A GAME THEORY TO SOLVING THE COST OF SOCIAL DISTANCING AMONG NODES (FAMILY) IN RED ZONE IN EPIDEMIC BY NSGA-II ALGORITHM

Special Subject 2

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Abstract

The pandemic has left humanity with several scars, particularly among individuals living in the red zone who must deal with local issues such as well-being, care, and interest, as well as the massive issue of varied charges that are dependent on the government's distance order. Along with issues from the pandemic, the cost of social distancing rises as a big problem for families with normal or low standard of living located in the red zone of the epidemic. This paper presents a research review of a numerical model applied based on the Unified Game-based model of game theory with a focus point to solve the cost of the social distancing among nodes (family) in the red zone. The NSGA-II equation was used in this study to figure out the balance point in Nash equilibrium, which will help players balance the criteria and bring the best results of minimizing the various costs that people have to lose during the pandemic. The main objective of this article is to optimize the social distancing plan and solve the cost for nodes to receive the benefit. As well-being is possible for some but not for others, this discovery would pave the way for lowering costs during social distancing and asserting equality for persons living in the red zone.

Keywords: Game theory, Cost, Family, Red Zone, Epidemic, NGSA-II

1 Introduction

It is worth noting that the pandemic health crisis has turned into a global economic crisis on a very large scale including countries around the world, which causes a lot of damage to public health. The pandemic has affected over 2,415,370 people [2] and has become the most serious worldwide issue, according to WHO, until April 20, 2020.

The number of infections as of June 5, 2022 has increased by 250% of the number on April 20, 2020 to 513,384,685 infections. Not only that, the number of deaths due to this disease reached an unimaginable number of 6,246,828 cases

[2]. Without proper social distancing measures, that number could increase even more.

Situation by Region, Country, Territory & Area

Name	Cases - cumulative total	Cases - newly reported in last 7 days	Deaths - cumulative total	Deaths - newly reported in last 7 days	Total vaccine doses administered per 100 population	Persons fully vaccinated with last dose of primary series per 100 population	Persons Boosted per 100 population
Global	513,384,685	3,717,085	6,246,828	13,817	148.34	59.46	21.48
+ By WHO Region							
Europe	216.092.321	1.686.611	1.993.019	5.190	166,95	63	28,27
Americas	153.467.634	653.857	2.727.100	5.579	176,31	67,81	32,72
South-East Asia	57.909.547	102.059	786.698	1.053	140,27	62,12	6
Western Pacific	55.403.390	1.215.166	225.920	1.746	219,61	82,51	44,49
Eastern Mediterranean	21.708.991	12.379	342.369	178	99,41	43,19	9,32
Africa	8.802.038	47.013	171.709	71	28,94	14,31	1,07

Figure 1: Numbers at a glance until June 5, 2022

Hence, the government has taken a number of steps to prevent the pandemic. However, there is no certain method for preventing disease spread throughout a breakout, incident, or pandemic. And a rather effective measure is social distancing which divides the state into many fields, consisting of red, yellow, green... . This report especially focuses on the red zone in the epidemic . To illustrate it clearly, red zone is a state or a certain region where the number of people infected with covid exceeds a certain level. Furthermore, that area will have special rules that people will need to follow, such as staying home, closing all crowded places of business....

In a little more detail, this research focuses on the economics problems rather than other fields.. Therefore, financial issues become extremely important and require meticulous resolution. The types of financial problems affected during this epidemic include the cost of patient treatment and the cost of living of households in the red zone during the social-distancing time. According to a paper written by Celik , for the families living costs, there was a crucially important decrease in the income of the family as well as significant increase in expenditure while living in the pandemic, especially in the red zone such as nutrition, purification, communication, etc. (Celik) [21]. Furthermore, in a pandemic, the charge for drug supply, people with pre-existing conditions, and the severity of health problems are substantial contributors to medical costs (Zhengli) [31]

In which, the cost of treatment is calculated based on many sources of family spending for the epidemic such as testing fees, vaccination fees, buying many types of medicine and the cost of paying human resources in the health sector.

Unfortunately, there are even more internal issues influencing household economics, such as rising daily living costs as personal income falls. Game Theory developed as a potentially high-potential strategy among all problem-solving methodologies addressing this form of conflict of interest. Game theory is a mathematical area that represents competitive and cooperative human interactions, with "games" consisting of individuals, their actions, and the results of those actions. Game theory, which is frequently utilized in competitive economic and political situations, may be useful for predicting behavior and promoting actions that benefit a larger system. In the case of health care, it simulates individuals' decision-making criteria while receiving health treatments. NSGA II used in this paper is the well-known, quick sorting and evolutionary multiple objective genetic algorithm, which deals with conflicting objectives i.e. in our paper the government enacted plans to control the pandemic in the red zone. Moreover, NSGA-II is an optimal simultaneous solution for each objective without being influenced by any other strategy. [49] The collection of non-dominated options offered by NSGA II allows the government to be more flexible in developing social distancing initiatives..

