane.

The main objective was to get the user to focus on critical decisions and feasible actions with a positive impact with clarity and simplicity, qualities that are often missing during crises. To this end, the system would act as a checklist of action items, a well-regarded approach to handle emergencies for airplane pilots and medical surgeons. The initial focus on the individual at the time to build this model helped the team to learn and assess how this model could be scaled-up

and adapted to support decision-making for groups of individuals, communities, and –perhaps, in the future- first responders and emergency managing agencies.

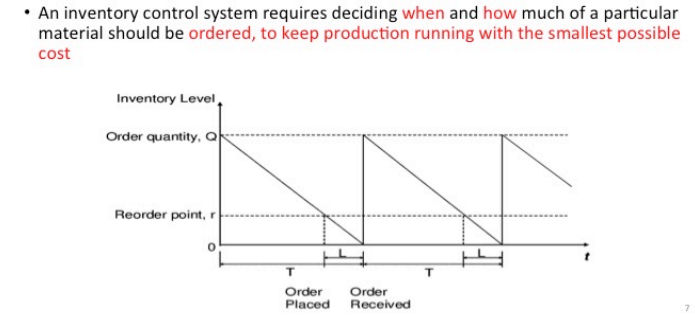


Figure 2. A typical inventory control model

Figure 3. Wellness level can be seen as an inventory

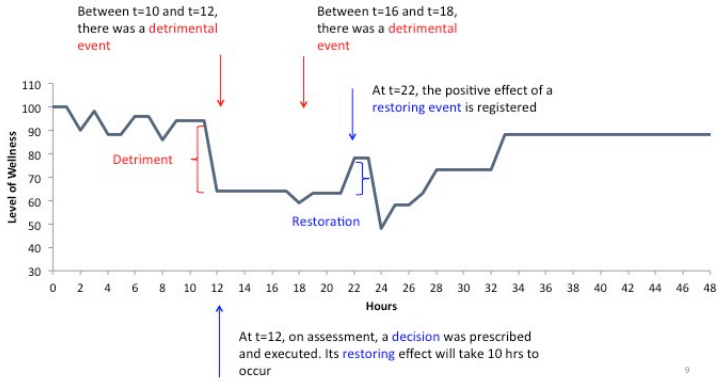


Figure 4. Principal elements of a wellness control model.

Mathematical Notation

The following mathematical notation was adopted in order to discuss the wellness control model proposed to approach decision making during and right after a hurricane.

Indices

i Time period i = 1,2,3,...,i

j	Detrimental event in i	$j = 1, 2, 3,...,j_i$
k	Detrimental event's category	$k = 1,2,3,...,k$
l	Detrimental event's subcategory	$l = 1,2, 3,...,l_k$
m	Suggested solution to detrimental event	$m = 1,2,3,...,m_{kl}$
n	Solution in a particular time period i	$n = 1,2,3,...,n_i$

Constants

i	Number of time periods
j	Number of detrimental events in the i^{th} time period
k	Number of categories
l_k	Number of subcategories for the k^{th} category (event ID in category)
m_{kl}	Number of suggested solutions for the kl^{th} event
n_i	Number of restorations to take effect in the i^{th} time period
d^{kl}	Detrimental effect of the event in the k^{th} category and the l^{th} subcategory
d_{ij}^{kl}	Detrimental effect in the i^{th} period of the j^{th} event in the k^{th} category and the l^{th} subcategory
r^{klm}	Restorative effect associated to the m^{th} solution in the k^{th} category and the l^{th} subcategory
r_{in}^{klm}	n^{th} Restorative effect taking place in the i^{th} time period associated to the m^{th} solution in the k^{th} category and the l^{th} subcategory
lt^{klm}	Lead time for the restorative effect of the m^{th} solution in the k^{th} category and the l^{th} subcategory

Text variables

e_{ij}^{kl}	Detrimental event, reported by user
s_{ij}^{klm}	Solution suggested by model

Numerical variables

d_i	Total detrimental effect assigned to the i^{th} time period	$d_i=S_j d_{ij}^{klm}$
r_i	Total restorative effect taking place in the i^{th} time period	$r_i=S_n r_{in}^{klm}$
W_i	Wellness level in the i^{th} time period	$W_i = W_{i-1}-d_i+r_i$

How it works

The idea behind individuals reporting the detrimental events that occur to them is to be able to gauge his/her wellness level periodically. The way the model works is that an individual can report any given problem from a list of events, and this event will be classified at that moment using a classification function.

$$f(e_{ij}) = klm$$

Once reported by the user in time period i, the classification function will identify the j^{th} event using its respective sub-indices (klm). This characterization will help locate the event's restorative effect, as well as the projected time it will take to restore individual's wellness, that is, its lead time. Figure 5 illustrates how the mathematical notation defined above comes together in the proposed model.

