Strategies to Improve the Logistics of a COVID-19 Screening Process Within a Lean Six Sigma Framework

Jeanne-Marie Lawrence
Teaching Instructor
Department of Technology Systems, College of Engineering and Technology East Carolina University
Greenville, NC 27858, USA
lawrenceje@ecu.edu

Abstract

The COVID-19 pandemic has changed the way the world operates, forcing nations to adopt new procedures to combat the spread of the coronavirus while concurrently maintaining economic activity. During the pandemic, several countries implemented systems and processes to screen travelers who legally entered their borders before allowing them to intermingle with the general population. The Caribbean, which depends heavily on tourism, is no exception. While the primary goal of a screening process is to protect the local population from disease spread, a secondary goal should be to ensure traveler satisfaction in terms of timeliness, accuracy, agility, and cost-effectiveness of the logistics of the process. This paper primarily addresses the latter goal by proposing a multidisciplinary approach to improve the logistics of a COVID-19 screening process in a small island state. The recommendations are based on the absence of key disciplinary areas and perceived skill gaps between the professional cadre and workforce, and the computer and digital literacy of the nation. A lean six sigma framework is used to demonstrate how a structured methodology can be applied to implement the potential solutions.

Keywords
COVID-19 Pandemic, Lean Six Sigma, Multidisciplinary Strategy, Air Passenger Screening and Caribbean

1. Introduction
Passenger mobility is vital to the economic mainstay of many countries, particularly small island states that depend on tourism for a substantial portion of their domestic product. Few countries can afford to prohibit entry of visitors or residents on a long-term basis despite the threat of an ongoing global pandemic. This reality has been an immense challenge for governments, health and medical professionals, tourism executives, airport managers, and other stakeholders, who recognize the need to manage the health risks associated with incoming travelers, while simultaneously ensuring the efficiency and effectiveness of the control processes.

Efficiency and effectiveness are two words that are often used interchangeably but which have very different meanings. According to the Merriam-Webster dictionary, efficiency refers to “the ability to do something or produce something without wasting materials, time, or energy”, while effectiveness is “the power to produce a desired result”. From these definitions, it is clear that it is possible to have an effective system that is lacking in the area of efficiency or vice versa. For example, during the COVID-19 pandemic, many Caribbean islands developed screening protocols to check incoming air passengers for potential signs of infection before allowing them to mingle with the general population. Not only were these systems unique to each island, but the degree of efficiency and effectiveness varied among the islands. Among these, Dominica was effective in the early identification of incoming infectious cases to prevent disease outbreaks and community spread within the local population. The island registered only 197 COVID19 cases and zero deaths over the first 18 months of the global pandemic (Johns Hopkins University and Medicine, 2021). However, less attention appears to have been paid to developing the processes to meet traveler satisfaction.

1.1 Logistics
Logistics is about managing the flow of resources efficiently and effectively. Regardless of the number of incoming passengers on a flight, travelers expect the screening operations to be expedient, state-of-the-art, lack redundancy, and result in accuracy. A well-designed and managed logistics system will facilitate the rapid movement of products and information to the correct locations in the shortest possible time. Recognizing some of these issues during the

COVID19 pandemic, Štimac et al. (2021) point out that operational processes and their optimization will need to be the main priority of airports in the future. In view of this point, it would be useful to identify approaches that could be applied to improve the efficiency and effectiveness of the screening processes. Among these, a multidisciplinary strategy within a lean six sigma framework provides a methodological approach to identify and solve the logistical challenges.

1.2 Lean Six Sigma

Lean Six Sigma applies a holistic and collaborative approach to improve a process by combining the principles of two philosophies – "lean" and "six sigma". Lean methodologies focus on efficiency by reducing waste and eliminating non-value adding activities. Examples include decreasing cycle time, reducing waiting time, improving service delivery time, eliminating unnecessary steps, lessening defects, and optimizing resource usage. The first step in applying lean principles is to determine who the customer is and the type of value desired. This is followed by mapping the value creation process, customer flow, demand pull, and continuous improvement.

Six sigma uses data and statistical techniques to reduce the variation in a process, thereby making it more reliable and effective. The goal is to have a maximum of 3.4 failures per million opportunities. The six-sigma methodology is underpinned by a rigorous methodology that involves five steps: Define (D), Measure (M), Analyze (A), Improve (I) and Control (C) or DMAIC. The approach involves actual measurement of process variables, analysis of root causes, formulation of solutions, and implementation of controls. By combining lean and six sigma, a process can benefit from reduced costs and higher agility, delivery, and quality.

Various authors have reported success in applying lean six sigma methods to improve service operations. For example, Zilm et al. (2010) decreased throughput time and improved health care space utilization in emergency operations. Mohamed Isa and Usmen (2015) improved design and construction services at a higher education institution, and Sunder (2016) increased profitability in retail banking operations. Lean six sigma has also been applied to many other service operations to improve performance (Psychogios et al., 2012; Furterer, 2009; de Koning et al, 2006).

1.3 Objectives

The COVID-19 pandemic provided no advance warning to the world and, consequently, many of the systems implemented to deal with the pandemic were developed rapidly and under tremendous pressure. Dominica applied a meticulous approach to keep residents safe and introduced the concept of a "Safe in Nature" destination. Notwithstanding the positive aspects from a medical perspective, it was also obvious that the system, as implemented, lacked the capability to handle high volumes or fast speeds – capabilities that will become increasingly necessary as economic activity returns to normalcy and tourism is increasingly targeted as an engine for economic growth. It is for this reason that documentation and analysis of the process has been undertaken – to provide a baseline from which improvements can be made, particularly as the number of air travelers increases in the future.

