International Journal of Service Science, Management, Engineering, and Technology
Volume 13 • Issue 1

Utilitarian Ethical Triage Bayesian Decisions With Monetary Value During COVID-19 - A Bayesian Probability Analysis

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ABSTRACT

Utilitarian ethical triage decisions with monetary value are complex and difficult to estimate, with possible benefits for a patient compared to other patients. A triage decision during an emergency combines expected economic value. It includes social and bioethical factors. A new Bayesian approach addresses risk probabilities and improves utilitarian triage decisions. Admission to the ICU (Intensive Care Unit) and the allocation of ventilators for patients depends on a risk-based comorbidity score. It considers the medical prognosis, social factors, personal and social costs. The rankings of the critical factors among patients with predefined ethical treatment success criteria depend on the likelihood of response to treatment and the patient's social circumstances. A sensitivity analysis with regression coefficients shows how the expected monetary value of patents is correlated to make a better judgment. Patient 3 in scenarios 1 and 2 is ranked consistently in priority. Low-ranked patients are placed on a waiting list as the demand for intensive care units increases dramatically with the number of patients infected with COVID-19 or its variants. The problem with utilitarianism ethics is that high net worth patients get an advantage, although disadvantaged patients with social liability are given due consideration. Furthermore, this research introduces a new hedonic Net Present Value based calculus of utilitarian ethics.

KEYWORDS:

COVID-19, Decision Making, Hedonic Calculus, Sensitivity Analysis, Social Ethics, Triage, Utilitarian Medical Ethics

1. INTRODUCTION: UTILITARIAN ETHICS AND COVID-19 TRIAGE

ICU triage is a screening process for quick patient admission and identifies patients needing intensive care for immediate treatment. It aims to utilize resources in emergencies effectively. The recent COVID-19 pandemic has engaged the classification and allocation of scarce health resources as the focus of discussions on bioethics. Multiple expert participants in the medical system develop triage protocols and guidelines, and there is a dispute over whether to use some specific inclusion or exclusion criteria. Who should have priority if they have a similar prognosis? Should we prioritize the vulnerable, young population and healthcare professionals in society? Or is a random selection a fair standard? It is not easy to get ventilator support or secure the ICU during the COVID-19 pandemic.

DOI: 10.4018/IJSSMET.298670 *Corresponding Author

The healthcare resources are limited, and the demand for facilities outnumbers the infected patients. The patients, families, healthcare professionals, and administrators struggle to resolve an emotionally challenging issue. The utilitarian ethical theory that determines good and evil by focusing on outcomes to rationalize decisions makes it easy for decision-makers to resolve complex problems. Utilitarianism believes that the most ethical choice will benefit the most significant number. It is a standard moral method of reasoning used to explain costs and benefits. However, it is difficult to predict whether the outcome of an action will be good or bad. It is a limitation of utilitarianism. Utilitarianism tries to explain values in the form of justice and individual rights. Utilitarianism is a rational approach to determining good and evil, but with some limitations.

The purpose of triage regulation is to reduce the burden on decision-makers. Screening identifies patients who need to allocate critical resources as needed. Solid and transparent evaluation criteria are essential for making decisions (Emanuel, et al., 2020a). It should reflect the dignity of the patient and a fair distribution of vital resources and maximize the benefit to society following the expected benefits of quality life. Allocation of scarce resources following ethical guidelines' provides moral justification for healthcare professionals. Decision-making and patient triage processes should be transparent, comprehensive, evidence-based, and support the process of appeals by new evidence or expert opinion (Tanzi, et al., 2020; De Panflis, et al., 2019). Other ethical principles include autonomy that emphasizes freedom, self-determination and making decisions about one's own life without interference from others. Hedonism advocates happiness or the absence of pain as an essential principle that determines ethical behavior. Hedonism is consequentialism, which takes many forms. For example, normative hedonism is considered happiness as a motivation to people.

On the other hand, happiness and pain derive decisions in hedonic ethics calculus. Egoistic hedonism requires people to consider only their joy in making decisions. In contrast, altruistic hedonism believes that creating happiness for all is the best way to measure whether the action is ethical. Regardless of the type of hedonism, the critic believes that it is a moral guide, ignoring all other values such as freedom or justice when evaluating good and evil.

The patient's willingness or consent of a representative accommodates the triage review. If the treatment does not have the advantage of cure, almost all the guidelines justify the end of the treatment (Gómezvíteeda, de Maeeneer, and Gastmans, 2019; Curtis and Vincent, 2010; Jump et al., 2008). Patients who are healthcare professionals get priority as front-line support workers. Most guidelines require transparent and verifiable grading decisions (Bovenberg et al., 2021; Chen and Lin, 2004). Complex cases may require alternative evaluations. Triage decision using computer algorithms is convenient and suitable for clinical data, patient information, and ethical considerations. The software can help to make clinical decisions. It Supports patient characteristics clinical knowledge, and patient data is readily available during decision making (White and Lo, 2020). Treating critically ill patients during the pandemic is complex because of the lack of ICU ventilators and medical staff. Management of critical care resources and examination of high-risk patients require due assessment. European countries have issued COVID-19 screening guidelines over several years. Countries like Austria, Germany, the United Kingdom, Belgium, etc. Italy, Switzerland, in crises and life-threatening conditions, COVID and non-COVID patients can receive treatment on predefined criteria (Emanuel, et al., 2020a; Committee on Bioethics 2020; UNESCO, 2020; Singer and Mapa) 1998; Matheny Antommaria, et al., 2020; Daugherty Biddison, et al., 2019; Solomon, et al., 2020). Infectious diseases like COVID 19 can put severe stress on all health systems. Ventilation support, intensive care unit admission, and special treatment requirements are more frequent in patients with COVID19 infection. Resource shortages add complexity and put stress on healthcare professionals. Insufficient resources to support COVID-19 infected patients, families, and society as a whole are nervous with anxiety. Lack of intensive care unit resources complicates the ethical issues that arise. There are several ethical procedures for allocating scarce resources. Some principles are inconsistent and later explored. For example, utilitarianism maximizes economic interests, and egalitarianism emphasizes equality, need, and opportunity. Demonstration-based ethical principles and termination of medical support employ various bioethical principles to control medical resources. Additionally, A new hedonic calculus shows how to implement utilitarian ethics for COVID-19 patients queuing for critical resources.

1.1 Research Issues

There are few articles on utilitarian triage that evaluate patients on both clinical and non-clinical ethical factors. We propose an expected monetary value approach by utilitarian screening that combines medical prognostic social value, bayesian probabilistic estimation of outcomes, net present worth according to life expectancy, hospitalization cost, dependent responsibility, psychological, and support to a patient. The utilitarian decision tree (Figure 3A, Figure 3C, Figure 3B, and Figure 3D) analysis with conditional probability estimate (Table 4C) will provide better judgments.

1.2 Paper Organization

In section 1, briefly, the triage procedure and ethical guidelines are discussed. Then, the research issues are listed and outline the research questions. The section includes the literature review. The practice of medical ethics during a pandemic appears in section 3. The aim of the research and research problems are further elaborated in section 4. A unique data collection method and cases studies are listed in section 5. The research methodology is outlined in section 6. Data analysis and algorithm are discussed in section 7. In section 8, the research concluded with remarks. Finally, a list of references is presented in section 9.

2. LITERATURE REVIEW AND RESEARCH BACKGROUND

The global pandemic COVID19 has changed all countries, dealing with emergency medical systems in a transparent style. Patients with severe disease require special attention. Bed allocation in the ICU (intensive care unit) concerns health care facilitators based on equality of health care and ethical guidelines (Sprung et al., 2008; Emanuel et al., 2020). Countries severely affected are China, the United States, Italy, and Spain (Rosenbaum, 2020; Truog et al., 2020; Cesari and Proietti 2020). Currently, after the second wave of COVID-19, it is India. These countries had to form rules for allocating scarce resources. ICU bed allocation, professional service, and life-supporting resource allocation have clinical and ethical consequences. The resource allocation policy should be fair, and the general public should have access to this opportunity. There are several ethical approaches to allocating resources. Some principles are inconsistent. Utilitarianism insisted on maximizing profits. Equalitarianism emphasizes equality, needs, and opportunity (Singer and Mapa 1998). McDougall, 2014; discusses ethical principles on the allocation of medical resources. Resource allocation guidelines determine who and how patients prioritize other patients for intensive care based on triage criteria. Patients with a good prognosis are preferred (Ehni, 2021). This principle is based on quantitative triage criteria and clinical judgment. Ethical considerations are the most promising prognosis concerning expected health outcomes regarding the quality of life and possible survival scenarios after intensive care (Aziz et al., 2020). Kaner et al. (2013) discussed scenario-based analysis in a different application.

Severe comorbid disease, chronic disease, borderline age limit, expected quality life expectancy, and complex illness denies ICU admission based on composite score (Aziz et al., 2020; Jeffrey 2020; White and Lo, 2020; Auriemma et al., 2020). The clinical triage judgment can be a questionable criterion. Some ethical guidelines are general patient-related clinical decisions (Escher et al., 2019; Angelos 2020).

Ethical guidelines should not consider gender, race, religion, disability, sexual orientation, or political vision. Fairness must come first to respect social dignity and human rights (Curtis and Vincent 2020; Mannelli 2020; Cesari and Proietti 2020). When necessary, a utilitarian approach to maximizing profits during a pandemic is fair (Jöbges 2020).

End-of-life care emphasizes options for suppression and cancellation of ICU treatment and is related to severe chronic diagnosis, need ICU facilities, patient age, and religious beliefs (GómezVírseda et al., 2019; Curtis and Vincent, 2010; Mannelli; 2020). Resource allocation based on social values such as dependents, social usefulness of patients, and economic benefits generated by patients is usually ignored and based on arbitrary decisions and discrimination. Measuring a person's worthwhile actions or a person's social worth is difficult and often neglected. Although screening findings aim to promote objective criteria, the social value of patients does not fall under these criteria (Robert et al., 2020). For first-come-first-served patients or for patients accessing a facility for the first time, first-come-first-served screening is critical. Under this rule, the priority for patients with no or adverse prognosis is questionable. This policy could impose penalties on marginalized groups with low socio-economic income. People suffer the disadvantage of not having access to information and access to medical systems (Auriemma et al., 2020; Lai et al., 2020; Raith et al., 2017).

