# Quality Engineering Helping Civilian Populations on War Fallouts and Climate Change[1]

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Summary

We discuss and describe the application of statistics-based quality engineering methods such as reliability, logistics, industrial and systems engineering, and operations research to the design, development and improvement of systems that mitigate war fallouts on civilians trapped in closed war zones, and the effects Climate Change. We provide three examples of such implementation in the current war in Gaza, developed under our guidance by Syracuse University graduate engineering students. We expect, with this paper, to contribute to the War Relief efforts.

## 1.0 Introduction

This is the third yearly paper we write, discussing the role of *Quality Engineering* (QE), a collection of methodologies that use *statistical* procedures: *reliability*, *logistics*, *operations research* and *industrial engineering,* for mitigating adverse events on civilian populations.

Our first paper was in written in July of 2021, and dealt with applying the *Quality Engineering Methodology* (https://web.cortland.edu/matresearch/QualityEngineeringToolsCovid-19.pdf) *to Covid-19 Systems Design and Improvement*. The second one, was written in July of 2023, and dealt with *Quality Engineering Tools for Mitigation of War Fallouts on Civilian Populations*, (https://web.cortland.edu/romeu/QualEngToolsWarFalloutMitigation.pdf) using as example the war in Ukraine. The present paper deals with mitigating the effects of war fallouts on civilian populations trapped in a *closed war zone*, such as a city under siege, where people and articles have severe difficulties getting out, and aid has extreme difficulties getting in.

In all three papers, we used QE methods for the analysis of such adverse events, and for their implementation, thus providing more efficient solutions. For, QE methodologies are valuable in planning, designing, implementing, streamlining and improving effective engineering solutions, rendering mitigation procedures easier to manage and execute.

This paper, just as the previous two, pursues *three objectives*. *First,* to *illustrate the use of QE methodologies*. *Secondly,* to *provide practical examples of their implementation* in the mitigation of adverse consequences on civilian populations, making authorities aware of QE tools and uses. Finally, to *showcase the good work developed by our Syracuse University graduate students*

[1] We dedicate this work to the civilians who have undergone the ill-effects of war, especially to the children, with the sincere hope that some of the techniques developed here may help mitigate their suffering.

during their *MFE634 Q*uality *Engineering* course, that we teach every Spring (see its syllabus: https://web.cortland.edu/matresearch/MFE634SylS17.pdf) for the MAE Dept.

These graduate students develop every semester, under our guidance, several group final projects (https://web.cortland.edu/matresearch/PastProjectTopics.pdf) examining real life problems, and implementing QE tools that provide efficient solutions for them.

In our MFE634 course we do not dwell on the causes nor the responsibility of the parties to these events, as our interest as engineers is to help improve the conditions of those that are reluctantly caught in the midst of said incidents. We follow two important educational principles: Dr. John Dewey's *learning by doing theory* (https://www.pedagogy4change.org/john-dewey/), and *The Role of Engineering in* (https://repositories.lib.utexas.edu/server/api/core/bitstreams/da224561-af8b-463e-8e74-2e23e44ed263/content) *Society*, by S. Nichols and W. Weldon.

## 2.0 General Preparation

In this section we overview general preparation activities for a QE project. The main *QE tools* are in PPT https://web.cortland.edu/matresearch/QualEngGralMfe.pdf, and in Sections 2.0 and 3.0 of paper https://web.cortland.edu/matresearch/QualEngToolsHurricaneMitigation.pdf, that discusses the use of QE tools to help civilians bette 0r prepare to survive natural disasters.

In this paper we will examine three projects: the first two are related to war relief efforts, and the third is related to climate change. We consider essentially two types of war theaters: open and closed. An example of open war theatre was the Battle of Britain, in 1940, when German planes pounded London. But the attacking army was on the other side of the Channel, which allowed children, elderly, women and other fragile population, to evacuate to the countryside; and food, medical equipment etc. to be brought in. The open war theatre scenario was analyzed in detail in our already mentioned QE 2023 paper, using the Ukraine war as an example.