To develop an efficient and effective process for screening incoming air travelers for COVID-19 infection, it is useful to begin by mapping the end-to-end process to understand the essential flows, key activities and tasks, potential bottlenecks, and opportunities for inaccuracies and redundancies that could lead to inefficiencies. Among these flows, the physical flow of travelers, the flow of information (both health and demographic), and the flow of funds are the most important. Building on this premise, this paper seeks to achieve the following:

(1) To map out the physical and information flows associated with the screening process for arriving air passengers to Dominica who are fully vaccinated and present negative PCR test results
(2) To identify points of failure and bottleneck areas that can be targeted for improvement
(3) To improve the process by applying a multidisciplinary approach within a lean six sigma framework

2. Literature Review

International travel is recognized as one of the main conduits for transmission of infectious diseases (Wong et al., 2015; Sun et al., 2021). Global mobility has the potential to result in the rapid spread of disease when arriving infected passengers circulate among the local community. Given this reality, small island states, particularly those dependent on tourism for economic survival, but which have limited physical and healthcare resources, must take the necessary precautions to prevent the spread of disease. Sun et al. (2020) note that small island states have the potential to control disease spread during a pandemic if they have the political determination and an appropriate plan. Wang (2021) argues that two particularly challenging issues that pertain to the implementation of control measures at border checkpoints are (i) mitigating health risks and (ii) ensuring the efficiency of inspection processes. However, the academic literature provides little guidance on how these goals can be accomplished. Due to the rare occurrence of pandemics, studies are interspersed over long periods. Fortunately, the COVID-19 pandemic, one of the few truly global outbreaks in recent times, presents an opportunity to study the operations that underlie health control measures.

Common public health controls during a pandemic include travel restrictions and quarantine protocols (Bielecki et al., 2020). Quarantine, as a means of control, is not new and has been used for several centuries. For instance, there is evidence that in the fourteenth century, quarantine measures were applied to arrest the spread of the bubonic plague (NPR, 2020). In more recent times during the COVID-19 pandemic, over 150 countries have implemented various quarantine protocols for incoming travelers (Bielecki et al., 2020). In conjunction with quarantine measures, passenger screening is also used to detect possible infection. While there is an ongoing debate about the usefulness and limitations of this approach (Quilty et al., 2020; Wells et al., 2020), the method is still applied to detect infection and prevent community spread (Mantri et al., 2021). In a study conducted in the United States, it was shown that airport screening of passengers during a pandemic could reduce the number of infected cases by between 0.8 and 1.8 million and the number of deaths by between 16 and 35 thousand (Malone et al., 2009). During the 2003 SARS epidemic and 2009 H1N1 pandemic, airport screening measures were implemented in several affected countries (Quilty et al., 2020). More recently, to prevent the spread of COVID-19, hub airports such as Addis-Ababa's international airport in Ethiopia initiated passenger screening protocols from as early as January 2020 (Deribe, 2020).

Various authors have examined the issues relating to the effectiveness of controls to combat the spread of diseases by infected arriving travelers. Malone et al. (2009) examined the impact of airport screenings at foreign country exit points and at U.S. airports on reducing the number of infectious cases and deaths in the United States. Peddinti et al. (2021) proposed a framework for real-time detection and identification of patients with COVID-19 infection in public spaces, such as airports and hospitals, using Deep Learning algorithms that extract images from thermal videos taken with thermal cameras. Although not related to air transport, Niemelä et al. (2021) recognized the need to manage passenger flows in an ocean transportation setting. The authors proposed an approach that uses a risk matrix based on passenger likelihood of infection and integrated a combination of behavioral, procedural, and technical solutions to achieve near zero risk. In another study, Dickens et al. (2021) developed a mathematical model that applied Monte Carlo simulation to determine the likelihood of missed infectious cases at different quarantine durations and recommended quarantine period adjustments based on the level of risk associated with the country.

While much of the emphasis has been placed on managing the health risk, the efficiency of the processes that impact traveler satisfaction have received far less attention. However, there are a few articles that provide some insights and useful directions. Mantri et al. (n.d.) reported that in the early stages of the COVID-19 pandemic, from January to March 2020, the average screening time at Jaipur International Airport (JIA) in India averaged 2 to 3 minutes per passenger based on an assignment of 25 to 90 incoming air travelers per team per flight. JIA, which has the capacity to handle about 1,000 passengers at a time, trained and deployed 11 medical teams, each consisting of one medical officer and two paramedical officers, to conduct passenger screenings on a rotational basis. The procedure involved having arriving passengers complete a questionnaire, followed by having their temperature taken. For suspect cases, further screenings were conducted by another medical officer, followed by transportation to a hospital, and quarantining at a government facility until two consecutive tests yielded negative results. It is evident that for a system like this to work smoothly, whether implemented before or after vaccination, the processes need to be well-coordinated and executed. However, several problems can plague the process, from bottlenecks due to staff shortages to lack of a holistic, multidisciplinary approach to coordinate the requirements of all stakeholders (Mantri et al., n.d.). To address these concerns, the authors developed a fishbone diagram to classify the risks into seven categories.

In another study, Wang (2020) developed a mathematical model based on queuing theory to optimize the health inspection of passengers at border checkpoints. The model used a color-coded risk management hierarchy to selectively inspect arriving passengers that were classified as high, medium, and low risk based on a passenger's voluntary declaration on an online statement and background assessment. Štimac et al. (2021) raised some longerterm issues that have implications for the efficiency of screening operations. They noted that current International Air Transport Association (IATA) guidelines on terminal space requirements, maximum queuing time, and occupancy levels are not appropriate in a pandemic situation and suggested a shift in focus to ensure the physical and technological capacity is available to meet service levels. Suggestions included re-designing terminals for social distancing, introducing contactless technology, and implementing additional terminals for health screening.

From the above references, it is clear that each method focuses on solving a particular problem in the process without specifically considering the entire process from passenger arrival to release into the general population. Although Mantri et al. (n.d.) present a broader perspective than other researchers, the authors have still not approached the problem from a process perspective. Yet, Christopher (2011) stresses the importance of managing processes rather than functions to improve performance. It is from this perspective that this paper seeks to contribute to the literature on screening processes for incoming air travelers during a pandemic, by examining the process for a small island state and discussing how lean six sigma principles can be applied to improve traveler satisfaction.