The allocation of resources on the randomization process accidentally benefits the patient. In this case, ethnicity, sexual, racial, and socio-economic status remain absent, and all life is weighted equally. It eliminates biases, discrimination, and everyone has a similarly likely chance to access facilities. His rule can compete with the utility principle. Random assignments may not provide a reasonable resource allocation when saving more. It is difficult to withdraw and maintain vital support treatment. In general, the decision is led by the patient's prognosis. The ethical principles of utilitarian theory may be valid, but the considerations of moral ethics, religious ethics, and human dignity differ from decision-making processes. Different decision-making criteria create different results in triage decisions. The prioritization that distinguishes the suitability of a person's treatment is based on the patient's benefit from the treatment. A subgroup of sick patients may have low priority and therefore decide to discriminate, seek treatment in the intensive care unit, or be denied mechanical ventilation. The patient is disenfranchised for life-saving treatment due to pre-existing health problems. A policy that excludes the elderly, the disabled, the many health problems would be unfair. That is clear discrimination. A patient's ability to recover quickly compared to those with less rapid recovery is a discriminator (Auriemma et al., 2020; Herreros et al., 2020).

In a pandemic, it is expected that triage ethical issues will arise due to resource allocations of ICU. Medical professionals will face moral dilemmas and legal issues. Triage decision is difficult due to limited time, critical resources, support infrastructure, and human capital supporting essential medical services. A proper triage is likely to reduce stress among the decision-makers so that it is defensible, the evaluation is open, accountable, transparent, and involves essential stakeholders (Liberatore and Nydick, 2008). The fairness of resource allocation should be based on equality. We are facing a moral dilemma due to a pandemic disproportionate to the health care facility. Potential impacts include people with income disparity among people of unprivileged background, individuals in nursing homes, homeless people, and people with insufficient government documentation. A universal ethical policy aims at a fair distribution of the resources needed to respond to the pandemic. Frontline medical work is exposed to stress, anxiety, and concerns about their well-being. Review decisions during extreme situations or in crises during a pandemic is very delicate. It raises questions about legal issues, responsibilities, professional practices, and job security. Ethical triage that considers the exclusive dignity of each person suffering from an infection, social dependency, segregation, social distance, and hygiene protocol compliance reflect community harmony and solidarity (Sulmasy, 2021) is a highly complex problem.

2.1 COVID-19 Treatment Cost Issues

Some economists and health professionals argue that they do not need to balance saving lives and to save the economy. Prioritizing the fight against the coronavirus is described as beneficial to the economy (Varona and Gonzales, 2021). The monetary value of the trade-off between health-related risks and rewards to prevent statistical mortality is generally expressed in terms of statistical life value (SLV). It is different from real-life value. It is not the price someone pays to avoid a certain death but the value that changes the likelihood of death. In economics, there is no standard concept that can be used to value a particular human life. The SLV estimate considers the risk an individual is willing to take and the amount they are willing to pay voluntarily for a minor drop in death rate, but not the "cost-of-life." One way to calculate SLV is to calculate the net present discounted value of lifetime earnings.

Different cost and risk assessment approaches are discussed in Galli and Wood, 2021; Galli, 2018; Galli, 2021. Whether to use some discount factor is debatable. Lifetime income growth and inflation must be taken into account. Economically, there is no fundamental insight into the value of individual human life (Minelli et al., 2004; Bazarbashi et al., 2020; Linertová, 2021; Akbar et al., 2020). When considering the balance of risk and reward, the economy often examines the SLV. It differs significantly from the actual value. This is not the price someone pays to avoid certain death, but rather the value one places on the change in the probability of death (Alharbi et al., 2021). The SLV emphasizes that it is an estimate of the willingness to pay for a slight decrease in the risk of death, not the value of human life. One method that can be used to calculate SLV is to add the total present value of lifetime income. There are some issues with using this method. One potential cause of variability is that other discount rates may be used in this calculation to result in different SLV estimates. Another potential problem with using wages as a value for life is that the measures do not consider the value of time not spent on work. The World Health Organization (WHO) divides annual GDP into per capita income and estimates the value. A healthy yearly payment of care costs less than three times that number. They believe that treatment costs less than the annual gross domestic product per capita are more economical.

For example, in a country with a GDP per capita of $ 65,000, treatment costing less than $ 195,000 per year is considered cost-effective. An analysis by the Australian Pharmaceutical Benefits Advisory Committee found that drugs may be approved if the cost of quality adjustments per year of life is less than 1.35 times GDP per capita. Poland had a break-even point of three times GDP per capita in 2012, and Thailand has a per capita GDP factor of 0.8.

Many countries and organizations that use cost efficiency in healthcare recognize and resolve these issues. In general, the "National Institute for Health and Care Excellence" will provide treatment if the cost per additional lifespan (adjusted for quality of life) is between £ 20,000 and less than £ 30,000. Therefore it is more likely to recommend a warranty. However, authorities also consider other factors, particularly the disease, the target population, the level of evidence of effectiveness, and the availability of alternative therapies.

Although there is no "willingness to pay" data for QALY (quality-adjusted life-year) in KSA, yet, an attempt has been made recently by Bazarbashi et al., 2020. They reported a willingness to pay value for QALY is about $25,000 for 1 year period. Alharbi et al. (2021) report that the COVID-19 recovery rate is in the range of 97.8% (Tabuk Province) - 96.7 (Northern Border Province). The mortality rate range is 2.6% (Makkah Province) - 2.4% (Al Jawf province). Furthermore, they reported the mortality rate in Saudi Arabia to be around 1% to 2%. Alharbi et al. (2021) refer to a study to estimate the statistical life value assuming a Covid 19 mortality rate of 1.5%. taking a mean value, suppose that there is 15 in 1,000 chance of dying from an infection then the VSL at risk of death is 1000x $ 25,000 / 15 = $ 1,666,667. The amount of $ 1,666,667 is a statistical life. To scale the secondary data later in our study, we use the GPD value. As per the world bank report, the per capita GDP of Saudi Arabia in 2020 is $20,110 and for the United States is $63,543 for the same period. This is a approximately 1: 3.2 ratio.

3. RESEARCH ISSUES IN TRIAGE AND ETHICAL RISK FACTORS

Risks factors associated with a patient determine triage screening. The factors are social, medical, and psychological. The risk level determines the patient's ability to survive or respond to treatment. These consolidated risk factors will affect the overall condition of a patient. The risk can emerge from internal and external sources.

3.1 Internal Considerations

In this case, the process of decision-making focuses on how the healthcare system in total interacts together to provide the best patient care under the constrained available resources. The following factors are considered.

a) Nondiscriminatory: The triage process for implementing pandemic response measures must ensure proper medical care and justice for humans and assume appropriate responsibilities. Justify motives for the proposed decision.
b) Unambiguous: Policies, treatment, and recommendations for ICU admission should be open to all interested parties.
c) Completeness: Decisions should eliminate conflicts of interest involving the appropriate stakeholders.
d) Reliability: The decision is consistent and robust. The ethical guidelines, evaluations should be supported with evidence.
e) Integrity: Front-line healthcare workers should be supported with an opportunity to maximize integrity, minimize moral distress and provide emotional support.
f) Support: Teamwork between all stakeholders is vital to develop a fair decision support system.
g) Agility: the healthcare systems should be systematic in infrastructure layout appropriate to respond to an emergency. The line of authority and subordination should be defined without any duplication. The healthcare system should function effectively and remain available in the future as a sustainable process.
h) Flexibility. The decision-making framework should adjust to the recent changes in case of unique knowledge circumstances and unexpected events.
i) Rationality: Evaluations should be Rational and not arbitrary; there should be no subjective or administrative bias; it should be evidence-based, feasible, and the decision is subject to review.

3.2 External Considerations

The critical ethical principles and values related to this category include:

a) Equity: Society expects an equitable distribution of resources with justice. Regardless of their ethnicity, socio-economic condition, structural health inequality, race, a barrier to access health care due to policy, geographic location, age, disability, financial condition, adverse health conditions, some do not have access to healthcare. When resources are limited equity principle will have conflict in decision making. In such a case, a decision should weigh equitability, benefits, and harms to society.
b) Dignity: Culture, norms, values of diverse populations should be considered as much as possible. Respect for individual privacy and confidentiality of personal information should prevail. Decisions based on beliefs, values, spirituality, culture, and literacy should consider a holistic societal view.
c) Vulnerability: Care should be taken for economically, educationally, and geographically marginalized, and those who face severe burdens to access healthcare facilities should be supported to minimize harm to society due to transmission of infection.
d) Harm to society. The general public should be protected from harm, injury, infection due to risk emanating from COVID-19, any other similar disease, and severe illness or death.
e) The benefit to society: The policymakers should aim to minimize harm to the community while maximizing the benefits to the society with a decision, such as utilitarian principle, that fosters the overall health condition of the population. There will be a situation where striking a balance on this principle will be disturbing, but principles of social, ethical, moral, justice should be evaluated carefully in such circumstances.

3.3 Ethical Significance

The equal chance chances of survival of the patient, as a criterion, during an emergency or pandemic, is considered impartial. It does not include exclusion factors, non-clinical factors, namely, religion, race, ethnicity, sexual orientation, social status, wealth, education, and quality of life. An ethical standard should guide a plan that recommends the allocation of critical resources reasonably. In case of an emergency and triage, the chance of survival should be defined rationally. Triage decisions should not focus just on long-term survival.

3.4 Utilitarianism

Utilitarian ethics holds that, in any case, a morally correct decision is a decision that produces the most significant benefit for all parties involved. Utilitarianism has some limitations when used as the sole method of ethical decision-making. Utilitarian estimation needs to evaluate the benefits and setbacks generated by the decision-making model and evaluate the benefits and harms of other alternative decision-making effects. When the decision model assigns a monetary value to life, and human dignity, calculating and comparing the value of various benefits and costs is difficult, sometimes challenging, and controversial. If moral decisions are guided by justice, the utilitarian principle itself cannot recommend, but it will influence the decision. The focus of utilitarianism requires fair consideration of the direct, indirect, direct, and long-term consequences of decisions that affect individuals, society, and families. The utilitarian principle requires to:

a) identify a variety of activities that one may take in a given situation;
b) analyze all potential benefits and problems of the given case;
c) suggest the course of action that presents the best payoffs after all scenarios of negative consequences are considered.

The factors that are likely to impact the patient's risk appear in Table 1. It includes clinical factors, human dignity, and social ethics. These factors are assigned risk scores. The cases of each patient are evaluated with the six predefined criteria. The six clinical and non-clinical factors are ranked with the four patients based on risk measurement.