An example of closed war theatre was the siege of Leningrad, in 1941-1944, where the German armies encircled that city and prevented, for over 125 weeks, anything from entering or leaving it. This type of war theatre makes it much more difficult for civilians to survive, and is the one we are analyzing in our current paper, using as example the ongoing war in Gaza.

The very first thing required for the development of a successful QE Project is the selection of one or more *Champions*: high level officers that will ensure the fulfilment of the QE Project Team requests and needs. In our current projects, given their international nature, Champions must be high level military commanders, or international organizations officers, such as UN and WHO executives, Cabinet Ministers, Red Cross/Red Crescent, NATO and EU officials. Without their help, the QE Project team's requests and demands may be ignored.

Then, we must decide which of two types of systems we will develop. We may need to *modify and improve an existent, but inefficient system*. Or, *if said system is non-existent, we will need to create it, from scratch*. Finally, we must define, with the Champion and other project leaders, the scope of the project, and select an appropriate composition for the QE project team.

All types of systems require designing and implementing command, control and communications centers, with substations able to oversee complex operations, including redundant sub-systems to back-up possible communication failures, and maintenance capabilities to resolve breakdowns.

All this information is obtained from interviews, brainstorming sessions, past studies, etc. done using subject matter experts, before the start of implementation. From the Brainstorming session we build a qualitative Fishbone (Ichikawa) chart, that shows which factors affect the response or performance measure under study, and its respective levels. Said chart will eventually become a quantitative equation (ANOVA, Regression, Experimental Design framework), that will provide the necessary information to assess the proposed feasible and efficient solutions.

Before starting to measure, we need to implement a Measuring Systems Analysis (MSA) to be sure that results obtained come from real variation in the variables of interest, and not from the measurement errors due to deficient gages or ill-trained operators. Then we define quantitative relationships between variables of interest, and generate useful hypotheses to test and verify, with the data collected from the system (before and after improvements are done).

Thorough FMEAs and root-cause analyses need to be implemented, examining those steps that may go wrong or work poorly, finding causes, consequences and possible correction strategies, as well as any other issues that we may have forgotten to include, or may have miss-calculated.

Finally, we must state, implement and evaluate the suggested fixes to the problems uncovered, establishing the necessary controls for said solutions to become permanent system features.

## 3.0 Quality Engineering Student Group Projects

In this section we discuss the three applications of *QE statistics-based methods* used to design and implement solutions to said *problems*. These projects were developed, under our guidance, by *MFE634 student groups, and are explained in detail in the three PPTs* discussing their group final projects. We strongly recommend these students, for their good work here showcased that demonstrates their knowledge of the subject, as well-qualified Quality Engineers.

### 3.1 Quality Engineering Project to Feed Civilian Populations Caught in Closed War Zones

To develop a solid QE project, one should start by implementing a COPQ (Cost of Poor Quality) analysis, defining its four categories: internal, external, appraisal and prevention themes. This information may be obtained through a thorough Brainstorming exercise, that helps create a qualitative Ishikawa chart. There, factors that affect our overall objectives (e.g., food acquisition, storage and processing), are expressed through appropriate Performance Measures (e.g., number of persons fed, total calories). The Ichikawa or Fishbone chart eventually becomes a framework for more quantitative statistical procedures such as Regressions, DOEs, ANOVAs, etc.

Additional information material about key issues involved in the system is obtained from the interviews of subject-matter experts. Process flowcharts and Value Stream Maps (VSM) help identify system bottlenecks, non-value-added steps and other problems that can later be modified or discarded, substantially improving the operation of the system. They also provide guidance as to what data to collect and where and when, in the system, they should be collected.

Before starting data collection, an MSA (Measuring Systems Analysis) should be implemented, to determine if the measurements taken include undesired elements, such as operator or gage errors. Gage R&R analyses detect these problems. If a large percentage of the measurement results come from actual part variation, and only a small percentage comes from operator and/or gage errors, the MSA results are acceptable. Otherwise, we must first address the measurement system problems, retest it and, once accepted, we can safely start measuring the variables.