3. Methods

The setting for the study is Dominica, a small island state in the Lesser Antilles in the Caribbean. At the time of the study, the mandated quarantine period was two days for arriving travelers who were fully vaccinated and presented negative pre-arrival PCR test results within 72 hours of arrival, while unvaccinated travelers were required to quarantine for seven days. The study pertains specifically to fully vaccinated travelers.

The study applies an experiential methodology using a naturalistic observational approach. The approach is considered ethical if the identity of the subjects is not revealed and observation takes place in a setting in which the subjects are performing their normal public duties without expectations of privacy (Jhangiani et al., 2019). An experiential observational research study differs from a traditional experimental approach in that the researcher is not only involved in generating the content of the study (what is being investigated), but also in formulating perspectives and making suggestions from the information acquired (Heron, 1981). In an observational study, the researcher examines behaviors without intervening and takes notes for further analysis and inference. The main benefits of using this approach are its simplicity and the ability to allow subjects to behave as they normally would in the setting being observed without pressure to change their behaviors to impress the observer or meet presumed standards. The main disadvantages include difficulty in replicating the study, the inability to control the physical setting or extraneous variables that can impact the environment or results, and the possibility that the researchers might attempt to interject their own biases. In addition, the root cause of behaviors may not be fully known unless the researcher conducts further investigations or expands the study. Thus, while a naturalistic observational approach provides insights into a problem, it might only be used as a preliminary step in conducting a broader, more systematic study.

Through observation of the process and multiple inquiries to health administrators, medical professionals, and laboratory personnel following breakdowns in the system, the researcher was able to develop flow charts of the logistics of the process (i.e., the physical flows of passengers and information flows of demographic and health data). The total time from arrival to release from quarantine was measured and results were triangulated against information gained from inquiries to three other certified-quarantine facilities while attempting to make reservations for quarantine. The general methodology of the study is summarized in Figure 1 below:

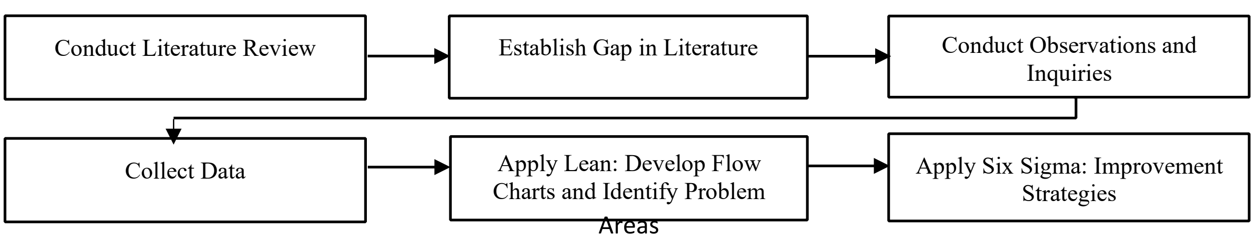

Figure 1: Research Methodology

4. Data Collection

The data was collected in two stages:

4.1 Pre-Arrival: During the first stage, the researcher made notes about the process while attempting to schedule a reservation at various government-certified quarantine facilities. The researcher also noted the data requested on a pre-arrival passenger questionnaire that was available via the Internet. The questionnaire was a requirement for obtaining clearance to travel and needed to be completed and submitted via the Internet at least 24 hours in advance of arrival. The form comprised the following three sections: (a) Demographic data

(b) Flight/Route data (this section also included questions on COVID-19 health history and disease symptoms)

(c) PCR / RD Test Results (tests conducted to determine COVID-19 infection)

It is worth noting that the form was later amended after the study period to request additional information from passengers on accommodations booked for quarantine. Table 1 provides further details on the data requested.

Table 1: Data Collected on Pre-Arrival Health Questionnaire

Demographic Data	First Name*, Middle Name, Last Name*, Email*, ID Type*, ID Number*, Date of Birth*, Gender (male / female)*, Permanent address (House / Apt #*, Street Number, State*, Zip Code, Country*), Local Address (House #*, Village*, Parish, Health District, Phone Number*, Occupation, Nationality)
Flight / Route Data	Date of Arrival*, Time of Arrival*, Flight No.*, Place of Embarkation*, Date of Embarkation*, Airports travelling to including stopovers, Countries visited in last 21 days*
Health Data (included under flight/route data)	COVID-19 diagnosis within last three (3) months? (Yes/No)*, Date of illness (if yes), COVID-19 vaccine received? (Yes/No)*, Date vaccine received (if yes), Proof of vaccination (upload), Contact with someone diagnosed with COVID-19 within last 14 days? (Yes/No)*, Current symptoms (fever or chills, mild fever and cough, shortness of breath, extreme fatigue, new loss of taste or smell, diarrhea?)
PCR/RD Test	PCR/ molecular test for COVID-19 taken? (Yes/No)*, If yes, date swab taken, Upload results

Source: Govt. of Dominica (2021) *required

4.2 After Arrival: The researcher collected data by making notes throughout the process – i.e., upon arrival at the airport, during the swabbing process at the hospital, and during the waiting period for test results and release:

(a) **Pre-Arrival:** The researcher observed the steps for a letter of authorization to be issued, measured and recorded the time duration for issue, and noted staff performance when the system failed to issue the letter.

(b) **Airport Screening Process**: The researcher measured and recorded the time durations for each step in the screening process at the airport, travel to a COVID-certified facility, and check-in at a COVID-certified facility. The researcher also noted the documents issued, personnel involved, and use of technology.

(c) **PCR Testing:** The researcher measured and recorded the traveler's wait time at the hospital/health center. The researcher also noted the type of data requested, method of recording, use of technology, and personnel involved in collecting the data at the facility.

(d) **Release of Laboratory Results and Approval to Checkout**: The researcher measured and recorded the time to register the traveler and take nasopharyngeal swabs. The researcher also noted the personnel involved in the process and the use of technology. The researcher made notes on the information provided through multiple inquiry calls to health and laboratory personnel and COVID-certified accommodations.