In which solving the cost of social distancing, with different strategies, examines the functions which would happen including free-social, partly quarantine and fully quarantine plan. Plans for social distancing attempt to minimize contact frequency and raise psychological distance, lowering the threats of individual transmission. This mathematical model helps the government to recognize the costs families need to pay in the pandemic. Therefore, the optimized option for the social distancing plan produced by the model of game theory yields benefits for all governments as well as the people living in the red zone

The organization of this paper is presented as follows. In the Section 3 about the Model of the game theory, we construct an epidemiological-economic model based on the Unified Game Based Model by modeling the costs and plans to solve the social distancing problems in a red zone. Subsequently, the drawbacks and benefits of each plan are examined in Section 4 to find the optimal social distancing plan. Lastly, conclusions and suggestions for future research are discussed in Section 5.

2 Literature Review

The pandemic has been going on for 2 years so far, there have also been many results of the research on this topic, such as on distance measures, the cost of social distancing, and how we control the pandemic? It may include the choice of players that the optimal benefit of the most rational isolation decision by Zhijun Wu [46] on dilemma games. It also includes the social distancing practices, mentioned in Timothy C. Reluga [37], where it can lower the duration of an outbreak, but the advantages of social distance are depending on how much people employ it. Reluga3 and Medlock use a similar approach, demonstrating that while distinction can mimic vaccination, it can induce hysteresis phenomena far more readily than vaccines. Another study by Reluga [38] also shows that changing an individual's behavior during social distancing can be expensive, but the benefit it brings much or not depends on each person's own behavior and epidemic situation.The cost optimization of vaccinations and social distancing, introduced in the study by W.Choi and E.Shim [22], are associated with a wide variety of costs. The relative cost of each strategy determines which strategy is likely to be preferred by everyone, creating an unequal disparity between them. Such disparities can inadvertently increase the severity of epidemics, and both governments and individuals need to optimize their strategies to balance them. The research produced by Mubayi shows a classical framework of fundamental cost analysis of the isolation social distancing for people on the dynamics of infectious pandemic. This research found that, in the quarantine rates, the sum of cost decreases with increases provided a significant value on any resource allocation plan and in an unmanageable case, a constant response to deal with the infectious disease seems the best among limited sets [33]. A framework, which includes mathematical epidemiological elements and game theory of vaccination, was proposed by Alam addresses contemporary situations when adopting simultaneously as well as separately the quarantine policies. Adam study investigated the dynamics of disease of reducing human immunity with mandatory control policies supported by game theory [13]. Moreover, the paper shows that the disease progression rate higher in several places should use a better disease attenuation tool like isolation policies. The study based on the evolutionary game theory by Kabir [30] shows the compliance with economic isolation over time, as the risks of individuals against the conclusive cost of quarantining at home. A plan in reducing the duration and overall pandemic cost suggested in the paper is emergency-relief funds to personal level.