3.5 Table 1 summarizes the clinical and non-clinical factors for triage and patient screening based on the discussions in sections 2 and 3. There are six factors identified as PF1, PF2,...., and PF6. In addition, sub-factors can exist for each factor. This table, along with explanations and pertinent information, is provided to experts to assess a patient's condition. Table 2 lists the requirements of the patients' cases.

4. RESEARCH PROBLEMS AND RESEARCH ISSUES

Literature is rare that describes utilitarian triage both with qualitative and quantitative methodologies. Furthermore, practical classification approaches that combine clinical and non-clinical issues to explain probabilistic and social costs are rare in published articles. This study describes an expected monetary value theory. It presents a classification algorithm that includes social cost and stochastic estimate of hospitalization cost, a patient's net worth, human capital development cost, the financial burden to a family, risk factors associated with a patient, and patients survivability if ICU support is extended. A cost-benefit analysis is the core philosophy of the utilitarian triage decision. Furthermore, multiple stakeholders are involved in decision-making. Therefore, it is possible to reduce the stress of health care personnel with an unbiased triage policy.

Table 1. Comorbidity: descriptions and operationalization of critical criteria to determine patient priority

Factor	Sub-Factor	Item	Scale
PF1		"Disease severity (Prognosis / Comorbidity) Score based on overall conditions of a patient" (PF1.1 to PF1.17)	1=Less Severe; 9=Severe disease
	PF1.1	"Cancer"	1=Early Stage; 9=Advance Stage
	PF1.2	"Chronic kidney disease"	
	PF1.3	"Chronic lung diseases, including COPD (chronic obstructive pulmonary disease), asthma (moderate-to-severe), interstitial lung disease, cystic fibrosis, and pulmonary hypertension"	1=Low; 9=High
	PF1.4	"Neurological conditions: Dementia"	1=Low; 9=High
	PF1.5	"Diabetes"	1=Low; 9=High
	PF1.6	"Down syndrome"	1=Low; 9=High
	PF1.7	"Heart conditions (such as heart failure, coronary artery disease, cardiomyopathies, or hypertension)"	1=Low; 9=High
	PF1.8	"HIV infection"	1=Low; 9=High
	PF1.9	"Immunocompromised state (weakened immune system)"	1=Low; 9=High
	PF1.10	"Liver disease"	1=Low; 9=High
	PF1.11	"Overweight and obesity"	1=Low; 9=High
	PF1.12	"Pregnancy"	1=Low; 9=High
	PF1.13	"Sickle cell disease or thalassemia"	1=Low; 9=High
	PF1.14	"Smoking"	1=Low; 9=High
	PF1.15	"Solid-organ or blood stem cell transplant"	1=Low (Simple); 9=High (complex)
	PF1.16	"Stroke or cerebrovascular disease"	1=Low; 9=High
	PF1.17	"Substance use disorders: (alcohol, opioid, or cocaine use disorder)"	1=Low; 9=High
PF2		"Response to treatment"	
	PF2.1	"Sign of improvement (Probability of improvement due to treatment)"	1=Good sign; 9=Poor sign
	PF2.2	"Difficulty in doing activities independently" (High -Low)	1=Easy of doing the task; 9=need assistance
PF3		"Age: (Diagonosis Purpose)"	1=Young; 9=Advanced age
PF4		"Dependent Responsibility (caring for someone else)"	
	PF4.1	"Maternal and infant care"	Yes/No (Score No=1, Yes=9)
	PF4.2	"Dependent family members (They need support). "	Yes/No (Score No=1, Yes=9)
PF5		"Surgery: if and when necessary."	1=High Success; 9=Low Success
	PF5.1	"No Willing to do surgery (Patient)"	Yes/no (score No=1, Yes=9)
	PF5.2	"Chance of successful surgery"	1=high chance; 9=poor chance
PF6		"Rehabilitation support (Available): Resilience, Recovery."	

This study shows multifaceted triage decisions with a utilitarian approach to rational decisions considering all possible patient conditions. A decision tree with expected monetary value (EMV) and triage risk factor sorting can generate decisions to minimize or maximize risk objectives. A Delphi approach (Azam et al., 2017; Ahmed, 2021) can first determine uncertainty with triage decision factors. To qualify the triage factors, we use the if-then risk assessment classification. The patient conditions listed in Table 2 and Table 1 is ethical factors in evaluating patient risk scores.

The research methodology combines different variables that are important in advancement in triage decisions. There is anxiety between medical professionals and infected patients in triage decisions. The research suggests a probabilistic utilitarian triage model that computes a social expected value. One way to estimate an earned value is to look at the problem as a project (Golpîra, 2015). Without prejudice, the suggested triage will include the correct stakeholders to reduce the burden of anxiety for both healthcare professionals and patients. Therefore, the primary research questions are to:

a) Identify social cost that COVID-19 infected patients will burden on the healthcare facility;
b) Assign degree of risk severity among the COVID-19 infected patients with comorbidities;
c) Combine multiple medical and non-medical triage factors to prioritize patients;
d) Evaluate the expected social value of utilitarian triage to rank and classify patients;
e) Illustrate the quantitative utilitarian triage decision model with case studies.

5. RESEARCH METHODOLOGIES

Rapid ethical decision-making helps to assess alternative policies in triage evaluation. It allows policymakers to gain insights into a variety of alternatives. The proposed decision analysis is evident, formal, flexible, and attractive, considering ethical consequences. The expected monetary value generates metrics for decisions. The model forms a tree-type structure. There is a difference between the best model and the intuitive decision people make about a legal problem in many cases. Inconsistency is a standard limitation in human reasoning. Any analytical technique that contradicts human behavior is the wrong basis for making decisions. However, narrative variation is a strong argument in support of the standard method because the implicit choice of the expert may not be reliable often.

A triage decision tree facilitates sequential decision analysis and shows the available options. Uncertain events affect each choice. Decision tree problems at risk depend on probability. Several possible conditions for the nature of the outcome are likely to arise, each with an estimated probability. For example, a condition in which the natural states are mutually exclusive, collectively complete, and the total probability should add up to a numeric value of one.

The decision tree is composed of three forms of nodes. Usually, decision nodes are square symbols, chance nodes contain circular symbols, and end nodes have triangular signs. A terminal node is the result of a decision. Lines that originate from a node in a rectangle mark the various options present in the node. Given a decision table that contains conditional values and probability estimations of all the states of occurrence, the expected value EV (x) of each alternative is determined by adding the probabilities, $p(x_i)$, and the state of event (x_i) for an outcome "*i*" (where; x_i = *patient state "i", i=1,2,…n*).

$$EV(x) = \Sigma_{i=1}^{n} p(x_i) x_i$$

The following steps briefly illustrate the research methodologies. The composite steps are qualitative and quantitative to formalize the COVID-19 patient triage process. The triage objective is utilitarianism. Here the social and medical treatment cost of a patient when infected with COVID-19 are evaluated.

Step-A) The medical and social ethics criteria are first determined with a risk analysis framework. Then, a factor will qualify when tested with an If-Then-And-Impacting-Objective (Table 3D). The ethical factors with a specific patient give rise to patient prognosis score for triage decision.

Step-B) Experts will rank the classified factors with a Delphi technique taking one patient at a time. The listed factors will be evaluated pairwise as risk profiles for all combinations to determine the rank of each factor using a hierarchical scheme (Saaty, 1986). The pairwise comparisons of factors are estimated to assign risk scores. The scale, as illustrated in Table 3A and Table 3D, is required for data gathering. A decision matrix, as shown in Table 4A, is formed. Figure 3B is an exhibit of software (Goepel, 2018) that normalizes the factor risk scores as a dimensionless scalar quantity for unbiased decisions. The risk factors are compared pairwise by experts in the field. The factors are evaluated with a defined objective, and the data is recorded in assessment form (Table 3B).

Step-C) The comparisons of risk factors in a questionnaire are generated by software (Goepel, 2018). The question records judgment scores with a scale ranging from one to nine. The factors are subdivided into subfactors for further analysis and guide for data entry assistance. The assumption is that if an ethical risk factor "A" is "absolutely more important" against the factor "B" and suppose that a score of 9 is assigned, then the risk factor "B" should be "absolutely less important" compared to factor "A" and the rating 1/9 is assigned. All risk factors are compared pair by pair. The input values form a particular matrix pattern (Table 3C). The social and medical ethical factors are raked for priority and probability of recovery from comorbidity. Assessing the chance of survival from a given condition is necessary for ranking patients' comorbidity scores. The example of scores is shown in Figures 1A and 1B. Figure 1A displays the risk factor of a patient. Likewise, Figure 1B shows the combined risk scores for patients 1, 2, 3, and 4, respectively.

Step-D) All the risk factor scores for each patient are consolidated to rank the patient's prognosis. The reciprocal of the normalized prognosis score is evaluated to determine the probability of treatment or medical intervention success.

Step-E) The above steps are done with software where the expert opinion is recorded. Measurement indexes are computed in each stage to judge the reliability of the evaluation and data collection process.

Step-F) Due to the absence of direct information on Covid 19 treatment cost, secondary sources data is processed to support the decision model. A computation scheme processes the data with high variation with a PERT probability distribution. The comorbidity treatment cost is identified, including hospitalization cost with COVID-19 patients requiring ventilator support.

Step-G) The net worth is computed as the "Total human capital cost" with secondary data sources. This cost is a liability of the society or family to train a person with a specific trade or profession.

Step-H) The net future worth is determined with a yearly discount factor of 5% over the patient's productive lifecycle time in years against the expected life expectancy.

Step-I) A utilitarian triage decision model is proposed to evaluate the economic gain with minimization or maximization criteria. Initially, a triage result is derived with a probabilistic decision tree analysis. Once the ethical factors are assigned economic value, a decision tree is formed. The decision tree comprises risk factor scores in the likelihood of chance and the expected monetary value as loss or gain, and a patient's net worth in economic value. It isn't easy to find data for the decision tree. We are using regression-based sensitivity analysis (Figure 3E, Figure 3F, and Figure 3G) to illustrate an innovative methodology to develop the triage decision. Depending on the objective, the decision will decide on the option that offers the highest or lowest EMV. The decision is exclusively based on direct and indirect monetary value decisions. The immediate economic value is those decisions where a financial figure is available. The indirect monetary values, such as social conditions, are those where no explicit values are known. In such a case, the values are inferred indirectly from correlated information. For example, "dependent responsibility" is a social factor. If the patient is deceased, the loss to the family and society is computed as the net future value of financial projection for statistically expected survival time. The EMV risk aversion decision will rely on a significant risk score on social factors.