Table 2: Notes on Process Performance During the Observation Period

Pre-Arrival Letter	An automated letter of authorization to travel was issued via email upon receipt and approval of the requested information. In instances where it was not received, the officers contacted for assistance lacked the authority to override the system.
Airport Screening Process	The officer at the airport used a manual approach (pen and paper) to record traveler's demographic and health data on a tabulated form. The total time taken to screen the health data for six passengers was recorded. Each passenger was provided with an Airport and Ministry of Health/Port Health card on which the passenger's name, flight and flight #, vaccination status (fully vaccinated, not vaccinated), and date for PCR test was manually entered, signed, stamped, and dated. Fully vaccinated passengers were fitted with a red non-digital wristband.
Hospital Testing	The same demographic and health data provided on the pre-arrival questionnaire and at the airport was again requested by a hospital staff member. The information was recorded manually using paper and pen. The travelers' nasopharyngeal swabs were taken by a medical practitioner.
Quarantine	Without multiple inquiries, it was possible that the quarantine period would have been extended another night. Permission to checkout was granted at 8:00 pm on the fourth day.
Release of Laboratory Results	Upon review and release by a medical officer, batched lab reports were physically transported to the health center where swabs were taken. The medical practitioner who took the swabs was required to review the results and contact the quarantine facility via telephone.

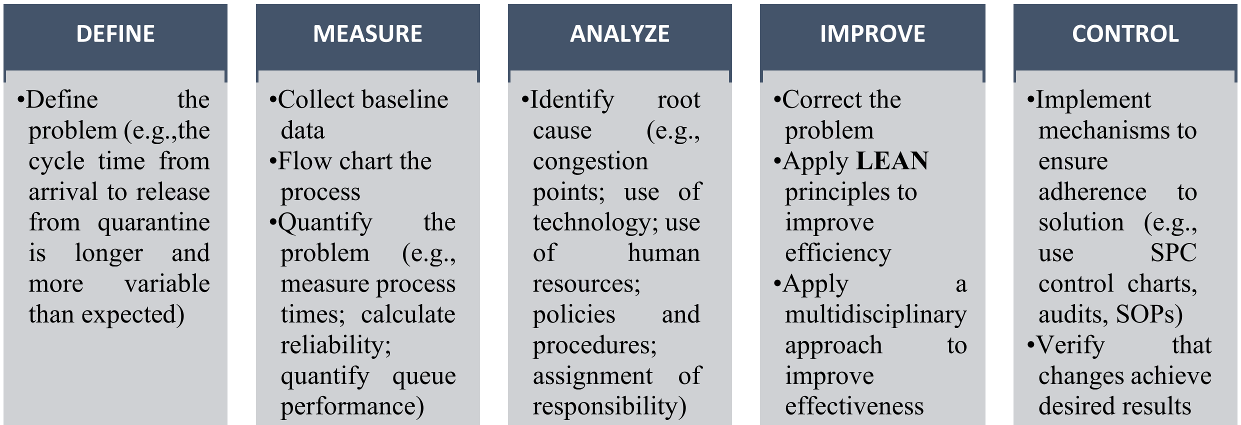

Figure 2: Application of the DMAIC Framework to Improve COVID-19 Screening Process

5. Results and Discussion

Both efficiency and effectiveness are necessary for a screening process to meet traveler expectations. Passengers travel long distances and arrive at their destinations fatigued. Poorly designed systems prolong this discomfort and reduce the system's capacity to handle even low volumes of travelers, potentially triggering negative attitudes toward the island as a tourist destination. To identify and solve the issues pertaining to efficiency and effectiveness, the DMAIC framework in Figure 2, which incorporates both lean and six sigma principles, provides a strong methodology.

5.1 Numerical Results

Data collected from measuring the time durations of each step in the process are presented in Table 3.

Table 3: Sample Total Time from Arrival to Release from Quarantine (for a two-day quarantine period)

Day/Time	Screening Process Steps	Approximate Time (mins)	Cumulative Time (mins)
Day 1	Arrival at main airport		
Day 1	Wait in queue for health screening by officer at airport *data is based on position in queue (approx. 5 mins/person)	30	30
Day 1	Service time by health screening officer at airport	10	40
Day 1	Wait time in queue for immigration screening	2	42
Day 1	Service time by immigration officer	1	43
Day 1	Wait time in queue for Customs check	3	46
Day 1	Service time by Customs officer	2	48
Day 1	Wait time in queue for assignment to taxi	15	63
Day 1	Service time to load taxi	3	66
Day 1	Service time to be transported to approved COVID-certified facility (varies based on location of facility selected)	20	86
Day 1	Wait time for check-in at approved COVID-certified facility	15	101
Day 1 - 3	Wait time in quarantine at COVID-certified facility	2,167	2,268
Day 3	Service time to be transported to hospital for PCR test	30	2,298
Day 3	Wait time for check-in at hospital for PCR test on Day 3	10	2,308
Day 3	Service time by medical practitioner for swabbing	3	2,311
Day 3	Service time to be transported back to quarantine facility	40	2,351

Day 3 - 4	Wait time in quarantine at COVID-certified facility	2,040	4,391
Day 4	Total time from arrival at airport to checkout from quarantine for 2-day quarantine		4,391 mins (or 3.05 days)

5.2 Flow Charts
Through experiential observation and inquiries at points of delay, the researcher developed flow charts (See Figure 3 and Figure 4) for screening of fully vaccinated air passengers who presented negative PCR results prior to arrival.