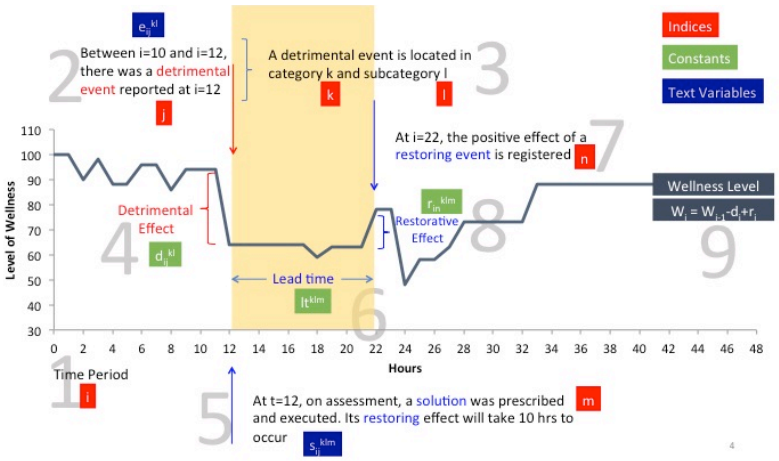


Figure 5. Principal elements of a wellness control model

Verification

In order to test if the individual wellness inventory level log (iWILL) could represent a series of possible scenarios with reasonable fidelity, four different personal accounts of experiences for Hurricane Maria were tested. The resulting timed wellness profiles are shown in Figures 6 through 9, as proof of concept. On each of these cases, the first 48 hours of experience were reflected with sufficiency. Two important observations arose with this exercise: (i) the initial wellness level must be assessed systematically on every instance, and (ii) it is expected that after 48 hours the individual wellness level differs from the initial level.

Figures 6,7 8,9. Verification profiles

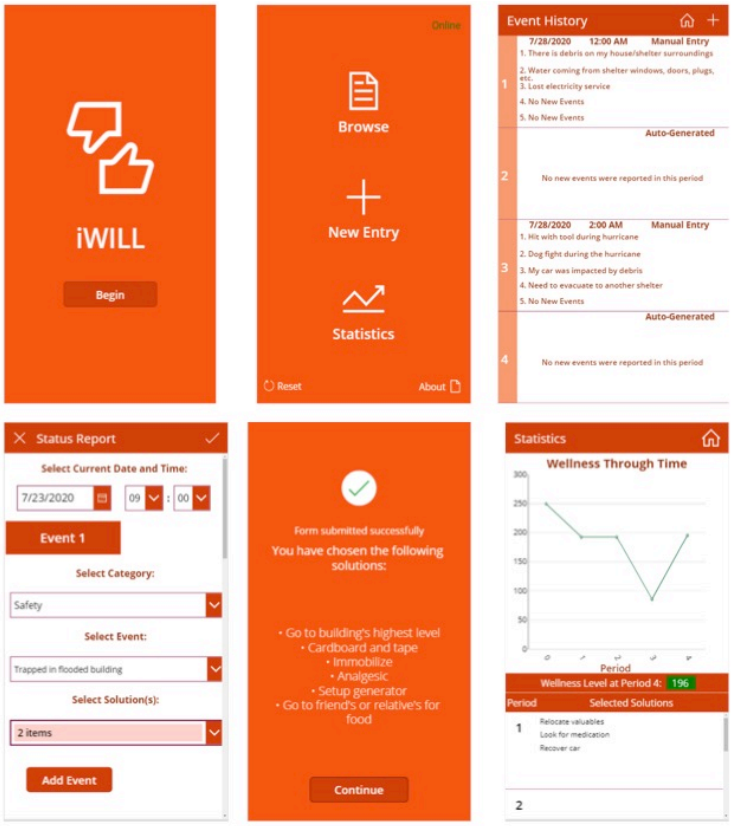
The second stage of this project lead up to the creation of a coded prototype for the inventory model. It was intended for this model to (1) to have the capacity to guide individuals through the real situations that they could face during and at the aftermath of a hurricane disaster and (2) be able monitor individual's wellness.