6. CASE STUDY

A hospital in a middle eastern country specializes in trauma treatment and has large emergency rooms. The ICU supports the hospital for emergency care. In a COVID-19 outbreak, the hospital will be remodeled to provide care for COVID-19 patients. All patients of any age are competing for the ICU. Patients over the age of 65 with certain illnesses are expected to be at risk of becoming infected with COVID 19. Patients may require hospitalization and special attention by the intensive care team for severe complications. They may face life-threatening conditions, including death (Samanlioglu and Kaya, 2020). The ICU is operating at full capacity. However, the occupancy rate is the lowest.

Situation 1: The ICU facility is full (No Occupancy)
Situation 2: Just now, an ICU patient passes away. There is now a bed available.
Situation 3: Few patients in ICU have complex comorbidity and poor prognosis.

Question: Patients are admitted with COVID-19 infection to the hospital. Who will get the emergency support?

Justification: Apply utilitarian Bio-Ethics and Social Ethical factors, wherein the greatest good for the most significant number is measured. Where it is possible, apply agnosticism ethics, a principle that advocates the existence of God and shows compassion as a moral duty. Finally, rank the COVID-19 patients with a monetary expected value approach.

6.1 Factor Score

Experts decide the importance and weight of the criteria with a software data input. Computer models help to organize data in tabular and matrix form using software (Goepel, 2018). The Delphi data collection method includes brainstorming sessions with two experts. The risk factor scale is shown in Table 3A. Each factor in Table 1 will be evaluated pair by pair. The example of factor comparison pair by pair is illustrated in Table 3B. A reciprocal scale is applied between the compared factors. For instance, if the factor “A” is 3 times furthermore important than the factor “B”, in that case, the score between the factor “B” and “A” is assigned a value of 1/3. The total combination of comparisons is 15, with 6 factors taken two at a time, i.e., ${}^{6}C_{2}$=15. The data in the form of a matrix is populated with estimates of the risk factor for each pair of factors. A [*6x6*] matrix will be formed after comparison. A section of the matrix appears in Table 4A.

Table 3B is a factor comparison scale. To implement the factor comparison scale, first, we take a patient, say Patient1. The listed risk factors are shown in Table 1. For Patient 1, we compare factors (1) “Prognosis and comorbidity” with “Response to Treat; (2) “Prognosis and comorbidity” with “Age”; (3) “Prognosis and comorbidity” with “Dependent Responsibility”; (4) “Prognosis and comorbidity” with “Surgery”; (5) “Prognosis and comorbidity” with “Rehabilitation Support.” Total comparisons are six combinations of 2 or ${}^{6}C_{2}$ = 15. Figure 2A is an example of a risk factor score for Patient 1, while Figure 2B is the result for all four patients.

Figure 1B is the ethical factor risk scores plotted against the four patients. For example, the “Dependent Responsibility” displayed as “Depend. Resp.” has a risk score of 0.39, 0.07, 0.25, and 0.05, respectively, for patients 1, 2, 3, and 4. Figure 1A is the risk score display for patient one on all six ethical factors, both social and medical.

Table 2. Case data

Patient	Age.	Sex	Comorbidities	Other Conditions
#(ICU)	Years		Description	
ICU#1	77	Female	A female patient with health problems related to hyperlipidemia and hypertension is admitted to the trauma section from a primary care unit. She is 77-year-old. Very few people in the main care unit are COVID19 positive. She had no direct contact with them. Later, she had a temperature of 102°F and was referred to the ED. she was found to have a chest infection and sporadic fever. She had weakness, cough, tiredness, and palpitation. She tested positive, later, with COVID-19. During admission, she had a 101°F temperature. The recorded blood pressure is 149/77 mm Hg. The heart bit rate per minute is recorded at 100 hours. The breathing rate is 20 / min. In indoor air, saturation at the oxygen level is 95%. The X-ray chest showed the prevalence of lung infection. Patients have been documented for possible pneumonia and interviewed by a COVID19 infection. Two days later, the condition of the patient has deteriorated. It is now found to have hypoxia on 85% oxygen saturation. It has a heat to reach 104 ° F. It is intubated. Now she was transferred to the ICU. The patient's condition remained critical in ICU.	He has a large extended family. She is caring for the family members as and when required. She assists the family in household works. She is a role model and integrates the family socially.
Similar other ICU admissions are listed briefly for the case study				
ICU#2	62	Male	Osteoporosis, hypertension, hypercholesterolemia, diabetics, dementia	He is a Banker and Financial investment specialist. He is single.
ICU#3	80	Female	Osteoporosis, hypertension, hypercholesterolemia, fracture, chronic obstructive pulmonary disease	She is a couple and living in a home and has a spouse. They are mutually supporting each other.
ICU#4	89	Female	Osteoporosis, hypertension, hypercholesterolemia, fracture	She lives in an old-age care facility. She is alone and has distant relatives.
New Cases				
Case 1	35	Male	The emergency department calls the ICU to admit a patient in the emergency room with a severe reversible brain injury after an automobile accident. He is young and is a driver. He got infected with COVID 19 from the passenger.	He has a wife and two young children at home. He is the only bread earner.
Case 2	70	Male	A highly specialist medical practicing doctor, a cardiologist, got infected with COVID 19. His health condition is deteriorating day by day. He needs immediate ventilator support. He has diabetes but is in a controlled state.	He has two grown-up children and a wife. They are independent. His service in a hospital is necessary. He has a happy family

continued on next page

Table 2. Continued

Patient	Age.	Sex	Comorbidities	Other Conditions
Case 3	46	Female	A female teacher is COVID-19 Positive. She has diabetes and has other medical conditions: She is overweight and suffers from hypertension.	She has 3 children and looks after the family, including her older parents. She is a single mother. She is financially well.
Case 4	83	Male	He is an entrepreneur and also a social worker affiliated with NGO, providing support to the community. He is suffering from osteoporosis, hypertension, hypercholesterolemia, lumber plexopathy, atrial fibrillation. Due to his social work activities, he is now a COVID-19 patient. His net worth is $10 million (USD).	He lives with extended family and runs a successful business employing several people. His business skills and advisees are necessary to run the business operations.

Table 3. (a) Risk factor evaluation scale

Rank	Description	Clarification (Comapre Ethical Factors: *x* and *y*)
1	"Equal importance"	Factor ***x*** and ***y*** contribute equally to the objective
3	"Moderate importance of one over another"	Slightly favor factor ***y*** (***x*** is less critical)
5	"Essentially importance"	Strongly favor factor ***y*** (***x*** is less critical)
7	"Exhibit importance"	Factor ***x*** is favored very strongly over ***y***
9	"Absolutely"-"import"	Favoring factor over ***y*** (***x*** is less critical) is of the uppermost thinkable order of rank
2, 4, 6, 8	"Intermediate values between the two adjacent judgments"	Apply when finding the middle ground. For instance, four go in for the central value somewhere between 3 and 5

Table 3. (b) Guideline: expert opinion and recommendation in a pairwise evaluation of assessment

Pairwise Factor Comparison Scale																			
	In case "Factor A" is to a greater extent important than "Factor B," please suggest and record a score (One value from 1 to 9)																		
	Measure 1 = Alike 3 = Reasonable 5 = Strong 7 = Especially Strong 9 = Maximum																		
			Most Significant							**Alike**					**Most Significant**				
Factor	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	
		A															**B**		
	Measure 1 = Alike 3 = Reasonable 5 = Strong 7 = Especially Strong 9 = Maximum																		
			Most Significant							**Alike**					**Most Significant**				
Factor	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9	
		A	**In case "Factor B" is to a greater extent important than "Factor A," please suggest and record a score (One value from 1 to 9)**														**B**		

Figure 1(a) Decision matrix A with reference to patient case 1 risk factor weight

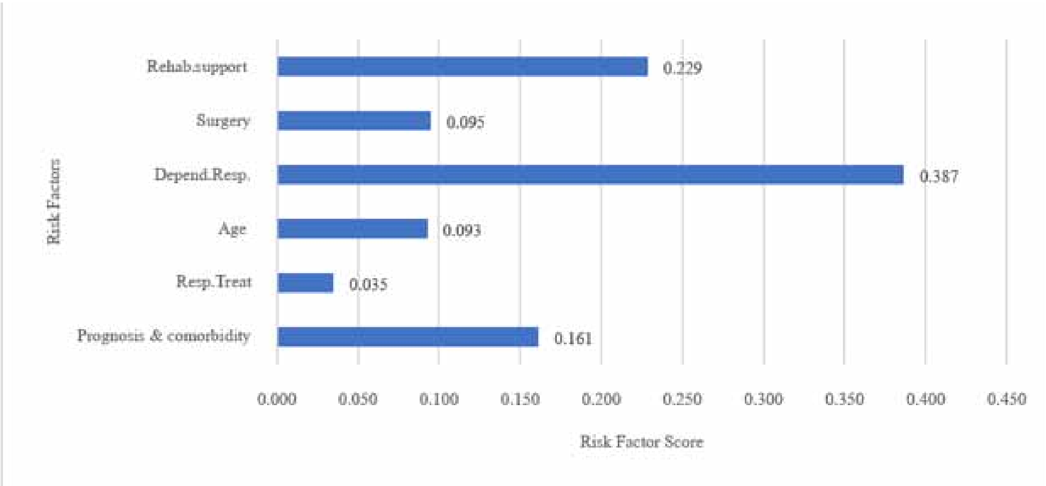


Figure 1(b) Patient and prognosis probability (risk)