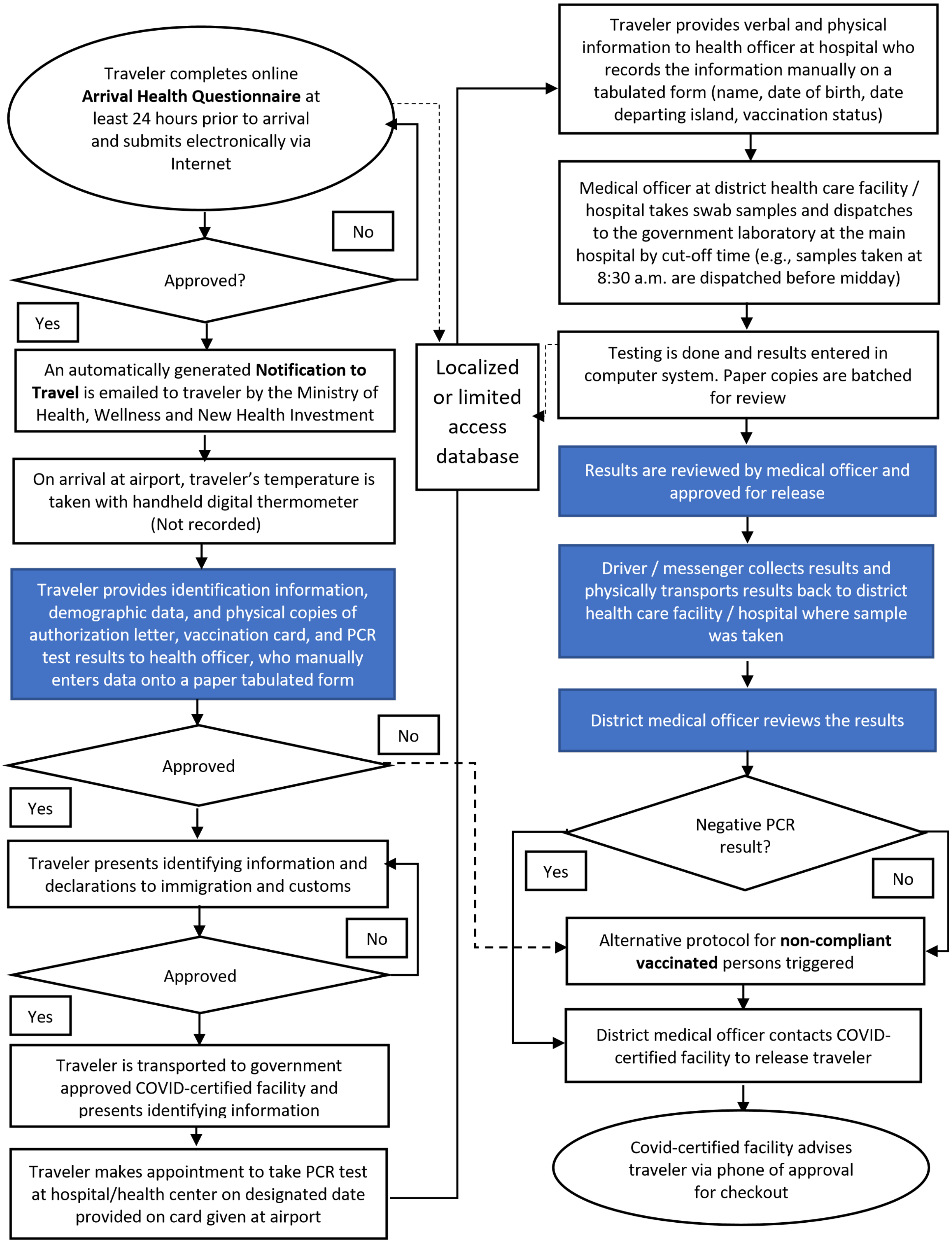

Figure 3: Information Flow for Incoming Fully Vaccinated Travelers During a Two-Day Quarantine Period
(Shaded boxes = bottleneck points)