Table 1: Table of publication

Study	**Method**
Wu, Z. (2021).Social distancing is a social dilemma game played by every individual against his/her population. PLOS ONE, 16(8). https://doi.org/10.1371/journal.pone.0255543	Game theory, Nash equilibrium, mathematical model
Reluga, T. C. (2010). Game Theory of Social Distancing in Response to an Epidemic. PLoS Computational Biology, 6(5), e1000793. https://doi.org/10.1371/journal.pcbi.1000793	Game theory, Nash equilibrium, mathematical model
Anuj Mubayi, Christopher Kribs Zaleta, Maia Martcheva, Carlos Castillo-Chávez. A cost-based comparison of quarantine strategies for new emerging diseases[J]. Mathematical Biosciences and Engineering, 2010, 7(3): 687-717. doi: http://www.aimspress.com/article/10.3934/mbe.2010.7.687	Game theory, Nash equilibrium, mathematical model
Muntasir Alam et al J. Stat. Mech. (2020) 033502	Compartmental epidemiological models
Kabir, K. M. A., and Tanimoto, J. (2020). Evolutionary game theory modelling to represent the behavioural dynamics of economic shutdowns and shield immunity in the COVID-19 pandemic. Royal Society Open Science, 7(9), 201095.https://doi.org/10.1098/rsos.201095	Compartmental epidemiological models with the concept of behavioral dynamics from evolutionary game theory (EGT)
Reluga T. C. (2013). Equilibria of an epidemic game with piecewise linear social distancing cost. Bulletin of mathematical biology, 75(10), 1961–1984. https://doi.org/10.1007/s11538-013-9879-5	The analysis of a special case of the differential SIR epidemic population game with social distancing when the relative infection rate is linear, but bounded below by zero, closed-form equilibrium solutions
Choi, W., and Shim, E. (2021). Optimal strategies for social distancing and testing to control COVID-19. Journal of Theoretical Biology, 512, 110568. https://doi.org/10.1016/j.jtbi.2020.110568	Optimal control theory, a mathematical model of COVID-19 transmission, single-strategy model, disease-free equilibrium , Optimal testing strategy
Thunström, L., Newbold, S. C., Finnoff, D., Ashworth, M., and Shogren, J. F. (2020). The benefits and costs of using social distancing to flatten the curve for COVID-19. Journal of Benefit-Cost Analysis, 11(2), 179–195. https://doi.org/10.1017/bca.2020.12 A. Yinka, A., Ebiesuwa, S., and Blaise, O. O. (2020). Game Theory : A Case of Infectious Diseases. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 202–213. https://doi.org/10.32628/cseit20647 [48]	Epidemiological and economic forecasting, mathematical theory of epidemics, SIR model - standard SIR framework Game Theory
Anderson, R. M., Heesterbeek, H., Klinkenberg, D., and Hollingsworth, T. D. (2020). How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet, 395(10228), 931–934. https://doi.org/10.1016/S0140-6736(20)30567-5 [11]	Experimental run, base on the real factors

Andersen, M. (2020). Early evidence on social distancing in response to COVID-19 in the United States. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.3569368 [9]	Game Theory
S. Cato, T. Iida, K. Ishida, A. Ito, K.M. McElwain, M. Shoji,Social distancing as a public good under the COVID-19 pandemic,Public Health,Volume 188,2020,Pages 51-53,ISSN 0033-3506, https://doi.org/10.1016/j.puhe.2020.08.005 [20]	Apply economic theory to analyze a cross-sectional survey. Economic theory is complemented with empirical evidence
Auliya A. Suwantika, Inge Dhamanti, Yulianto Suharto, Fredrick D. Purba, Rizky Abdulah,The cost-effectiveness of social distancing measures for mitigating the COVID-19 pandemic in a highly-populated country: A case study in Indonesia,Travel Medicine and Infectious Disease,Volume 45,2022,102245,ISSN 1477-8939, https://doi.org/10.1016/j.tmaid.2021.102245 [14]	Susceptible-Exposed-Infected-Recovered (SEIR) compartmental mode.
Zachary Barnett-Howell, Oliver John Watson, Ahmed Mushfiq Mobarak, The benefits and costs of social distancing in high- and low-income countries, Transactions of The Royal Society of Tropical Medicine and Hygiene, Volume 115, Issue 7, July 2021, Pages 807–819, https://doi.org/10.1093/trstmh/traa140 [16]	Use compartmental epidemiological models, embed estimates of the welfare value of disease avoidance.

We found that there are no studies that focus on mathematical models for monitoring and controlling individual finances to prevent this epidemic. Therefore, the main contribution of this paper was to detect and analyze these issues which provides the necessary complement to epidemic costing tasks thus ensuring all arising financial problems are under control and also increasing the probability of success in repelling the global epidemic. Based on a mathematical method to solve the cost of the social distance among nodes (family) in the red zone in an epidemic, the solution calculates specifically each cost, each plan for players can choose social distance or without restriction. Hence, the players can easily know which strategies are best and worst, thereby making the most rational decisions.

2.1 Problem description

We presented the concerns and explained them in the most accessible way possible so that readers can grasp the issues raised by this article. The situation here was how to optimize the costs of social distancing by applying game theory for people living in the red zone when the living costs are limited and no government subsidies were available. This process involved a group of people bargaining and persuading each other to come to a favorable agreement and maintain a sustained relationship.

Vaccines for the pandemic did not provide immediate protection.. It took at least 14 days after the first injection to take effect, and the level of protection after the first injection was only very low. One month after the second dose of vaccine was administered, the vaccine would have optimal protection and this effectiveness was only about 60% - 90% depending on the type of vaccine [13].

Therefore, in the long term, this will create inconvenience and potential risks for people, especially those living in the red zone, when they have to live in an isolated environment without comprehensive protection for a long time, and at the same time, not receive a guaranteed subsidy or improved mobility. People living in isolation in general and people living in the red zone, in particular, would have suffered from the distance prohibition by the government and get bonded to the cost of the vaccine, the living expense, the medication cost, the testing cost, and the fine cost which indicated at the current time. Moreover, setting a negative externality on people divided by the hierarchy with low cover costs leading to the conflict between people and the management. Consequently, players in this game had to come up with methodologies to find the best solution to maintain the optimal cost they need to consume due to the social distance during the pandemic.