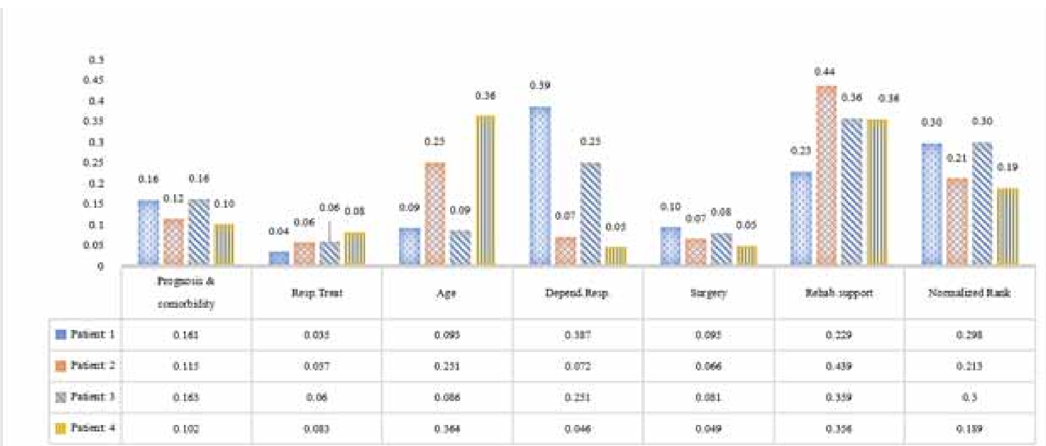


Table 3. (c) Decision matrix A

									Expert: 1 and 2							
1	Criterion	Prognosis & comorbidity	Prognosis & comorbidity	Response to Treatment	Response to Treatment	Age	Age	Dependent Responsibility	Dependent Responsibility	Surgery	Surgery	Rehabilitation support	Rehabilitation support	Normalized Score: Expert:1	Normalized Score: Expert:2	Normalized Score: Expert:1&2
2	Expert (1 & 2)	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1&2
3	Prognosis & comorbidity	1	1	0.2	0.11	4	3	1	0.5	2	0.33	1	0.2	0.136	0.056	0.0892
4	Response to Treatment	5	9	1	1	9	5	3	5	5	5	1	5	0.358	0.500	0.4413
5	Age	0.25	0.33	0.11	0.2	1	1	0.33	0.5	0.14	0.5	0.2	0.2	0.033	0.046	0.0399
6	Depend. Responsibility	1	2	0.33	0.2	3	2	1	1	2	1	0.2	0.5	0.106	0.102	0.1067
7	Surgery	0.5	3	0.2	0.2	7	2	0.5	1	1	1	0.25	1	0.086	0.122	0.1028
8	Rehabilitation support	1	5	1	0.2	5	5	5	2	4	1	1	1	0.281	0.174	0.22
9	SUM													1	1	1
10	CR:	0.079	0.063													
11	GCI: (Group)	0.1055														
12	CR: (Group)	0.028														
13	Lambda: (Eigen Value)	6.1782														
14	Shannon Entropy	**α =**	**4.464**		**β =**	**1.021**		**γ =**	**4.559**							
	Mean Relative Error	**26.8%**														
	Consensus (Group):	**95.2%**														

Table 3C is the consolidated results of expert evaluations on ethical factors. The purpose here is to prioritize all six ethical factors by two experts. The validity of the expert opinion is confirmed by the consistency ratio (CR) 0.79 and 0.063, which are below the recommended value of 0.1. The combined CR value for the group is 0.028, computed from Shannon entropy (Azadfallah, 2018, Jost, 2006). This value is well below the threshold value of 0.1, hence confirming the validity of data collection. The group consensus is 95.2%, which is above 80% value. Thus, the computed scores are robust in measurement.

7. DATA ANALYSIS

We report costs as reported in recent literature (Temsah et al., 2021, Alghamdi et al., 2021). Rapid development, worldwide trade, and huge numbers of tourists from around the world during the Umrah season and Hajj period put KSA at major risk of spreading tropical viruses. Among them, dengue has been considered a widespread sickness for 20 years. Dengue has taken a heavy toll on the economic burden to the local area, costing US $ 110.17 million each year, which corresponds to a mean cost of US $ 11,948 per patient. The different installation costs vary greatly, and the loss of productivity in one year represents approximately 80% of the total cost. It translates into an average cost per patient of US $ 11,948 (Akbar et al., 2020). Temsah et al. (2021) reported pediatric intensive care unit long-term hospitalization costs in KSA. The total cost for 48 patients was US$46.12 million for approximately 60 days. This amounts to USD 0.961 million per patient. The mean inpatient cost per patient per day thus amounts to USD 16,014. Alghamdi et al. (2021) found that the average annual direct medical cost per patient with HF (heart failure) was $ 9,563. Additionally, other studies have shown that hospital costs for patients who have preserved ejection fraction (HFpEF) and experienced reduced ejection fraction (HFrEF) in Mecca ranged from $909 per item to $7,999 per item for one day. They find that the annual cost of HF patients in Saudi Arabia was lower than the estimated cost reported in some countries, including Italy's $ 15,952. $ 15,334 in Ireland; $ 24,873 in the USA; and $ 25,532 in a European country like Germany. However, the costs reported in Saudi Arabia were higher than the annual costs of Korean HF patients reported having cost between $ 868 and $ 1560.5. $ 2343 in Nigeria; $ 4755 in Poland; $ 5044 in Sweden; $ 7053 in Greece; $ 7792 in Spain.

In the COVID-19 pandemic, we expect a mixed patient cohort with multiple comorbidities. The mean patient treant cost is computed as a beta distribution on the range of costs reported in the literature as discussed above. In risk analysis, the PERT distribution is used to measure the impact of uncertainty in cost estimation because it is intuitive that the three parameters approximate the distribution. Consider that the treatment cost is assignable to a "minimum value" defined as [a], the "most likely value" [b], and a "maximum value" [c] in the form of PERT is a continuous probability distribution. It is a conversion Beta distribution with a four-parameter given that the projected value is the "average value" of the distribution. It is defined as the weighted average of the minimum, most likely, and maximum values that the assignable medical cost it may take, with 4-times the significance to the "most likely value." It is chosen as the most probable value, marked as the weighted average of the "minimum", "most likely", and "maximum" values that allocable medical expenses can cover. The mean value is computed as . The standard deviation of the distribution is . From discussions above consider that a=$9,563, b=$11,948.00 and c=$6,014, for comorbid patients. The mean is computed as $12,228. The standard deviation is $1,075. For COVID-19 infected patients requiring ventilation support, the cost figures are: a=$6,339, b=$21,178, c=36,018. The mean cost is $21,178, and the standard deviation is found as $4,946. Patients with complicated cases will get maximum support to recover. The cost escalates, and the comorbidity cost is added to hospitalization cost and ventilation support cost.

From alaryexplorer.com, the average salary of the salary of Doctors, Nurses, Teachers, and Drivers in Saudi Arabia is $10,452, $4293, $4720, and $1,224, respectively. The purpose is to estimate the net future value as a patient's benefit if medical intervention is successful, say with a discount factor of 5%. The estimate shows that the average salary will have a ratio: 8:4:4:1 approximately for Doctors, Nurses, Teachers, and Drivers. For comparison, the average salary of a specialist Doctor in the USA and the KSA are $11,750 and $10,452, respectively, as found from the same source. This is a 1.12:1 ratio or almost at per.

The current life expectancy for Saudi Arabia in 2021 is about 75.37 years, as per the report of the united nations. For computational purposes, the value is rounded to 75 years. For example, we compute the simple return on investment (ROI) for "Patient:2" as 4.2 years. It is based on the human capital development cost for "Patient:2" and expected income as a yearly salary. For "Patient:1", the "primary human capital development cost" is $526,172/(Income Ratio for "Patient:1") = $526,172/(8) ≅ $65,772. The corresponding ROI is $65,771.50 /$1,224 = 53.74 Months = 4.5 Years. We further assume that "Total human capital development cost" = "Primary human capital development cost" + (ROI) x (GDP per capita). Assume that the financial liability of "Patient: 1" is offset until the end of the simple payback period corresponding to the ROI. Therefore the "Total human capital development cost" for "Patient:1" = $65,772 +4.5 (GDP Per Capita) = 65,772 +4.5 x ($20,110) = $156,267. Tables 4A and 4B illustrate the computed values.

We assume that the productive remaining working life is five years compared to the life expectancy value. Therefore, the NFV estimation is based on a 5% discount rate and further suppose that the payment is due at the end of the period.

$$NFV = PV\left[1 + \left(\frac{r}{k}\right)^{nk}\right] + PMT\left[\frac{\left(1 + \frac{r}{k}\right)^{nk-1}}{r\ /\ k}\right]$$

Table 4. (a) NFV of the patients

#	Patient	Wage/Month ($: USD)	Productive Life in Yeras (Life Expentacy to current age)	NFV Income at Life Expectancy ($: USD)
1	Patient 1	1,224	40	1,867,849
2	Patient 2	10,452	5	708,963
3	Patient 3	4,720	29	3,681,930
4	Patient 4	- (Not assigned salary estimate but as an entrepreneur, net worth is set at the beginning of total 3 years of survival) ($3 Million now)	0 (As life expectancy exceeds current age. But assume that the intervention will prolong life to 3 years (Based on a consolidated prognosis score of 0.189)	Not Calculated due to life expectancy more than the current age, but net worth is added as an entrepreneur. Net worth at the end of 3rd year ($3 Million now) grows to 3,484,417

To estimate human capital development costs, we use secondary data. First, the income ratio of Doctors, Nurses, Teachers, and Drivers is calculated in the proportion: 8:4:4:1.

Table 4. (b) Human capital development costs

#	Patient Case	Primary human capital development cost and ROI (≅PBP)	Primary human capital development cost, PBP and GDP	Total human capital development cost
1	Patient 1	$526,172/(Income Ratio) =$526,172/(8) = $65,771.50 (Human Capital Developemt cost) PBP = $65,771.50 /1224 = 53.74months = 4.5years	$65,772 +4.5 (GDP Per Capita)	=65,772 +4.5*($20,110) = $156,267
12	Patient 2	Human Capital Development cost (4.2 as PBP)	$526,172 +4.2 (GDP Per Capita)	=526,172 +4.2*($20,110) = $610,634
3	Patient 3	$526,172/(Income Ratio) =$526,172/(4) = $131,543.00 (Human Capital Developemt cost) PBP = $131,543.00/4720 =27.9 months =2.3 years	$131,543 + 2.3 (GDP Per Capita)	=131,543 + 2.3*($20,110) = $177,796
4	Patient 4	NO PBP computed	Conservative estimate: 3 x (GDP Per Capita)	Conservative estimate: 3 x ($20,110) =$60,330.

Where,
r = Yearly discount rate (%)
n= Number of years
k= Payment frequency monthly
PMT= Payment amount
PV= Present value
NFV = Net future value (Note: Payment due at the end of period)

The combined prognosis score for patients are: 0.2984, 0.2127, 0.3003, and 0.1886 respectively. Assume that the patient will improve and respond to treatment by 29.84%, 21.27%, 30.3%, and 18.86% of the time, respectively for Patients: 1, 2, 3, and 4. Consequently, we interpret that the patient is not responding to treatment by 70.17%, 78.73%, 69.97%, and 81.14%. The ethical factor risk indicates the prognosis score about the patient's survivability. The higher the score, the patient is favored in triage decisions. The "triage risk factor score" interpretation is that a patient has complex comorbidity. The probability that a patient is not surviving complements the likelihood that the patient is surviving. For example, consider that a COVID-19 infected patient is surviving is 0.2984. Additionally, suppose that the patient has comorbidity. Then the COVID-19 infected patient will not survive with comorbidity is (1-0.2984)=0.7016. From the secondary data source, we find that the probability that a patient dies with COVID-19 infection ranges between 0.01 to 0.02.