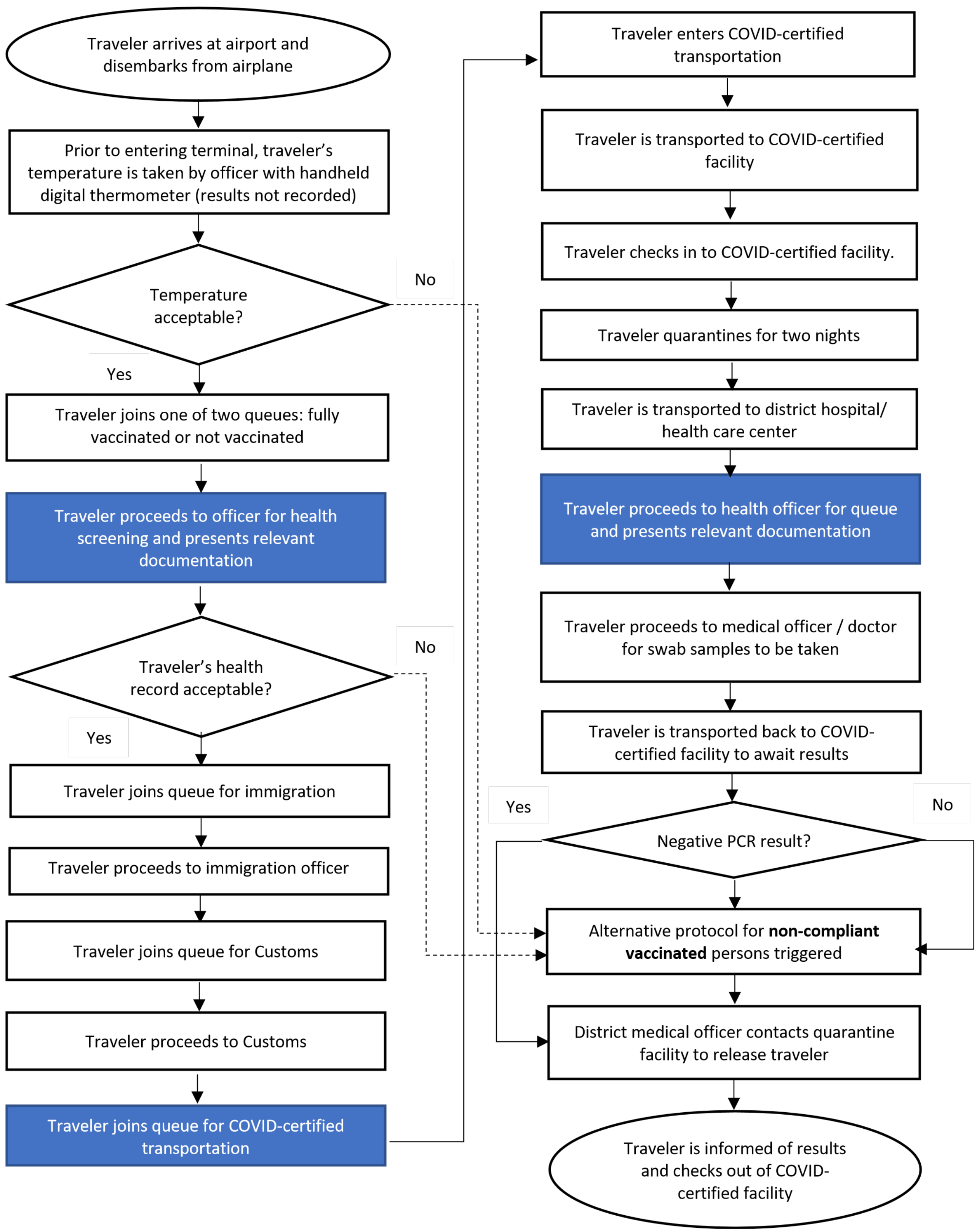

Figure 4: Physical Flow of Incoming Fully Vaccinated Travelers During a Two-Day Quarantine Period
(Shaded boxes = bottleneck points)

5.3 Proposed Improvements

The following recommendations are based on the perceived skill gaps and levels of empowerment between the professionals who develop the policies and those carrying out the daily activities in Dominica. Another focus is on the levels of, and gaps between, the required and actual levels of digital literacy (government and workforce). Additionally, due to the low level of industrial activity on the island, disciplines such as industrial and systems engineering, which offer a wide range of tools for improving processes, are lacking. Figure 5 depicts these issues.

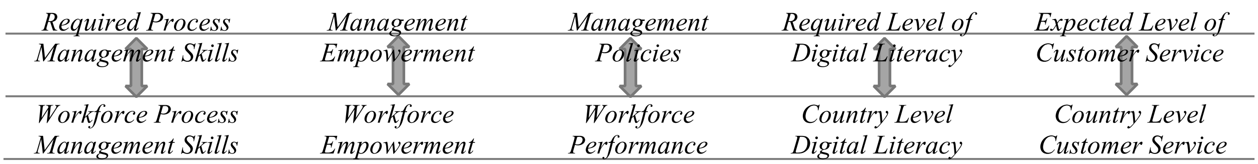

Figure 5: Skill Gaps that Need to be Closed to Improve the Logistics of the COVID-19 Screening Process

To properly apply a lean six sigma approach to improve the screening process, the desired goals of the process must first be stipulated. In this case, there are two goals: the primary goal is to reduce the infection risk to the local population. This can be defined in terms of the risk exposure that the country is willing to accept. The secondary goal is to ensure that travelers enjoy the experience of traveling to a safe destination. This can be stated in terms of the degree of traveler satisfaction to be achieved. Once the goals are set, the problem must be defined. The main problem is a longer cycle time than expected from traveler arrival at the airport to check out from the quarantine facility. This step is followed by measuring key process variables. Table 3 provides an example of the data that can be collected and used to flow chart the processes. The next step is data analysis. Figures 3 and 4 facilitate this step by depicting the process flows and congestion points. Table 2 also provides notes on factors pertinent to the problem. Once the process is mapped, it must be examined to identify opportunities for improvement. In the fourth step, a multidisciplinary approach is recommended to improve the process to meet the stated goals – i.e., reduce manual entries, duplication of data, queue times, physical transportation of test results, over-engineering of activities, and the possibility of errors. The Six Sigma DMAIC method advocates the use of a collaborative team approach to improve performance. In this regard, this paper recommends five key disciplines to improve the COVID-19 screening process: health and medicine, industrial and systems engineering, information systems management, and customer service (See Figure 5). The final step involves implementation of control measures to maintain the improvements.

5.3.1 Health and Medicine:

The primary purpose of the screening process is to safeguard the local population from disease outbreaks, prevent deaths, and reduce strain on the healthcare system. To achieve the desired results, the screening process must be capable of identifying infectious cases with a high degree of accuracy. The emphasis, therefore, needs to be placed on developing epidemiological and public health protocols and controls; developing protocols and controls for health data transmission, sharing, and timeliness; and ensuring the adequacy of health care personnel, equipment, and supplies to meet capacity requirements.

5.3.2 Industrial and Systems Engineering:

Increasingly, industrial and systems engineering principles are finding a place of relevance in designing efficient and effective healthcare systems. The following strategies applied to the screening process have the potential to improve the quality, consistency, and throughput of the process.

(a) ***Quality Management*****:** Quality management is not just common sense. It is a well-developed discipline with tools and methodological processes to ensure that a product or process conforms to the desired specifications and performs as intended. Some aspects of quality management that could be used to enhance the efficiency and effectiveness of the screening process are discussed further:

   (i) **Standards**: By setting specifications and tolerances for various aspects of the process, such as time durations for each step, those involved in the execution could be held to a higher performance standard. Additionally, the use of standards would allow the opportunity to compare the process to other similar processes and benchmark for improvement. While there were some standards in place, e.g., a cut-off time for dispatching the samples from the district health center/hospital to the main laboratory, it was unclear whether a similar time for return of the test results was in place or enforced. Other areas where standards could be established include setting tolerances for cycle times (from arrival of passenger to release from quarantine); defining the delivery frequency for laboratory tests and results (e.g., once a day, every four hours); establishing documentation quality standards (completeness and correctness); defining the type and method of delivery for technical support; and establishing procedures for handling complaints.

