Quality Engineering Tools for Mitigation of War Fallouts on Civilian Populations

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Summary

This paper describes the application of statistics-based quality engineering methods such as: reliability and logistics, industrial and systems engineering, and operations research to the design, development and improvement of systems for the evacuation of civilians out of the war zones, and for the transport of agricultural production, crucial to people in Third World countries, through said war zone. As an implementation example, we use the current war in Ukraine. We expect, with this paper, to contribute to mitigate War Fallout problems, and to improve War Relief efforts.

1.0 Introduction

This paper discusses the role of *Quality Engineering* (QE), a collection of methodologies based on *statistical* procedures such as *reliability, logistics, and operations research*, used in *industrial engineering*, to the mitigation of adverse war fallouts on civilian populations, both inside the war zones, as well as far away. We use QE methods in the analysis of such adverse situations and use them to provide efficient adaptive solutions. QE methodologies are effective in the planning, the designing, implementing, streamlining and improving good engineering solutions and mitigation measures, making these easier to manage and execute, even within the war zones.

This paper pursues *three objectives*. *First*, to *illustrate the use of QE methodologies,* in general. *Secondly*, to *provide practical examples* of their implementation in the mitigation of adverse war consequences on civilian populations, so local authorities become aware of their power and may use them. Finally, to *showcase the work developed by our Syracuse University graduate students* in their *MFE634* quality course: https://web.cortland.edu/matresearch/MFE634SylS17.pdf. Said MFE634 students, under our guidance, create yearly final projects, examining real life problems using QE tools, some of which are in https://web.cortland.edu/matresearch/PastProjectTopics.pdf

The current paper researches the difficulties in implementing war-related mitigation measures, by using QE approaches, and systems improvement methodologies. The use of QE and statistical tools, allows us to detect, avoid, or minimize many implementation problems, thereby helping to correct errors, or to provide mitigating actions, where specific difficulties are unavoidable.

In a war, at least two key categories of civilians suffer greatly: those who are caught in the midst of the war theatre, and those people, in other places of the world, who depend on materials that are produced in, or that travel through, said war theatre. For example, in the current Ukrainian war, said second category involves Third World populations that consume cereals and fertilizers. In the current Sudan civil war, such second category may include consumers everywhere, since neighboring Suez Canal can be damaged or disrupted, at any time, as a side effect of said war, hindering or delaying the passage of goods, through it.

We do not dwell here on the causes nor the responsibility, of parties to these wars, as our interest is to help improve the living conditions of those, reluctantly caught in the middle of these events.

2.0 General Preparation

We now overview general preparation activities of a QE project. The main *QE tools* are in PPT https://web.cortland.edu/matresearch/QualEngGralMfe.pdf and in Sections 2.0 and 4.0 of paper https://www.researchgate.net/publication/352998703_Quality_Engineering_Methodology_in_Covid-19_Systems_Design_and_Improvement.

Broadly speaking, we need to address several issues, to set up the two systems that we want to create (if inexistent), or improve (if existing, but inefficient). These two systems deal with (1) the evacuation of civilians out of the war zones and, (2) the creation of an efficient supply chain for the safe passage, through the war zone, of cereals and fertilizers from Ukraine and Russia, to the Third World countries in Africa and Asia that consume them. We review these issues, below.

For the first system, we need to estimate the number of people to evacuate, and then to establish how this will be done (land, air, water). This, in turn, implies estimating the number of vehicles that will be used (buses, trains, planes), as well as their travel time, the capacity of these roads, bridges, canals, trains, etc., to ensure that there is sufficient ability to move said evacuees out of danger. In order to select the best options, comparisons with similar efforts in other wars (First and Second World Wars, Korea, Viet Nam, Kuwait, Afghanistan, Irak, etc.) is in order.

It is necessary to establish where all these evacuees will be lodged (for several days) and provide for them food, water, beds, medical and safety personnel and equipment, electrical power (a key element that supports all other ones), etc. We need to establish an array of warehouses, where the equipment and material will be stored, to minimize supply chains to provision them. We need to organize a contingent of medics, police, etc., including its support material, that will stay on site to help those that will not be evacuated, as well as those in the evacuation stations. Some of these evacuees may be injured or sick, and will need medical assistance. This event lies outside the scope of the present evacuation project. It will be then necessary to establish contacts with other healthcare agencies, such as the Red Cross, or hospitals, to transfer said patients to their care.