The probability of death of a patient infected with COVID-19 is estimated based on the conditional likelihood when the patient has a suspicion of a previous disease (Table 4C). Therefore, it is necessary to identify potential risks associated with ethical factors for triage decisions. A comparative assessment of those above medical and social conditions and risks can modify the additional morbidity risk and pre-existing death probability. Conditional probabilities, as Bayes' theorem, provide a better risk assessment for patients. Bayes' theorem helps update new estimates of CODID-19 mortality rate by adding multiple criteria of risk associated with medical complications. It is a unique methodology included in this utilitarian triage. Next, we define the following scenarios and notations with probability for utilitarian ethical decision analysis.

Ethical triage factor decision implies how it will help a patient to rank combining medical and social factors. The triage factors are events associated with a patient due to comorbidity, social circumstances, and infection due to pandemic or COVID-19. The factor score is a probability of well-being indicating how likely a patient will benefit if provided medical care, i.e., the decision and intervention. Thus, the factor score in the form of probability determines the benefit medically and socially.

Next, we formally define ethical triage risk factors. An articulation is necessary to classify an ethical risk factor to include in the triage decision. In this case, we represent an event as a medical or social condition, which is the result or change of a set of specific circumstances, leading to multiple triggers in the form of comorbidity. A trigger is the outcome of an event affecting objectives. In this example, the objective is the chance of survival. The likelihood is the chance of something happening and influencing the objectives. The risk is the likelihood of an event associated with the severity of the outcome. Risk is a mix of possible events. It measures the probability of occurrence and impact in the form of survivability. The greater the complexity of risk, the greater the inherent uncertainty.

The formal way we define ethical triage risk factor is as: "If (a cause) occurs, then (potential risk) may emerge, which will trigger (impact) as a result it will <influence the current objective(s)>."

For example: if a patient does not undergo necessary "surgery," then the patient's survival is critical, affecting the "dependent responsibility," and the well-being of the patient's family and societal affiliation will be in jeopardy.

The patient has social value. Their ability to earn livelihood means. It can be salary for a year or other means of earning without using the discount rate for simplicity. Social ethical and comorbidity factors are the measures of a patient's s relative importance how likely to benefit from medical intervention if necessary for the patient's survival. For example, patient 1 has a comorbidity score of

0.161, and the response to treatment score is 0.035. It implies that the comorbidity score is significant than the response to treatment. Therefore, the patient is likely to be admitted as the comorbidity score is high. If the patient survives, the social cost estimate is the ability to earn in a year, ignoring the discount factor and the patient's ability to contribute socially.

Table 4. (c) Conditional probabilities (Patient 1, 2, 3, and 4)

Define the notations
S_1: Death (J)
S_2: Survive (J)
State of Survivability(Sj)
Co-morbidity Risk R(Sj)

Co-morbidity Risk R(Sj)
Conditional Probability
Joint Probability P(M∩Sj)
Posterior probability

Patient 1

	State of Survivability(Sj)	Co-morbidity Risk R(Sj)	Co-morbidity Risk R(Sj)	Conditional Probability [P(M/Sj)]	Joint Probability P(M∩Sj)	Posterior probability P(Sj/C)
S_1: Death (J)	0.02	Comorbidity Risk Survive	0.7017	0.01403321	0.045799425	4.5799%
S_2: Survive (J)	0.98	Comorbidity Risk Die	0.2983	0.29237264	0.954200575	95.4201%
	1			0.30640585	1	100.00%

Patient 2

State of Survivability(Sj)	State of Survivability(Sj)	Co-morbidity Risk R(Sj)	Co-morbidity Risk R(Sj)	Conditional Probability [P(M/Sj)]	Joint Probability P(M∩Sj)	Posterior probability P(Sj/C)
S_1: Death (J)	0.02	Comorbidity Risk Survive	0.7873	0.0157456	0.070226618	7.0227%
S_2: Survive (J)	0.98	Comorbidity Risk Die	0.2127	0.20846567	0.929773382	92.9773%
	1			0.22421126	1	100.00%

Patient 3

	State of Survivability(Sj)	Co-morbidity Risk R(Sj)	Co-morbidity Risk R(Sj)	Conditional Probability [P(M/Sj)]	Joint Probability P(M∩Sj)	Posterior probability P(Sj/C)
S_1: Death (J)	0.02	Comorbidity Risk Survive	0.6997	0.01399405	0.04539315	4.5393%
S_2: Survive (J)	0.98	Comorbidity Risk Die	0.30029744	0.29429149	0.95460685	95.4607%
	1			0.30828554	1	100.00%

Patient 4

State of Survivability(Sj)	State of Survivability(Sj)	Co-morbidity Risk R(Sj)	Co-morbidity Risk R(Sj)	Conditional Probability [P(M/Sj)]	Joint Probability P(M∩Sj)	Posterior probability P(Sj/C)
S_1: Death (J)	0.02	Comorbidity Risk Survive	0.8114	0.01622714	0.08069295	8.0693%
S_2: Survive (J)	0.98	Comorbidity Risk Die	0.1886	0.18487021	0.91930705	91.9307%
	1			0.20109735	1	100.00%