According to Linda Thunström, social distance saved lives, but it can also have substantial expenses for society, especially in large countries like the United States. In the coming months, despite significant fiscal and monetary stimulus, the results of the weakening economy pose a threat to low-income workers. According to Goldman Sachs economic forecasts released on March 31, U.S Gross Domestic Product (GDP) is expected to contract by 6.2 % in 2020, mostly due to the associated morbidity, productivity impacts of the epidemic, and mortality, as well as social distancing measures taken to combat it. In a variety of plausible scenarios based on the best available information as of 3 April 2020, they find that the economic benefits of lives saved outweigh the value of the projected losses of GDP by about $5.2 trillion using a 3 % discount rate and a 30 year planning horizon.[44]

To illustrate, the players mentioned here include four players as four families and 3 strategies will be explained more clearly in the following section. For each player, the strategy selecting considers the following criteria: (i) *choose a strategy that costs the least, bringing the best benefits to each player* and (ii) *that strategy provides safety for our families during the pandemic.* Public authorities should enhance the benefits derived from the actors. Particularly, if both sides can agree, the players will consider an exceptional concession for some of the costs of each strategy. When players just want to acquire the biggest benefit for themselves in each strategy, the problem arises. To deal with this situation, players need to balance the two criteria to come up with the most effective strategy. In some situations, players optimize costs but in terms of safety are not effective. Therefore, Nash equilibrium will help players balance the criteria and bring the best benefits.[40]

In the game model, the main players are nodes distributed among the red zone in the city. Recently, vaccination has been the great solution to deal with the pandemic. However, with the new dangerous variants of the Coronavirus, the vaccine-restraints as well as new variants emerged too rapidly than the development of the vaccine and the distribution of the vaccines which alleviate the economics of a nation. [36] In such a heavy situation, people still get infected by the Corona virus even when they are injected with vaccines. In this paper, we introduce four main properties and their characteristics which cover all the situations whether families are infected or vaccinated. Each players has characteristics that depend on their real life like: Living expenses (Ls), Medication cost (Ms) that affect caused by the pandemic:

- Player 1: *Vaccinated - Infected*: This family has been vaccinated and has been infected before participating in the game. Therefore, the chances of a second disease are decreased because this family's antibodies are nearly normal. As long as they have insurance of vaccines, there would not be a large expense to pay.

- Player 2: *Vaccinated - Not Infected* : This family has been vaccinated but has not been infected before participating in the game. There is only the protection of the vaccine, so there is still a risk for infection and higher than the first family.

- Player 3: *Not Vaccinated - Infected* : This family has not been vaccinated but has been infected with the disease. Therefore, participating in a strategy to protect post-pandemic health, avoid a second infection and be able to choose a safe time to vaccinate that family.

- Player 4: *Not Vaccinated - Not Infected* : This family has not been vaccinated, not infected yet. So, the possibility of infection with the disease is extremely high. In order to protect the family's health and save money, families should choose strategies that are suitable for their current circumstances.

According to the paper written by Troy Day, two commonly controlling pandemic techniques are isolation and quarantining of individuals that have high probability of infecting the pandemic. The paper also concluded that people get the highest benefit from the use of quarantine when the daily occurrence of the significant asymptomatic transmission of the pandemic while the isolation is ineffective. [23]

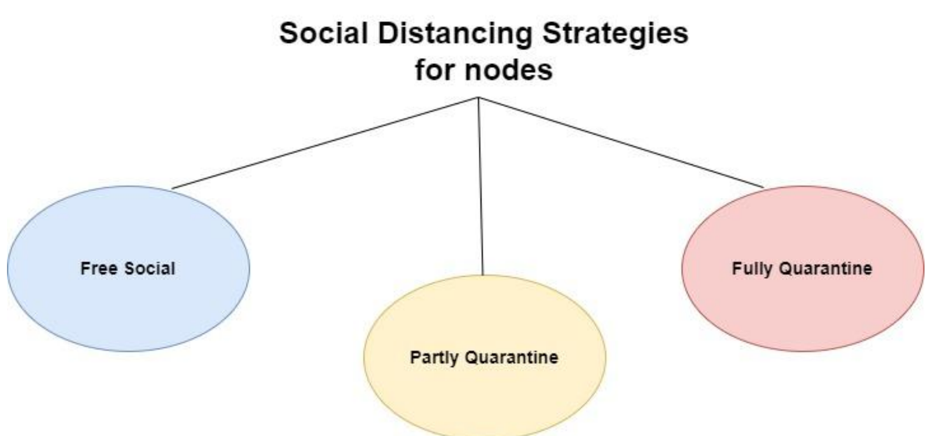

Figure 2: Social Distancing Strategies for nodes in the red zones.[25]

3 Strategies and their characteristics:

- *Free social*: No social distancing, free to participate i n social activities. So the risks of getting diseases increase.