For the second system, we need to estimate the quantity of grain and fertilizer in the fields, that will be transported out, first to gathering centers, then to transit centers, and finally to the ports, where they will sail out of the area. Thence, we need to estimate the number of vehicles that will move these grains and fertilizers, the equipment to load/unload them into transports, the drivers, mechanics and support personnel for such transportation operation, including food, fuel, spares, electrical power, warehouses to store them, etc. We need to calculate travel and load/unload time to ensure a JIT (Just in Time) transfer from stage to stage, in order to minimize warehousing.

Both systems require designing and implementing able command, control and communications centers, with substations able to manage these complex operations, including redundant systems to back-up communication failures, and capabilities to fix possible break-downs.

All this information is obtained from interviews, brainstorming sessions, past studies, etc. done using subject matter experts, before the start of the operation. A thorough FMEA and root-cause analysis needs to be implemented, examining those things that may go wrong or work poorly, or other things that we may have forgotten to include, or may have miss-calculated.

3.0 Quality Engineering Student Group Projects Addressing War Fallout Problems

In this section we present two applications of *QE statistics-based engineering methods* to design and implement war fallout *problems*. These two projects were developed, under our supervision, by *MFE634 student groups, and are explained in detail in two PPTs* discussing their group final projects. We recommend these students as well-qualified Quality Engineers, for their work, here showcased, demonstrates their strong knowledge of the subject.

3.1 Quality Engineering Project for the Evacuation of Civilians out of the War Zones

The objective of this project is to transfer civilians out of the war zones in Western Ukraine, to refugee camps in Eastern Ukraine, where they can either relocate in other Ukrainian regions, or move into an EU country that accepts them. The Champion of the project should be a prominent UN officer. Students identify problem areas/factors and their levels through an Affinity Diagram, and then create a process Flowchart to better understand the key event flows of the situation.

Based on such results, students develop a quality assessment, implementing COPQ (Cost of Poor Quality) analysis using the four problem categories: internal, external, appraisal and prevention. With this information students create a qualitative Ishikawa chart where issues that affect overall objectives are expressed through appropriate Performance Measures. This chart eventually serves as the framework for quantitative statistical procedures (e.g., Regression, DOE, ANOVA).

Much information material, to find out the key issues involved in the system, is obtained from the interviews of subject-matter experts. The process flowchart eventually yields Value Stream Maps (VSM), which help identify bottlenecks, non-value-added steps and other system problems that can then be modified or substituted, substantially improving said system.

Before collecting data, an MSA (Measuring Systems Analysis) to determine if the measurements taken include undesired elements, such as operator or gage biases should be implemented. Gage R&R analyses are employed to detect these problems. If a large percentage of the measurements come from the system, and only a small percentage comes from operator and/or gage bias, MSA results are fine. Otherwise, we must first fix the measurement system, retest it, and if accepted, then we can safely measure the variables.

Students then define a *Six Sigma (DMAIC*) improvement methodology to the existing mitigation procedures (if systems already exist, and we need to improve them). Alternatively, the five DFSS phases (Define, Measure, Analyze, Design and Verify) are used for the system does not yet exist.

There may be specific technical problems that we may want to analyze. This can be done via a Design of Experiments (DOE) and other statistical analyses. Students present examples of such analyses, using both statistical software, as well as Excel (in case said SW is not available).

If there are design new aspects that did not exist but we want to try, then we implement a Design procedure, using a DFSS (Design for Six Sigma), or a QFD (Quality Function Deployment). The latter is developed to illustrate the creation of an efficient evacuation plan. If an existing plan is proven inefficient and should be improved on, *VSM (Value Stream Map)* are implemented. First, develop the VSM for the *current state*, to assess the process. A second VSM is then developed, for the *future state*, and a comparison of process parameters (before/after changes) is performed.

We mentioned that support material (e.g. food) should be stored for use. But we need to assess their safety using *SPC (process control)* statistical procedures. It is not efficient to inspect every item (takes too much time), or impossible (destructive inspection) to do so. The alternative is to develop *Sampling Plans, and Control Charts*, which are explained in detail in the students' PPT.

Finally, the PPT discusses *Reliability* procedures, which are implemented to assess how methods or elements are able to fulfill their stated functions. Some procedures measure the probability of, say a bridge, to withstand specific traffic levels, and require data analysis. Others, are qualitative: Failure Modes and Effects Analyses (FMEAs) and Fault Tree Analyses (FTAs), and assess how and why system elements can fail, what are their consequences and what are the preventive and corrective measures that can be taken, given a failure, to prevent total system collapse.