Since it was necessary for the model to be able to represent reality in a reliable and sufficient way, a comprehensive list of events and possible solutions was developed aided by anecdotal evidence from people who lived through hurricane María on Puerto Rico.

Individual's reported feelings were taken into consideration as well for the construction of the model. The impression of the importance that individuals placed on several subjects (gauged in the questionnaire) was considered to determine the detrimental effects used in the model. For example, if individuals reported high levels of worry for the house during the event, an event related to the house or shelter reported during the hurricane would have a (proportionally) high impact in that individual's wellness. Solutions, on the other hand, represent the degree of recovery to the original wellness state before a detrimental event.

Stage III, Model Coding

The final stage encompassed coding an app to support the model developed in Stage 2. Figures 10-15 show screen shots of the resulting app, iWILL. Figures 10-12 (top row, left to right) show the cover, the user's menu, and the event history screens respectively. Figures 13-15 (bottom row, left to right) show the entry screen for detrimental events, the checklist screen with the restorations (solutions) proposed by the model, and the statistics screen where the wellness level and the history of decisions are shown.



Figures Top: (10) App Cover, (11) User's menu, (12) Event history
Figures Bottom: (13) Detrimental events entry screen, (14) Checklist screen with proposed restorative actions (15) Statistics screen with wellness plot and decision history

Contributions Made to the Research Project

I am the faculty member from the UPRM Summer Research Team. My responsibilities for this project included selecting the participating students, writing the initial proposal, managing the IRB requirements, making sure that we met the project timeline's milestones and completed the project deliverables. It was my task to craft the technical aspects of the project according to our continued conversations with the CRC mentors, the PHSU collaborators, and match them to the capabilities of the UPRM students. In addition, I acted as the communication bridge between the CRC mentors, the UPRM students, and the ORISE team.

New Skills and Knowledge

Through my involvement in this project, I learnt a lot about communication. Setting up and following a well-established communication plan between ORISE, CRC, UPRM students, and the PHSU collaborators during the pandemic was challenging, but to me it is now a blue print for future projects.

I enjoyed learning to explore a new area of research with mentors, which is uncommon after years of being a researcher. I am grateful to the CRC mentors and the ORISE team for this great experience.

Importantly, this project has helped me enter a new area of research: decision-making in times of crises. This area is both, exciting and full of opportunities. I intend to continue exploring it.

Research Experience Impact on My Academic/Career Planning

The area of decision-making in times of crises is particularly well matched to Puerto Rico. During the past three years, we have lived through devastating hurricanes, social unrest, continuous economic contraction, a swarm of earthquakes lasting six months already, and –of course- a pandemic in the island. This mentored summer research experience has given me a taste for novelty in the area. I hope that the follow-on proposal is granted to continue advancing in this path. Critically, this experience involved working with students, which sets me in the right path to positively impact the preparation of human resources from the onset. In conclusion, this new research area will be central to my efforts in the next couple of years.

Relevance to the mission of DHS

The DHS mission states '...we will safeguard the American people, our homeland, and our values'. This project supports the first part by empowering and aiding individuals to make decisions to preserve life grounded in science and the personal experiences of a team that survived one of the few category 5 hurricanes to ever touch land.

Furthermore, the mission of DHS abounds on the following: 'Together, we are committed to relentless resilience, striving to prevent future attacks against the United States and our allies, responding decisively to natural and man-made disasters, and advancing American prosperity and economic security long into the future." This project certainly intersects with the aspects of

responding decisively to natural disasters and provides a tool to explicitly impact recovery at different scales of time.

Specifically, in the cases of emergencies, this work focused on the individual and the decisions to be made to maximize the chances of survival especially in the presence of imperfect information. This work has the potential to allow the DHS to focus and more efficiently use its resources and, therefore, to better fulfill its mission.

Acknowledgements

It was a pleasure and an enriching experience to be mentored by Dr. Thomas W. Richardson and Dr. Robert W. Whalin from the DHS CRC. Thank you.

I am also grateful to the ORISE team, especially Beth White and Cedricka Harris for their diligence and availability. Also, thanks to Mr. Josh Kastrinsky for putting us in the cover of the DHS CRC website.

The valuable and voluntary contribution of Dr. Clara E. Isaza from PHSU is gratefully recognized.

This work was entirely possible thanks to the work disposition and enthusiasm of the students from UPRM and PHSU, Ms. Verónica Díaz-Pacheco, Mr. Frederick Y. González-Román, and Ms. Johany D. Negrón.

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