Figure 2(a) Net future value at life expectancy

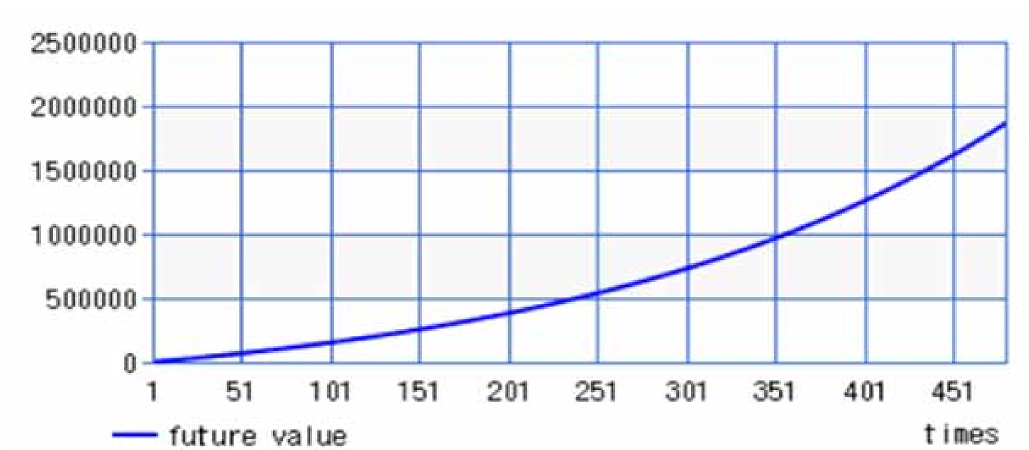


Figure 2(b) Net future value at life expectancy

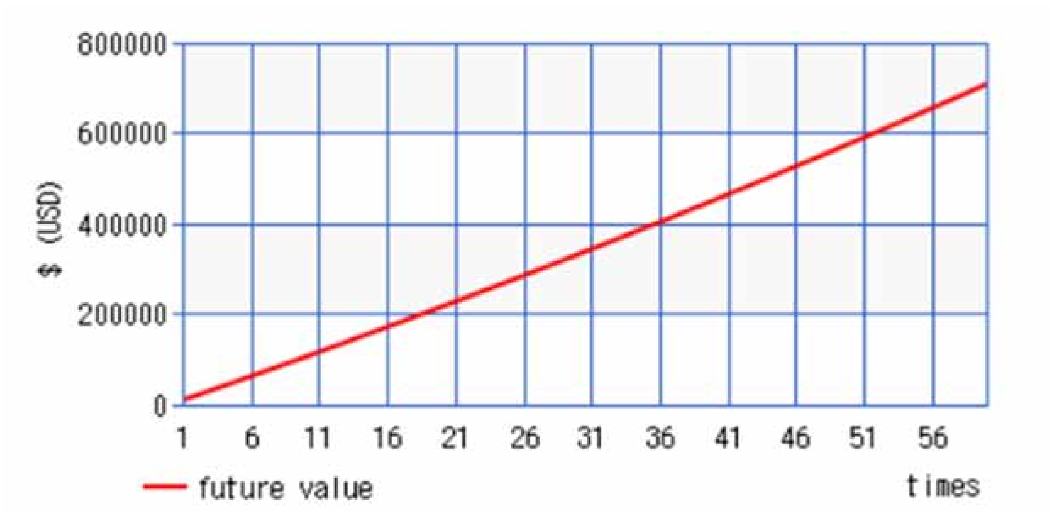


Figure 2(c) Net future value at life expectancy

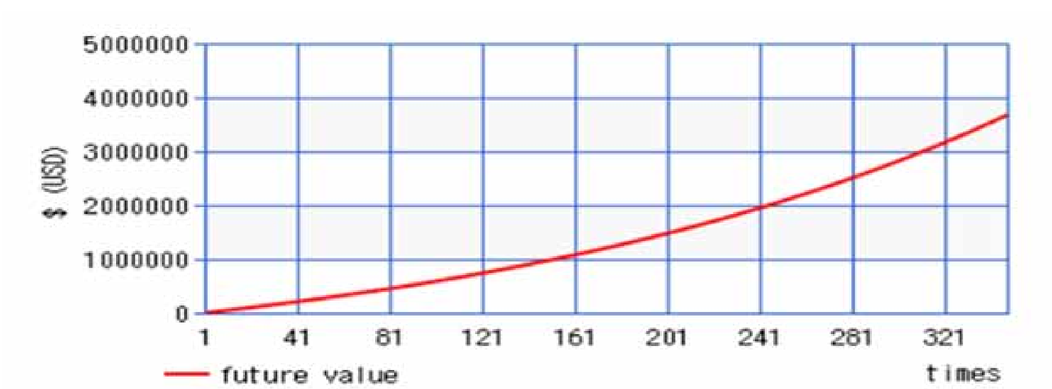


Figure 2(d) Net future value at life expectancy

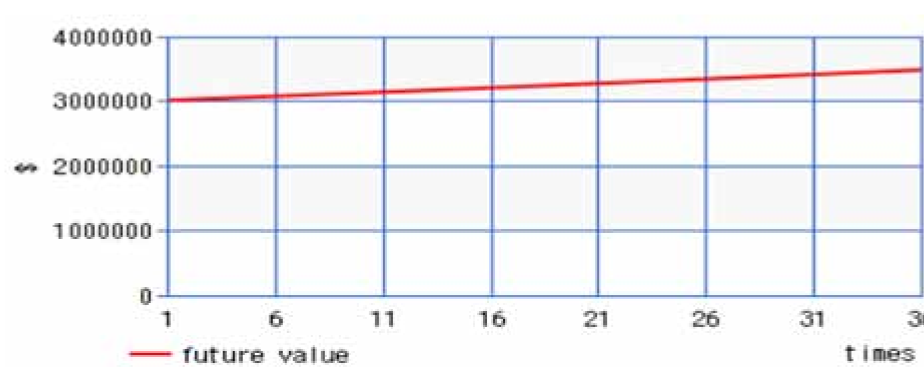


Figure 3(a) Scenario 2

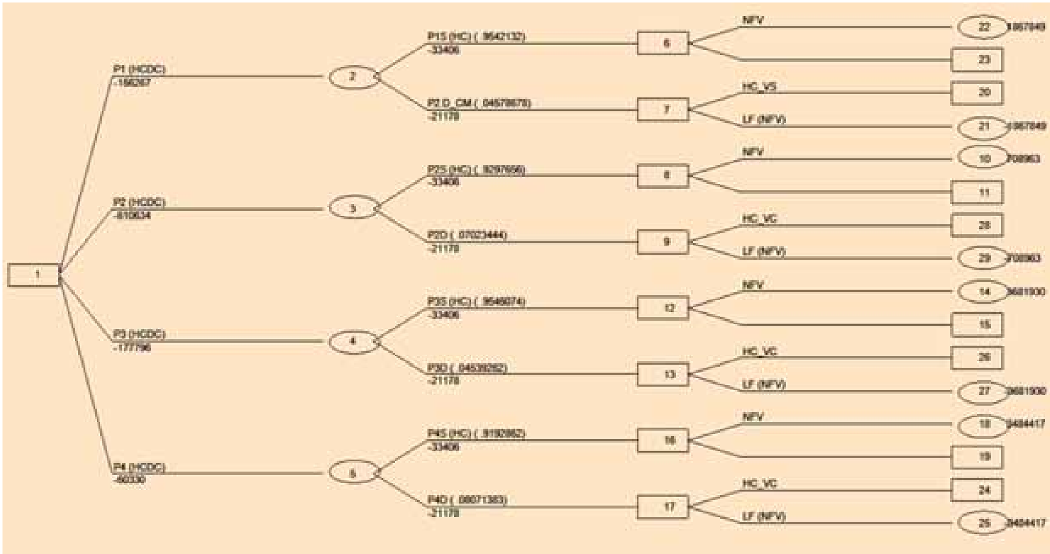


Figure 3(b) Scenario 2. Data in tabular format

								Min	-33,805
	Scenario 2 p=0.02							Max	3,137,018
	Human Capital Cost	Prob	HC/Vent.Cost	NFV	Case	Node Value	EMV_Branch	EMV_Node	Decision
Survive	-156,267	0.95420	-33,406	1,867,849	P1	-156,267	1,750,427		
Survive	-156,267	0.95420				-156,267			
Die	-156,267	0.04580				-156,267			
Die	-156,267	0.04580	-21,178	-1,867,849		-156,267	-86,516	1,663,910	1,507,643
Survive	-610,634	0.92977	-33,406	708,963	P2	-610,634	628,110		
Survive	-610,634	0.92977				-610,634			
Die	-610,634	0.07023				-610,634			
Die	-610,634	0.07023	-21,178	-708,963		-610,634	-51,281	576,829	-33,805
Survive	-177,796	0.95461	-33,406	3,681,930	P3	-177,796	3,482,908		
Survive	-177,796	0.95461				-177,796			
Die	-177,796	0.04539				-177,796			
Die	-177,796	0.04539	-21,178	-3,681,930		-177,796	-168,094	3,314,814	3,137,018
Survive	-120,660	0.91929	-33,406	3,484,417	P4	-120,660	3,172,467		
Survive	-120,660	0.91929				-120,660			
Die	-120,660	0.08071				-120,660			
Die	-120,660	0.08071	-21,178	-3,484,417		-120,660	-282,950	2,889,517	2,768,857

7.1 A Bayesian Decision Tree with EMV

The decision tree model is an outcome of investment protection in human capital. The result is minimized. In line with the utilitarian ethical principle, the intervention is rationalized economically with human capital. In this case, we do not depreciate the human capital, as the organization constantly invests in the employees to improve and upgrade their skills. It also enhances, ROI (return on investment) of the organization.

The patient in this model is an investment as human capital. The data to train a physician in Saudi Arabia is not available. The majority of the Saudi physicians are trained in western countries. The total cost of preparing a gastrointestinal, pulmonary physician, intensive care, and general cardiologist in the United States is $ 1,683,749. By comparison, the equivalent figure for the Kingdom of Saudi Arabia is approximately $526,172, with a per capita GDP ratio of 1:3.2. This figure is an indication of human capital development as an investment.

In our decision model, if a patient dies due to COVID-19 infection, we assume that the family and society is losing. The family suffers from care and income loss forever, and society has productivity loss. It is difficult to assess these losses. Therefore, we assume potential income loss to the family as the future value of income with a 5% discount rate. Further, we consider the length of periods as the patients remain working lifetime if the patient would have survived almost the average expected life. The utilitarian triage model will incorporate this loss into the family to evaluate the triage decision.

In contrast, if the patient survives, the patient further contributes to the society and family, as salve value, for the remaining valuable service time. Therefore, for simplicity, the triage decision tree model will include a future value projection at a 5% discount rate for the expected remaining service life. Figures 2A, 2B, 2C, and 2D show the computed net future values.

The limitation in this approach is purely based on economic gain to family and society and the patient's ability to add value to the community if the patient had survived. Although, the model will counterbalance for those socially marginalized patients by assigning a higher factor score, if necessary, on social factors such as "dependent responsibility."

Figure 3A displays the four patient cases. The top brunch emerging from rectangular node 1, is patient case 1. The notation "P1 (HCDC)" is the human capital development cost of $156,267 for patient 1. The human capital development cost is discussed in section 7 and shown in Table 4B. A negative sign implies a cost, while a positive magnitude implies a benefit in monetary value. From circular node 2, the tree branches off to triangular nodes 6 and 7. The conditional survival probability for the patient is 0.95420, and the possibility of death is 0.04580. the conditional probabilities are computed in section 7. The branch with the label "P1S (HC)" indicates the patient 1 survives, and hospitalization cost with ventilation support and comorbidity cost are shown as $33,406 (Figure 3B). This cost is identified in section 7. The notation "P1.D_CM" implies the patient dies due to comorbidity and COVID-19 infection and incurs a cost of $21,178. From the rectangular node 6, the branch to circular node 22 is "NFV" or net future value of the patient considering that the patient, upon survival, will earn an NFV till the expected statistical life expectancy. It is productivity gain and adds value to society as well brings well-being to family. The NFV is computed as $1,867,849, with 5% discount rate. The computations are shown in Section 7 and Table 4A. If the patient fails to survive, the patient incurs a loss to family and society. This loss of productivity and incurs suffering to the family members who are dependent on the patient 1. The branch from rectangular node 7 to circular node 21 is the loss to family ["LF (NFV)"] as a net future value. This value is taken as $ (-1,867,849) in case the patient has survived (Figure 3B).

The decision tree in Figure 3B is for a different set of probabilities when COVID-19 infected death probability is 0.01. Figure 3C shows the exacted values of EMV for utilitarian decisions. The notations for figure 3C are the same as explained before in scenario 1. Figure 3D shows the decision tree's exacted values with conditional probability of death due to COVID-19 contracted patients.

Figure 3(c) Scenario 1

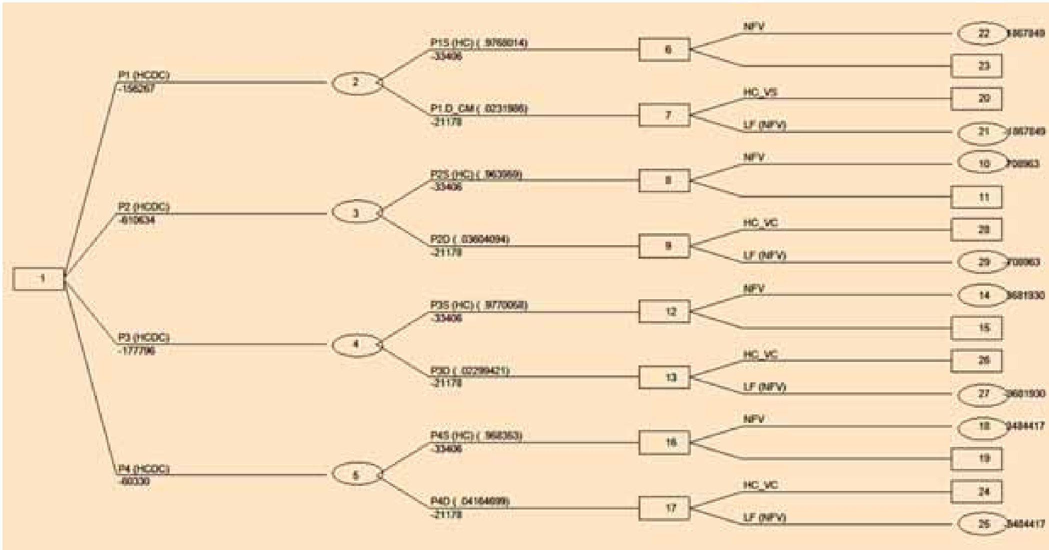


Figure 3(d) Scenario 1: Data in tabular format

	Human Capital Cost	Prob	HC/Vent.Cost	NFV	Case	Node Value	EMV_Branch	EMV_Node	Decision
								Min	14,260
	Scenario 1 p=0.01							Max	3,301,683
Survive	-156,267	0.97680	-33,406	1,867,849	P1	-156,267	1,791,886		
Survive	-156,267	0.97680				-156,267			
Die	-156,267	0.02320	-21,178			-156,267			
Die	-156,267	0.02320	-21,178	-1,867,849		-156,267	-43,823	1,748,064	1,591,797
Survive	-610,634	0.96396	-33,406	708,963	P2	-610,634	651,209		
Survive	-610,634	0.96396				-610,634			
Die	-610,634	0.03604				-610,634			
Die	-610,634	0.03604	-21,178	-708,963		-610,634	-26,315	624,894	14,260
Survive	-177,796	0.97701	-33,406	3,681,930	P3	-177,796	3,564,629		
Survive	-177,796	0.97701				-177,796			
Die	-177,796	0.02299	-21,178			-177,796			
Die	-177,796	0.02299	-21,178	-3,681,930		-177,796	-85,150	3,479,479	3,301,683
Survive	-120,660	0.95835	-33,406	3,484,417	P4	-120,660	3,307,287		
Survive	-120,660	0.95835				-120,660			
Die	-120,660	0.04165	-21,178			-120,660			
Die	-120,660	0.04165	-21,178	-3,484,417		-120,660	-145,997	3,161,289	3,040,629