- *Partly quarantine*: Partially social distancing is allowed to participate in necessary activities such as going to work, buying necessities. By avoiding exposure to other people, the individual is able to access more social activities. Therefore, there is still the risk of infection.

- *Fully quarantine*: zero social contacts, all activities will be held at home: work online, study online, and will be able to buy necessities once or twice a week. So, there is a low risk of infection.

In the pandemic, people have to deal with problems of cost also the most important of this paper:

-*Vaccine(Vs)* : In a study found that it would cost $9.4 billion to manufacture 8 billion doses of Pfizer/BioNTech's vaccines at a cost of $1.18 per dose, while $22.8 billion would be required to manufacture 8 billion doses of Moderna's vaccine at a cost of $2.85 per dose. [5]

-*Living expenses (Ls)*: The Elder Index, a county-level measure of the income necessary by older adults to meet basic needs, estimates that more than a third (36%) of Americans age 65 or older live in a county that is both among the highest third and fifth in terms of pandemic prevalence..[32]

-*Medication cost (Ms)*: According to a new research, the median charge amount for pandemic inpatient treatment — the fee for persons without insurance or who went out of network – was $45,683 for those 51 to 60 years old and $34,662 for those 23 to 30 years old. [29]. Besides, the social distancing in the pandemic essentially affect mental health and a lack of worldwide mental health services lead to unmanaged consequences for both short-term and long-term health problems. [28] But in this paper we consider only the medication cost while people are transmitted.

-*Testing cost (Ts)*: According to URMC, COVID Diagnostic Test - $150, COVID Antibody Test - $140. [27]

-*Fine cost (Fs)*: The finding by Navias paper stressed the need for a science-based fine dissimulation that reflects the communal cost of non-compliance with different social distancing plans. [25]

-*Risk (R)*: There is a wide range of benefits and risks associated with vaccines, depending on factors such as sex, age, community transmission, and vaccine doses. The risk of our paper will based on CoRiCal, which calculates estimates of the chance of different outcomes for your age and sex group per million people. [3]

Cost	Description	Special constant (constant that can be changed in real life)
Vaccinated	Vs: $2.85 per vaccine.	a1
Living expenses	Ls: expenditure that 1 family uses in 1 month (depends on reality)	a2
Medication cost	Ms: Medicines to cure covid in particular and other diseases in general	a3
Testing cost	Ts: Antibody Test - $140	a4
Fine cost	Fs: fine fee for people infected with covid in society	
Risk	R: Risk of infection of each player	

Table 2 : Properties of characteristics

This problem can naturally be depicted as an extensive-form game based on perfect information. In the game, players contribute methodologies to maintain their relationships and maximize their gains.

> -Players at the bottom of the hierarchy adopt weak policies with low implementation costs while imposing negative externalities on other players and thus enjoying lower infections due to stronger policies of the latter.
> - There was a guideline for preventive measures including social distancing, wearing masks, vaccination,etc... for each player to follow.
> - During the time of social distancing, the government will offer appropriate subsidy packages to help players in difficulty.

In general, we then could use the model elements to represent the data for calculating the Nash equilibrium point for this real-world problem in order to achieve an appropriate sustainability strategy.

Table of expense that 2 types of families (vaccinated and not vaccinated) have to pay in 1 month. That table showed the strategies players can choose and give them the most favorable outcome:

Family	Strategy	R	Vsi	Lsi	Msi	Tsi	Fsi	
Vaccinated	Free-social	50%	$2.85	$500	$200	$140	$100	a4=3
	Partly quarantine	30%	$2.85	$500	$200	$140	$100	a4=3
	Fully quarantine	10%	$2.85	$500	$200	$140	$100	a4=1
Not Vaccinated	Free-social	100%	0	$500	$200	$140	$100	a4=5
	Partly quarantine	80%	0	$500	$200	$140	$100	a4=4
	Fully quarantine	50%	0	$500	$200	$140	$100	a4=3

Table 3: Real expense of 2 players (vaccinated and not vaccinated)

The results calculated with the algorithm given in section 3.2, we have seen different results with different strategies. And the total cost is the total amount that players need to use during the time of social distancing during the pandemic:

Strategy	**Social distancing plan**	**Total cost**
Vaccinated	Free-social	$1072,85
	Partly quarantine	$1012,85
	Fully quarantine	$672,85
Not Vaccinated	Free-social	$1,500
	Partly quarantine	$1,300
	Fully quarantine	$1,070

Table 4: Total cost that players need to pay

With the results given from the examples taken from the real world, we can conclude that vaccinated and fully quarantined do the least economic damage to the family. Otherwise, if the families didn't vaccinate and participate in social activities, it would cause heavy damage to the economy as well as the health of players.