If a system already exists and we need to improve it, we can proceed with a *Six Sigma (DMAIC*) or other continuous improvement methodology. Alternatively, if a system does not yet exist then DFSS (Design for Six Sigma) and QFD matrix cascade methodologies are used.

There may be specific technical problems that we want to assess. This can be done via a Design of Experiments (DOE) and hypothesis tests. Our MFE634 students present examples of such analyses, using both statistical software, and Excel (when specialized SW is not available).

If there are new design aspects that did not exist before, but we want to try out, we implement a DFSS (Design for Six Sigma) or a QFD (Quality Function Deployment) Design procedure. If an existing method is proven inefficient and should be modified, the *VSM (Value Stream Map)* are implemented. First, develop the VSM for the *current state,* to assess the existing process. Then, after changes or improvements are implemented, a second VSM is developed, describing the system *future state*. Finally, a comparison of the key process parameters, before/after changes are implemented, is undertaken, to assess that the improvements actually work.

We will now briefly discuss water subsystems, given its importance to population subsistence. We assume that our Champion can ensure a steady flow of water to the city. The water should be acquired, tested, stored, distributed, used and, finally, disposed of. We need to assess their safety using *SPC (process control)* statistical procedures. To be efficient we must develop *Sampling Plans, and Control Charts*. Its distribution requires a network of pipes or a fleet of tanks, as well as appropriate reservoirs. Water is used for drinking, cooking, cleaning, hospital care, and sanitation uses. After being used, water must be safely discarded, or treated for safe reuse. All aspects of the support for water system operations should be taken into consideration, Failure Modes and Effects Analyses (FMEAs) and Fault Tree Analyses (FTAs) identify the root causes of failures, possible counter measures, and some redundant procedures. FMEA and FTA should be undertaken to assess how and why systems fail, what are their consequences, and what types of preventive and corrective measures can be taken to avoid total system collapse,

Finally, the student final project PPT discusses *Reliability* procedures, implemented to assess how methods can fulfill their stated functions, in time, and measure the probability of, say a water supply system to provide service for a week, without interruptions.

The reader can find said student group final project PPT, for the supply of food, water and shelter of civilians, in: https://web.cortland.edu/matresearch/CivililanFoodWater2024.pdf

### 3.2 QE Project to Provide Healthcare to Civilian Populations in a Closed War Zones

All the QE comments and observations developed for the previous section are also valid here. We also assume that the project Champions have arranged for a constant inflow of medical material to support hospital work. And, to illustrate the use of the QE techniques employed, we discuss their application to support the hospital key personnel (i.e. doctors and nurses).

To watch over the medical staff, it is necessary to provide for their personal and professional needs. This staff requires appropriate uniforms, gloves, aprons, head gear, shoes, etc. that they will put on at their arrival at the hospital and leave there, for replacement or cleaning at their exit. Thence, there is also a need for water, electricity, washing and drying machines, detergent, etc. and food and drink. There must exist a lounge where said staff can rest, while not at work, and in between shifts, as well as for the stay of redundant personnel, to fill in for absences. There must exist a system for transporting such staff from the hospital to their personal living quarters. And there must exist repair crews and the corresponding spares, to maintain the hospital running.

Operating rooms and ICU units must be outfitted with all the necessary equipment and staff, and a system for disposing of used bandages, clothes, medical equipment and even corpses must be set in place. The hospital must have an operating kitchen to feed the staff and patients, with the appropriate support personnel and equipment. Finally, there must exist a transportation system to move the injured, the hospital staff, medicines, equipment and all support personnel.

An extensive FMEA study should be conducted to analyze how each part of this complex system can fail, how can such failure event be prevented, or its damage minimized, what are its failure consequences, and how to create enough redundancy in its most crucial parts (e.g. the operating room equipment and personnel) so the system can continue running.