(ii) **Standard Operating Procedures (SOPs):** Along with setting standards, SOPs are important to specify *who* does *what*, *when*, and *how*. Documentation of SOPs is essential to ensure process standardization across all facilities. A methodological documentation system that involves procedure numbering, revision numbering, and sign off is foundational to developing proper SOPs.

(iii) **Statistical Process Control (SPC)**: SPC is a statistical tool used extensively to monitor manufacturing processes to determine whether the output falls within prescribed tolerances. SPC allows the construction of control charts to monitor deviations from established targets. By examining trends in the process, such as data entry times, number of errors, number of passengers processed within a given time, and deviations from prescribed tolerance levels, variations caused by common (inherent) and special (external) causes can be identified and corrected.

(b) ***Continuous Improvement***: The hallmark of an effective quality management system is a formalized process for ensuring target performance goals are consistently met. Data collected from task and cycle times and information garnered through feedback loops are indispensable in devising new and better approaches to achieve the dual goals of efficiency and effectiveness.

(i) **Feedback Loops:** Feedback loops are essential for service operations because they allow the *voice of the customer* to be heard. Both positive and negative information can be used to spearhead continuous improvement strategies. Since the arriving passengers are the foremost reason for implementing the process in the first place, understanding the impact on the customer is crucial. In a technology driven society, feedback loops can be easily achieved, for example, by designing and distributing a survey that can be launched on multiple electronic devices with results stored in a single database that is accessible to all key stakeholders. Feedback could be requested as the final requirement before checkout or encouraged to be completed immediately upon checkout.

(ii) **Audits**: Formal / random system audits against defined specifications are essential to ensure that a system is performing as intended. In the absence of audits, those who design the system can only assume that it is performing effectively. In countries where a huge gap exists between those making the policies and those executing the operations, regular audits are essential. Training would be necessary to prepare individuals to conduct the audit, compile a report, identify deviations to be resolved by a specific time, assign responsibilities, and wrap up the audit.

(c) ***Reliability***: Ensuring reliability through the reduction of variability is a central concept in logistics. Six sigma focuses on reducing variability that is likely to lead to stakeholder dissatisfaction. To measure reliability, the standard deviation for a sample of repeated observations is commonly calculated. The higher the number, the greater the spread of the data from the average, meaning that results are less reliable; conversely, the lower the number, the higher the consistency and reliability. With regard to the screening process, an example of a metric that could be measured for reliability is cycle time, which, in this case, could be defined in different ways – e.g., the total time from passenger arrival to release from quarantine; the total service time from arrival of a passenger at the airport to approval by the officer conducting the health check; the total time from receipt of a swab sample to entering of the results in a health information system. Other measures of reliability that could be applied to the process include mean time between failure (MTBF) (i.e., total operating hours divided by number of failures) and overall reliability of the system as a function of the reliability of the sub-systems (different steps) arranged in series, parallel, or both.

(d) ***Modeling Queue Formation and Bottlenecks:*** Queuing theory and simulation are two approaches that can be used to balance productivity against the cost of service. These techniques can be used as tools in designing an efficient system.

(i) **Queuing Theory**: Queuing theory is often used to analyze simple queuing systems to understand and improve performance through appropriate trade-offs between the cost of waiting and the cost of service. For infinite populations (e.g., samples arriving continuously to a laboratory), queuing theory can be used to answer questions such as how many officers/technicians are needed to conduct laboratory tests? What is the average waiting time for a laboratory sample to be served (tested)? What is the total time (waiting time and analysis time for a laboratory sample to be served (tested))?

How can the system be designed to minimize the cost of service? For an airport setting where flights are infrequent and passenger volumes are small, leading to a finite or nonrenewal calling population at single stage stations, the "machine-repairman model" could be applied to answer questions such as what is the average number of passengers waiting in the queue to be served? What is the average passenger waiting time in the queue? What are the utilization rates of the officers screening passengers? How can the system be designed to minimize service cost?

(ii) **Simulation**: Discrete-event simulation is another approach usually used to model more complex systems to determine if they are operating within the desired parameters. Simulation allows different system / process designs to be evaluated to determine the best option to reduce undesirable factors, such as waiting times, bottlenecks, and cost.

5.3.3 Customer Service Management:

Wisner et al. (2019) discuss good customer service management in terms of the *Seven Rs Rule*. For this study, the rule can be summarized in terms of delivering the right product/service (e.g., room, PCR laboratory test results), in the right quantity (e.g., availability of accommodation, availability of driver services), in the right condition (e.g., cleanliness, data accuracy, timely service), to the right place (e.g., facility, airport, hospital, laboratory), at the right time (e.g., within the stipulated quarantine period), for the right customer (e.g., arriving passengers), and at the right cost (e.g., cost to the passenger, cost to the government). "Right" in this case implies meeting a standard that is reasonable and acceptable to the stakeholders. Achieving "right" implies consistent compliance.

(a) ***Help Desk / System Support*****:** Digital systems are inherently invisible and, therefore, the aid of a support system to help travelers navigate through the interface is often needed. A Help Desk, staffed with individuals who are trained to troubleshoot and solve expected or recurrent problems, would go a long way in reducing traveler frustration and delays caused by information system and technology failures.

(a) ***Single Point of Contact***: Closely related to (a) is the assignment of a single point of contact to each passenger who could be contacted in the event of a process breakdown. This contact should ideally be different from the officer at the Help Desk – but one who has the ability to navigate across multiple functional areas to obtain and provide relevant and timely information and resolve process breakdowns. For example, a traveler who does not received timely notification of authorization to travel or timely notification of release from quarantine would contact this individual to investigate the problem and obtain definitive answers. Alternatively, this individual could proactively communicate system delays to travelers via electronic means to reduce the burden of incoming calls to resolve a problem.