The reader can find the student group final project PPT for the evacuation of civilians, in: https://web.cortland.edu/matresearch/UkraineWarRefugee.pdf

3.2 Quality Engineering Study for Creating a Supply Chain through the War Zones

The objective of this project is to transport, through the war zones, to ports in the Azof and Black seas, grains and fertilizers produced in Ukraine and Russia. Then, load these into ships that will transport them through the Mediterranean, to their Third World country destinations in Africa and Asia. The Champion of this project should be a prominent officer of the international agreement, organized by Turkey, to transport out such grains and fertilizers.

This project develops illustrative examples on how to implement assessments, discussions about root-cause analysis, and on the use of FMEAs to analyze critical steps, their possible failures, its causes, ways to prevent or circumvent these, design corrective action, etc. Such is of particular need when using heavy machinery such as cranes, to load ships with grain containers or with fertilizers, and we want to secure spare parts, as well as technicians to install them.

Having several alternatives in transportation modes, in delivery routes, in loading and unloading grains and fertilizers, in port facilities, etc., is of particular importance. In the war theatre, roads, bridges and railway lines may be destroyed or damaged at any time. Thence, more than a single delivery mode and route should be considered. Having a reliable communications system offers information about their condition and use, that are crucial to the efficient operation of the system.

In addition, a JIT approach to the transfer of goods between successive delivery points enables the minimization of warehousing facilities, and promotes a faster transportation of these goods.

The reader can find said student group final project PPT for the grains supply chain, in: https://web.cortland.edu/matresearch/UkraineGrainsSupply.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.

There are three important cohorts in projects that move people: the very young, the elderly, and young women. These three groups can be threatened by kidnapers, that sell young children in the black market, by thieves, that rob and kill the elderly to steal valuables they are taking in their flight, and by rapists that threaten young women. Thence, we need a law enforcement agency.

We also need to be vigilant about possible contagious diseases such as diphtheria. Sampling is a valid alternative when not having sufficient personnel to check all incoming people. Using an approach akin to rectifying inspection, when someone in the selected sample shows signs of a contagious disease, then everybody should get checked to weed out other infection cases.

A secure and efficient command and control center is key to the success of the project. A backup system, for the case the primary one goes down, is also a must. For example, cell phones can be our primary system, and email, the secondary one. Rapid communication enhances efficiency, as knowledge of cut-off routes, damaged bridges, and unsafe zones, for example, would not only save lives, but also improve the effectiveness of the evacuation efforts.

It is also necessary to find the funds to support these activities. It is hoped that countries that have spent hundreds of billions in arming both sides of this conflict, would contribute a few million to help support relief efforts for the civilians caught in this devastating war.

We have also shown how graduate engineering students can study 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.

Limited job opportunities currently exist for statistically-based engineers in areas of reliability, quality, logistics, industrial, systems, and operations research, to work in war disaster mitigation projects. These statistically-oriented engineers can then apply the above-mentioned quality and reliability disaster mitigation methods, to relieve the fallouts from the war.

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 this author.

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 general 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 research on statistics-based war fallout disaster systems analysis 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). Romeu is currently a Senior Speaker Specialist for the Fulbright Speakers Roster Program, and an Adjunct (Part Time) Professor at Syracuse University (SU), where he was, for sixteen years, a Research Professor and has taught graduate Statistics and Quality Engineering courses, for over 20 years. Romeu previously worked as a Senior Research Engineer for the Reliability Analysis Center (RAC), which was operated by IIT Research Institute (IITRI), then Alion, and finally Quanterion Solutions (QSI). RAC was an Air Force Information and Analysis Center now absorbed by DSIAC. Romeu has received seven Fulbright assignments: in Mexico (3), the Dominican Republic (2), Ecuador, and Colombia. 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), a Senior Member of the American Society for Quality (ASQ), where he is a past Regional Director, and also holds Reliability and Quality Certifications, and a Member of the American Statistical Association (ASA). Romeu created and directs the *Juarez Lincoln Marti (JLM*, https://web.cortland.edu/matresearch/) *International Education Pr*oject, which has supported higher education in Ibero-America for 30 years. The JLM Project maintains the *Quality, Reliability and Continuous Improvement Institute (*QR&CII), an applied statistics and O.R. free access web site (https://web.cortland.edu/romeu/QR&CII.htm).