2.2 Game-theoretical model formulation

As introduced in Section one, we used the Unified Game-based Model in our to solve the problem we mentioned in the topic. This modal based on the research of game theory and Nash equilibrium is a convenient tool for search the win - win solutions for the conflict with the following distinctive features such as: Algorithmic model solving is done in the available time, even with the data of large projects. The model has full features and data about the conflict. Unified and clear problem model. The model can be applied to algorithms to find the answer. The Model is comprehensive with many types of conflicts in Project Management. Through the aforementioned analysis of the content to be expressed in the game theory model, which is based on the generic structure for imperfect information games, cooperative games, and non-zero-sum games, the authors decided to apply the Unified Game-Based Model to a modified formula in order to solve our problem - solving the cost of social distancing. According to [45], the Unified Game-Based Model is defined as follows:

$$G = <P0, P, S0, S, F0, F> \tag{1}$$

Inside the formula based on Unified game based model,

G : is the game in strategic form

P0 : is the special player which represents for government

P = P0 ,...Pn : is the set of normal players which represent for families living in the red zone

S0= S0 ,...S3 is a set of strategies for the government which is planning the social distancing cost efficiency for the nation.

S= S0 ,...S3 is a set of strategies for families such as free social or total quarantine based on the vaccine injection and infection rate.

F0: is the payoff function of special player (the government)

F: is the payoff function of the normal player (family) corresponding to each strategies.

2.2.1 Payoff function for a normal player

$$Fi = a1 * Vsi + a2 * Lsi + a3 * Msi + a4 * Tsi + Fsi * R \qquad (2)$$

Where:

Fi : quantifies the total cost of player i a1, a2, a3, a4 are the expert setting value to balance the importance of these four factors on the cost for each strategy.

Vsi: is the Vaccine cost of player i

Lsi: is the Living expenses of player i

Msi: is the Medication Cost of player i

Tsi: is the Testing Cost of player i

Fsi: is the Fine Cost, defined by the government, of player i

R: quantifies the transmission risk of player i

2.2.2 For special player

$$F_0 = \sum_{i=1}^{n} F_i - \sum_{i=1}^{n} (F_{s_i} * R_i) \qquad (3)$$

F0: is the payoff function of special player (the government)

Fi: quantifies a total cost of player i

Fsi: quantifies a fine cost of player i

Ri : quantifies the transmission risk of player i

3 Applying NGSA II to support decision making for social distancing in game theory

3.1 Nash equilibrium

The goal of game theory is to help us understand how decision-makers interact. In the ordinary sense, it's a game "a competitive activity . . . in which players contend with each other according to a set of rules" [35]. Along with computer science, it has been used to a number of social scientific fields. We provided a decision-supporting strategy based on game theory in this study. A balance between the decision's benefits and disadvantages is necessary to address the cost of social isolation as a process involving numerous parties. Conflicts in the real world, like pricing competition and relationship bargaining, may be modeled using game theory. [41] We create a game played by multiple players, which is Vaccinated - Still Infected, Vaccinated - Not Infected, Not Vaccinated - Infected and Not Vaccinated - Not Infected. And all participants in a game pick and unite to form a blended procedure, which is a mix of probabilistic beliefs, strategy choices, and the choices of the other player. The benefit value represents the quality of each player's profile of action in terms of players cooperatively trying to reach an agreement. [34] We also contrast the dynamics of an induced epidemic with a scenario in which all rates of inter-individual interaction are under the direction of a global planner, generally a highly empowered government. We demonstrate mathematically that, compared to the societal optimum, the Mean Field Nash equilibrium offers a sub-optimal contact rate strategy, and we calculate the accompanying "cost of anarchy." Our modeling method can shed light on how governmental decisions pertaining to the costs brought on by contact rate decreases would affect individual responses to various cost structures.[26].