The reader can find our student group final project PPT, for the supply of medical assistance to civilians, in: https://web.cortland.edu/matresearch/CiviliansMedical2024.pdf

### 3.3 Quality Engineering Project to Prevent and Mitigate the Effects of Climate Change

The third project differs strongly from the two projects above discussed. However, it starts with a thorough Brainstorming session, requesting that scientists, engineers, users, government officials etc., contribute ideas to identify the key factors that accelerate climate change conditions.

Since Climate Change is accelerated by greenhouse effects, we start by analyzing it as a *SIPOC* (Supply, Input, Process, Output, Customer) *model*. Essentially, harmful gases are produced and then accumulate faster than they can be removed from the system. We need to determine what factors create them, which factors help the system get rid of them, and why aren't these factors working now. Fifty years ago, we had a similar situation, but it did not create the current crisis, possibly because the gas accumulation was much smaller, and the system could get rid of them much faster. To determine the root cause of this, we apply the *Five Whys* method:

*Why* are there more gases than before? Because there are more automobiles that use fossil fuels. W*hy* are there more automobiles? Because there are more people, and because these people live further away from their places of employment. *Why* do they live further away? Because of the *Sprawling Development Patterns*[2] that take place in modern urban centers. *Why* are such new development patterns occurring? Because, modern cities cannot grow vertically, so they grow horizontally, increasing the distances between homes and places of employment. *What* does this imply? Collective means of transportation (buses, metros, trolleys) have been substituted by one, two or more individual vehicles per household, increasing both traffic and commute travel time.

*How* has such *Sprawling Development Patterns* affected the system's capacity for ridding itself of harmful gases? Building new dwellings in a horizontal pattern requires demolishing virgin land (bushes, trees, grass) that would have helped the system get rid of adverse gases, and substituting said surfaces with asphalt, cement, housing structures, etc. that do not help.

We can see how reducing or suppressing the use of fossil fuels is not the only approach to solve this problem. Reducing *Sprawling Development Patterns* and developing and fostering more use of collective (instead of individual) means of transportation can have a positive effect in reducing or preventing climate change. Let's give a real-life example.

The I-95 freeway, from Washington DC to Richmond VA, has four lanes in each direction, plus a central two-lane for the use of drivers that pay the cost of its Toll. The rest of the drivers travel in the common use four lanes, encountering severe traffic and wasting valuable travel time, while at the same time, releasing adverse fossil fuel gases into the atmosphere.

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[2] https://www.nature.com/scitable/knowledge/library/the-characteristics-causes-and-consequences-of-sprawling-103014747/

The two central lanes, instead of being used exclusively by individual, toll paying drivers, could be used by inexpensive, frequently run buses, stopping every few miles at conveniently spaced *park and ride lots,* where the bus passengers could transfer to their own cars, driving a shorter distance home. If, in addition, a toll was established for individual cars travelling along the four-lane sides, and used to defray the costs of operating commuting buses, a significant reduction in traffic, as well as in the flow of adverse gases into the atmosphere, could be obtained.

Finally, a fiscal policy enticing vertical, in lieu of horizontal urban enlargement, would raise the density of districts, thus making again cost-efficient the use of collective means of transportation such as buses, trolleys, etc. This would also help reduce both traffic, and harmful emissions.

Simulation and Markov Chain optimization models[3], help compare the implementation costs, the reduction of traffic, and the release of harmful gases into the atmosphere, of the two discussed alternatives (moving from fossil fuels to wind/solar, versus reducing *Sprawling Development Patterns)*. Selecting the most efficient and cost-effective solution, or even a combination of them, is of relevant importance in Quality Engineering.

The use of FMEA and FTAs help evaluate critical steps of the system, as well as to determine the root-cause of possible failures, ways to prevent them, design corrective action, etc.

The reader can find said student group final project PPT for Climate Change Prevention and Mitigation, in: https://web.cortland.edu/matresearch/ClimateChangePrev2024.pdf

**4.0 Discussion**

Our current research deals with the application of statistics-based engineering methods such as reliability, logistics, industrial and systems engineering, and operations research, to the design, development and improvement of systems for mitigation of war fallout on civilian population and of systems for the mitigation of Climate Change effects.