(b) ***Workarounds for System Failure (Service Recovery)***: Planning of new systems inevitably includes planning for system failure and breakdowns. Despite meticulous testing, system glitches are likely to occur. Having an alternative process or system in place, trained staff, and associated documented instructions on how to work around system failures would not only empower officers but also greatly improve traveler satisfaction.

(c) ***Policies on Timely Communication*****:** Communication policies are a vital part of any time-bound system. Thus, the development of procedures to deal with traveler inquiries and complaints within a specific timeframe is paramount. For example, advising travelers to call back later due to the unavailability of staff to resolve a problem is likely to result in poor traveler satisfaction. Along the lines of setting policies on timely communication, consideration should also be given to reliably communicating negative PCR test results to the respective quarantine facilities no later than checkout time on the targeted day of release. For most hotel accommodations worldwide, the standard checkout time is 11:00 a.m. The current process involves the physical transportation of test results by a driver back to the hospital/health facility where the swabs were taken. It is a journey that is prone to both formal and informal stops and delays unless there is proper routing, strict adherence to timelines, and accountability for meeting designated cut-off times.

5.3.4 Technology and Information Systems:

Digital technologies have the potential to greatly improve the efficiency of a passenger screening process. However, foundational to implementing digital systems is a national legal and regulatory framework and adequate security measures to assure the integrity and protection of the information systems and associated data.

(a) ***Integrated Digital System***: A central database/integrated system that allows rapid retrieval of passenger demographic and health information by all appropriate stakeholders is critical to reducing redundancy, inaccuracy, and wasted time. In addition to health, medical, epidemiological, and laboratory personnel, limited access could also be granted to designated Help Desk staff, airport screening personnel, district health care / hospital staff, and COVID-certified facilities. To ensure privacy, security of data, and restricted access to unauthorized personnel, users should be trained, verified, subjected to double authentication, and required to change passwords frequently.

(b) ***Bar Codes / QR Codes for Rapid Data Retrieval:*** Barcodes offer a condensed visual format for labeling and tracking an item by scanning with a machine. Several bar code types exist, including the Universal Product Code (UPC), International Article Number (EAN), and 2-D Data Matrix used to trace retail products. Increasingly, however, Quick Response (QR) codes are becoming popular in many domains to provide more extensive information on an item via a web link to a database. Applications have been found in art galleries (e.g., to provide information on an artist or work of art), marketing (e.g., to provide information on supplier sustainable practices), and restaurants (e.g., to replace paper menus with electronic menus in a post-pandemic world). A QR code attached to a travel authorization letter could also be used to expedite the health screening process for arriving passengers at the airport or health facility/hospital by eliminating manual re-entry of data and allowing rapid retrieval of a passenger's record. QR codes could also potentially help to prevent possible identification fraud that could result from falsification of names on printed letters of authorization to travel.

(c) ***Other Tracking Systems for Data Retrieval and Security:*** Another technology worth considering is blockchain, a distributed digital ledger that provides a transparent and secure transaction between two entities. A transaction in this case could be defined as the exchange of information between a passenger and the Ministry of Health; passenger and airport; passenger and hospital; or passenger and laboratory. Blockchain is currently being used in various supply chains to monitor contract compliance, improve the flow of items, and trace and verify the authenticity of assets. The advantage of this technology is that transactions are permanent and immutable and are verified by multiple entities. Furthermore, any attempt to alter a traveler's data would trigger an alert to all entities in the network. Thus, for example, a COVIDcertified facility with access to a passenger's record would be unable to edit the passenger's information without alerts being generated to other parties in the network.

(d) ***Other Electronic Systems***: The development of custom applications (apps) that can be launched on mobile devices to provide information would be useful in providing a more integrated experience. As a last resort, email and fax can still be used to rapidly communicate laboratory results to hospital and quarantine facilities.

5.3.5 Management:

(d) ***Management by Exception***: Time is of the essence in a modern world. Management by exception is a philosophy that empowers employees to make autonomous decisions on matters pertaining to their work, with management intervening only when there is a significant deviation (evident in the data) from the ideal or desired outcome. This implies that in screening arriving air passengers, designated laboratory personnel could be given the responsibility and accountability to communicate negative COVID test results directly to the quarantine facilities, thereby allowing eligible travelers to save several hours of unnecessary quarantine confinement. The current process involves the physical transportation of laboratory test results back to the facility where the swabs were taken, prolonging the time for release of the traveler. Furthermore, a medical practitioner's intervention is required to contact the quarantine facility. It would be more efficient if this intervention was reserved for situations in which COVID test results are positive, in which case a new protocol for monitoring and treating the infectious traveler would be triggered. This approach would not only empower lower-level staff to be more invested in their duties but would also allow health professionals to focus their efforts and talents where their professional training could be more appropriately applied.

6. Conclusion

This paper applied a multidisciplinary approach within a lean six sigma framework to show how an existing COVID19 screening process for arriving air passengers to a small island state could be improved. Ideally, these dimensions should be addressed from the outset under the direction of a capable project manager and a competent and highly experienced team representing each of the five disciplinary areas. However, the goal of this paper was not to change, but to improve, a current system that handles low volumes of incoming passengers. An experiential observational approach was used to gather the data for the study. This method has its own limitations as extraneous factors, which the researcher might be unaware of, could impact the data collected. While the study represents an actual experience, the reliability of the data needs to be further improved by extending the study to cover a longer period and a larger sample of passengers. Future research could, however, focus on studying the implementation of the recommended strategies to determine the impact on performance. Another opportunity is to re-engineer and optimize the processes by making appropriate tradeoffs between efficiency and effectiveness. In such a case, consideration could be given to use of automation and the redesign of spatial layouts and workflows to facilitate a faster flow of passengers and data.

Biography

Jeanne-Marie Lawrence is an instructor in the Department of Technology Systems, College of Engineering and Technology at East Carolina University. She obtained her B.S. degree with honors from the University of Florida, M.B.A. from Hofstra University, and Master's in Supply Chain Management from the Pennsylvania State University. She is currently a doctoral student in the Department of Industrial and Systems Engineering at Mississippi State University.

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