3.1.1 Explained the Nash Equilibria formula

$$U_i\left(s_i, s_i\cdot\right) \geq U_i\left(s_i s_i\right), \forall s_i \in S_i, \forall i \in N \tag{4}$$

NE is a point at which no player can get a bigger profit by moving unilaterally. In other words, a profit-maximizing player will not stray from NE. In fact, if a strategy profile s' =(s1,...si',..., sn') is not NE, it implies that there must be a player I who may earn a better profit by using a different strategy when others select s'$_i, that is ui(si'', s_i') > ui(si', s_i')$

3.1.2 Proved the optimal solution from algorithm is a NE by using Nikaido Isoda function

In light of the Thomas-Kilmann model, collaboration is the best one among five conflict resolution options. It likewise shares a similar thought with Nash equilibrium and game theory, which is about parties cooperating to find an answer that satisfies all players. In particular, the Nikaido Isoda function characterizes

Nash equilibrium depicted as a Unified Game-based model:

$$f(x*, x) = \sum_{i=1}^{n} (fi(x) - fi(x[yi])) \tag{5}$$

According to Nikaido-Isoda in finding Nash equilibrium, applied to Unified Game-based model, when solutions are found:

$$f(x*, x) = f(S*, S) = \sum ni = 1(ui(si*, s-*i) - ui(si, s-*i)) \geq 0, \forall si \in Si \tag{6}$$

In this way, Nash equilibrium is the answer for the showdown here about natural issues connected with industrial parks. Multi-objective enhancement issues can be changed into single-objective advancement issues with the Nikaido Isoda function. From that point, multi-objective algorithms can in any case be effectively applied. Subsequently, Nash equilibrium and the algorithm can be all the more effectively applied. An adequately huge runtime will deliver solutions, which are candidates for the Nash equilibrium, as indicated by Nikaido Isoda.

3.2 Algorithm applied for problem formulation

3.2.1 NGSA II (Non-dominated Sorting Genetic Algorithm)

Based on this foundation, the algorithm was built. The method followed the general concept of a genetic algorithm, but with modified mating and survival selection. In NSGA-II, individuals were chosen first and foremost. As a result, there would be times when a front must be split since not everyone would be able to survive. In this dividing front, the crowding distance was employed to pick solutions.[42] In the objective space, the crowding distance was the Manhattan Distance. However, because the extreme points were intended to be retained in every generation, they were given an infinite crowding distance. NSGA-II also

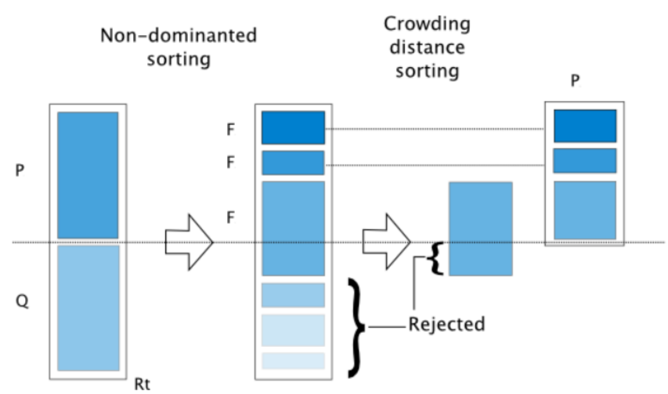

Figure 3: Non-dominated sorting by NSGA-II Implementation

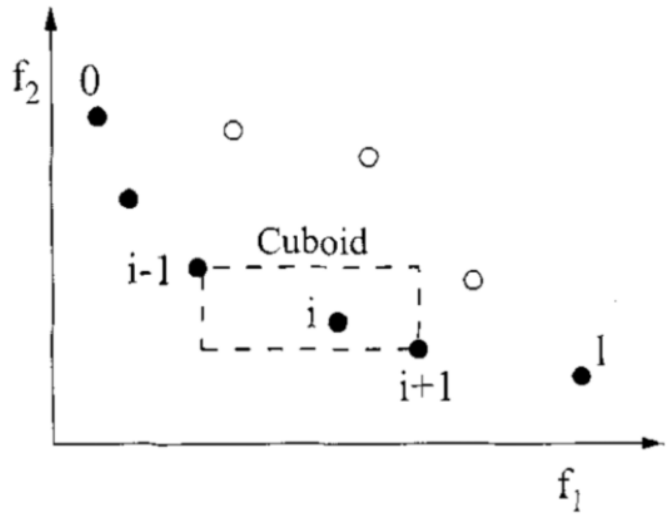

Figure 4: Estimated density (distance crowding)

employs a binary tournament mating selection to add to the selection pressure. Each person is compared first by rank, then by crowding distance. There is also a version in the original C code that uses the dominance criterion between two solutions instead of the rank.[4]

3.2.2 How this algorithm can be used in solving the problem.

In this article, we computed using the NSGA II method (Non-Dominant Sorting Genetic Algorithm II). Because the NSGA II algorithm was built on the basis of an evolutionary algorithm for selecting development points. Therefore, thanks to this algorithm, we could optimize costs for each household during the plague. For example, the cost of treating patients, and the cost of living, to be able to optimized it as low as possible while keeping its inherent role. Moreover, the algorithm also evenly distributed the estimated density (distance crowding) to have a reasonable distribution of optimal points. That could also be applied to this problem with households, keeping the most reasonable and safest distance during the pandemic. With the combination of 2 small algorithms in the NSGA 2 algorithm, the problem was solved and the statistical tables and data were calculated in the following section.