There are several important issues in QE projects that deal with people. The very young, the elderly, and young women, for example, can be threatened by bad actors (kidnapers, thieves, rapists etc.). Thence, we need a law enforcement agency to keep the order.

We also need to be vigilant about contagious diseases such as cholera, polio, diphtheria, etc. Sampling is a valid alternative when we do not have sufficient resources to check everybody. Using an approach akin to *rectifying inspection*, we could examine everybody in a pre-selected sample, if someone shows signs of a contagious disease.

A secure and efficient command and control center is key to the success of any project. A backup system, in case the primary one goes down, is also a must. For example, cell phones can be our

[3] See, https://web.cortland.edu/matresearch/ASQRDTalkStochasticJune2024.pdf

primary system, and email, the back-up. Rapid communication enhances system efficiency, as knowledge of cut-off routes, damaged streets, and unsafe zones, would not only save lives, but also improve the effectiveness of the project efforts.

It is also necessary to find funds to support all these activities. We hope that rich countries and international organizations like the Red Cross/Red Crescent and the United Nations, would help support relief efforts for civilians caught in this devastating war, and for Climate Change effects.

Finally, these projects show how graduate engineering students can examine and solve real-life problems. Such experience alerts them to their societal engineering responsibility, and provides them with additional application fields, where they can employ their engineering expertise.

## 5.0 Conclusions

Our current objective is to alert potential disaster relief organizations and government agencies about QE techniques that can be employed, and about the types of professionals that need to be recruited, to help these organizations improve their efficiency. QE techniques can be helpful in designing, implementing and improving mitigating solutions to the war fallout issues. Readers desiring further information about these projects or QE techniques, can contact us.

We also want to encourage disaster relief organizations and government agencies to undertake joint work with quality, reliability, logistics, and industrial/operations research engineers, and to use their methods, not only after said war relief and disaster systems have been designed and implemented, but also during the time that these types of systems are being considered.

We also want to provide practical examples to subject-matter researchers, government officers, and to the public, to help them understand what quality engineers do, and how these can help improve war fallout disaster mitigation systems, thus fostering greater collaboration.

Finally, this statistics-based research on war fallout mitigation and on climate change effects can be used as part of a general disaster relief course, or as part of an applied modeling and analysis graduate course in an industrial engineering, operations research, or applied statistics department.

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Jorge Luis Romeu retired Emeritus from the State University of New York (SUNY). He is currently a Senior Speaker Specialist for the Fulbright Roster Program and an Adjunct Professor at Syracuse University (SU), where Romeu has taught, for over 20 years, graduate Statistics and Quality Engineering courses, and served, for sixteen years, as a Research Professor. Romeu previously worked as a Senior Research Engineer for the Reliability Analysis Center (RAC), an Air Force Information and Analysis Center operated by IIT Research Institute (IITRI), then by Alion, and finally by Quanterion Solutions (QSI), until absorbed by DSIAC. Romeu has received seven Fulbright assignments: for Mexico (3), the Dominican Republic (2), Ecuador, and Colombia. Romeu teaches yearly workshops in New York City, on Quality Engineering, in Spanish, for Latin American professionals. He holds a *Licenciado en Matematicas y Estadistica* degree from the University of Havana, and a Ph.D. in Industrial Engineering and Operations Research, from SU. Romeu is a Chartered Statistician Fellow of the Royal Statistical Society (RSS), and a Senior Member of the American Society for Quality (ASQ), where he is a past Regional Director. He holds ASQ Reliability and Quality Certifications and is a Member of the American Statistical Association (ASA). Romeu created and directs the *Juarez Lincoln Marti (JLM*, https://web.cortland.edu/matresearch/) *International Education Pro*ject, which has supported higher education in Ibero-America for over 30 years. The JLM Project maintains the *Quality, Reliability and Continuous Improvement Institute (*QR&CII), an applied statistics and operations research free access web site that can be found in: https://web.cortland.edu/romeu/QR&CII.htm