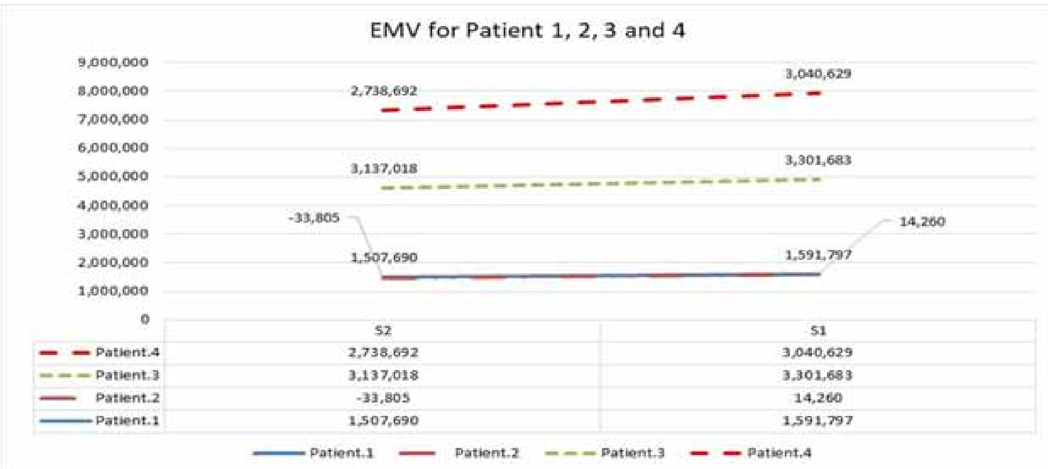
Figure 3(e) Sensitivity Analysis of Decision Tree (Intercept and Slope)

Patient:1	P(Death)	EMV		Patient:2	P(Death)	EMV		Patient:3	P(Death)	EMV		Patient:4	P(Death)	EMV
S2	0.045787	1,507,690		S2	0.070234	-33,805		S2	0.045393	3,137,018		S2	0.080714	2,738,692
S1	0.023199	1,591,797		S1	0.036041	14,260		S1	0.022994	3,301,683		S1	0.041647	3,040,629
	Intercept	Slope			Intercept	Slope			Intercept	Slope			Intercept	Slope
	1,678,176	-3,723,470			64,923	-1,405,698			3,470,728	-7,351,632			3,362,508	-7,728,744

The status of the patients is determined from the medical history of the patients. Further, the clinical data are reviewed in light of the factors for triage decisions. Finally, the software input is gathered from experts on the triage factors and patient conditions by factor-wise comparison.

The patient's risk is estimated by the comorbidity history and social conditions. Then, the triage decisions are reviewed according to the composite risk factors.

Figure 3(f) The EMV of Patients: 1, 2 3, and 4 (Showing the slope and interactions)



The relationship between EMV, the intercept, and the slope is expressed as the straight-line equation of the form: EMV=Intercept+Slope (Probability of Death). Here are the possible explanations for this equation. The slope defines the rate at which the EMV either increases or decreases depending on the unit increase or decrease of the probability of death. The intercept is the base value that a patient incurs as EMV when admitted for COVID-19 infection as a social, medical, and family liability.

Figure 3(g) Sensitivity analysis: Probability of death on the expected monetary value

	P(Death)	EMV	NET.EMV
Patient:2	0.07023	-33,805.4	14,057.0
Scenario:1	0.08023	-47,862.4	
	P(Death)	EMV	
Patient:2	0.02	36,809.0	14,057.0
Scenario:2	0.03	22,752.1	

Figure 3E is the probability of death due to contracting virus COVID-19 and Sensitivity analysis of decision tree showing intercept and slope. Intercepts determine the baseline hospitalization cost and rate of change of EMV with unit percent change in probability of death. Figure 3G is the computation of consolidated EMV in $ value with a revised estimate of Baysian death probability. Both scenario 1 and 2 shows the same result for patient 2. The EMV is a net gain implying the better than a negative EMV in the utilitarian ethical decision. Figure 3F displays the EMV as a straight line estimate for sensitivity analysis. Assume a linear dependence of the EMV on the probability of death; therefore, we can estimate the EVM values. The EMV is characterized with the slope and intercepts for the Patient: 1 as $1,678,176 and $(-3,723,470) respectively. If the death probability for a patient decreases from probability 0.045 to 0.035, the EMV vales are estimated as $1,510,619.9 and $ 1,547,854.6 respectively. Therefore, the EMV decreases by an amount related to the slope ($-3,723,470) but decreases by $37,234.7. It implies that for a unit decrease in death probability, the EMV decreases by the slope amount of $3,723,470. The intercept value of $ 1,678,176 means that if a patient is admitted to treatment for COVID19 infection with comorbidities, the expected EMV will be incurred as a baseline value of $ 1,678,176 whether the patient survives or dies.

7.2 Discussion

This utilitarian triage decision depends on expected monetary value consideration. For example, the sensitivity analysis using regression parameters shows how a patient's expected monetary value (EMV) is related to judgments (Figure 3E, Figure 3F, and Figure 3G). Maximizing the EMV, in Scenarios 1 and 2, patient 3 with an EMV of $3,301,683 and $3,137,018 is assigned priority in both cases. Human capital development cost, hospitalization cost, ventilation support cost, productivity gain for family and society in the form of net future worth if the patient survives till the expected life expectancy, and the loss of net future worth or hardship to family and society if the patient fails to survive. The objective criteria are either maximization or minimization of financial gain. If priority is given to a patient with a better prognosis than others, the gain is calculated as financial savings for those patients who have suffered hospitalization losses. This suggestion, though by definition is pure utilitarian, is an unfair utilitarian principle. However, the decision is evaluated with this option as well. But the decision to support a patient should depend on the local context and case-by-case evaluation. This evaluation is a guide for the decision-maker.

Decision support systems in medical applications are found in the literature with diverse issues (Vargas, 1990; Wollmann et al., 2012; Ijzerman et al., 2012; Bath et al., 2011; Cancela et al., 2015; Danner et al., 2011; Kitamura, 2010; Maruthur et al., 2015; and Singh and Avikal, 2020). But the quantification of triage decisions with ethical issues is rare in literature. The analytic hierarchic process is one of the DSS that systematically analyzes the judgments of several experts for unbiased decisions (Singh and Avikal, 2020; Danner et al., 2011). But there is rare literature that illustrates ethical triage with sequential decisions incorporating clinical and non-clinical ethical factors. Furthermore, no literature has so far reported Basyan EMV estimates on utilitarian ethical triage decisions.

8. CONCLUSION

A utilitarian ethical framework to prioritize patient and screening comorbid patients during a pandemic outbreak such as COVID-19 is discussed with a Bayesian probabilistic expected monetary value. This research shows how a new hedonic calculus quantifies the optimum utilitarian cost-benefit analysis. The purpose is to describe a triage methodology with revised conditional comorbidity that: Is transparent in assigning patient priority;

I. Follow utilitarian ethical principles that integrate social values, medical prognosis, dependent responsibility, and care for humankind;
II. Optimizes efficient use of essential resources, for instance, human capital, financial capitals; and critical infrastructures with informed prognosis;

III. Raise public confidence in triage policy decision-making;

Monetary value considerations are the guiding principle to suggest triage for COVID-19. The algorithm is distinct in many attributes, including a new approach to evaluating utilitarian measures. First, the economic value of human capital development, treatment costs for patients infected with COVID-19, hospitalization costs for patients with comorbidities, the net future worth of patients, and expected financial loss for the family accounted for to make a decision. Second, the Bayesian probability of the COVID-19 death forecast is assigned to evaluate the EMV (expected monetary value). Third, to classify relevant ethical factors, two different stakeholders, namely, internal and external stakeholders, are characterized. The internal stakeholder viewpoint considers collective bioethics in responding to an internal threat of a healthcare institution. The aim is to decide what is fair and just in a given situation for patient care. The external stakeholder consideration focuses on how the bioethics principles and human dignity are rationalized in a conflicting case. There are ethical principles and values within each category that need attention. The identified ethical factors are assessed pair by pair to assign risk scores. Expert judges evaluate the ethical risk factors, and the set scores transform into a risk as survival probability. The conditional probability survival decision trees estimate the expected monetary value to maximize or minimize the financial burden on the medical system, society, or family. Finally, regression analysis with slopes and intercepts shows how patents' EMV makes a better judgment as sensitivity analysis. If we maximize EMV, in scenarios 1 and 2, patient three is consistently ranked to assign priority.

FUNDING AGENCY

The publisher has waived the Open Access Processing fee for this article.

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APPENDIX A – ADDITIONAL INFORMATION

Institutional Review Board Statement

The study confirms the ethical guidelines of the “Declaration of Helsinki” and the research priority approved by the scientific research committee of the Faculty of Engineering at the Islamic University of Madinah (2020).

Data Sharing Statement

Data used and analyzed in this study will be available upon request. Most of the data includes in an embedded structure in the research article.

Funding

The Ministry of Education, Kingdom of Saudi Arabia, sponsored this project is in collaboration with the Ministry of Industry, Kingdom of Saudi Arabia, via grant No. 20/7.

Disclosure

Professor (Dr.) Shamsuddin Ahmed (SA)is the Principal Investigator of the research and received a research grant for the Hospital Capacity and Triage Plan in the emergence of COVID-19 from the Ministry of Education in association with the Ministry of Industry, Kingdom of Saudi Arabia. Dr. Rayan H. Alsisi (RHA) is the Vice Dean for Graduate Studies and Scientific Research. Both of them are affiliated with the Islamic University of Madinah, Kingdom of Saudi Arabia. Madinah – 42351.

The authors declare no conflicts of interest for this work.

Author Contributions

SA- was involved in all aspects of the research development, including securing funding, study design, software design, data analysis, writing, structuring research articles, and reporting research outcomes to the institutional research deanship.

RHA- participated in data acquisition and Institutional Support.

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