By using algorithm 2: NSGA 2 high-level pseudo-code for GA adjustment to our situation(Solving the cost of social distancing among nodes(family) in red zone in epidemic) [24]

while stopping criteria not reached do

Rt = Pt Qt;

F = total-cost (Fi);

Pt+1 = Ø and i = 1;

while —Pt + 1— + —Fi— N do

Apply total-cost of player i (Fi);

Pt + 1 = Pt + 1 Fi;

i+=1;

end

Sort(Fi, ¡ n);

Pt + 1 = Pt + 1 Fi[1 : (N - —Pt + 1—)];

Qt + 1 = (Pt + 1);

t +=1 ;

End

The first stage of NSGA-II is to randomly assemble a population P0 of people encoded using a particular representation, as explained in method 2. The population of parents P0 is then used to create the kid population Q0 utilizing genetic operators like mutation and crossover. A subset of individuals is chosen to represent the next generation based on the dominance principle and crowding distance after the two populations are combined to form an initial population R0 of size N. Until the last iteration is reached in accordance with the stop conditions, this process will be repeated.

4 Data Sets

The monetary expense incremented during no lockdown due to an ascent in tainted populace which prompted an ascent in clinical cost, while during social distancing the expense would likewise increment due to loss of work in various monetary areas. An endeavor to limit the expense by Having utilized an ideal strategy has been finished. The created ideal arrangement would give an answer for permitting financial exercises just whenever the shot at ascending in disease was low, in this way that would permit lower clinical expenses just as a break from loss of employment. To generate an optimal approach, we used the Non-dominated Sorting Genetic Algorithm- II (NSGA-II). Given that the SEIR model's components were substantially non-direct, the NSGA-2 computation was excellent for augmentation. In addition, when there were several objective capacities, this computation provided the Pareto front. The following objectives were used here:

1) The economic cost.

2) Normal number of contaminated individuals over the time of strategy.

State	Population	Initial Infected	Income(INR)	Economic Sector			% working in lockdown		
				Agri.	Manuf.	Serv.	Agri.	Manuf.	Serv.
Andhra Pradesh	49577103	10	52814	19.04	57.34	23.61	100	77	66
Delhi	16787941	10	129746	0.64	90.16	9.2	100	77	66
Jharkhand	32988134	10	27132	16.65	16.8	45.86	100	77	66
Karnataka	61095297	10	52191	13.5	59.42	27.08	100	77	66
Maharashtra	112374333	10	74027	7.54	64.03	28.43	100	77	66
Punjab	27743338	10	62605	20.84	50.86	28.3	100	77	66
Tamil Nadu	72147030	10	63547	7.28	63.7	29.02	100	77	66
Uttar Pradesh	199812342	10	23392	22.19	56.63	21.19	100	77	66
West Bengal	91276115	10	41837	16.6	65.05	18.35	100	77	66

Figure 5: Economics data of 9 states used in experiments

4.1 Data set description

Throughout this research, a perfect strategy for nine states over a period of ten weeks with an initial period of contamination of 22 days, when no forced social distance was used, was obtained. With the whole financial expense time above 300 days, Advancement had been completed over the average number of infected people. We obtained data for nine Indian states, which were chosen due to the diversity of labor force appropriation in various areas. These regions had already been shown on the assumption that they are not influenced by other monetary factors such as global exchange, production in various variables, and so on. The information contained their states, the population of each state, their incomes, the economic sector including Agriculture, Manufacturing, and Services, and the percentage of working in the social distancing. We didn't mean to show a real expression, our advantage was confined to investigating the pandemic in the presence of a few factors of relevance in order to demonstrate the age of an optimum strategy. Figure IV depicted a few nuances of the states.

5 Conclusion

Throughout this research paper, we introduced a particular perspective to understand the cost that affects people living in the red zone during the pandemic based on the Game theory and the NSGA-II algorithm to support decision-making by the government to enhance citizens' living. Due to the extreme complexity of the pandemic, the optimization option introduced by game theory and the Nash Equilibrium had been applied to this paper could be a great value for all social-economic fields. At first sight, we introduced the model of game theory for cost problems, which contained the costs of vaccines, medication, testing, living expenses, and the fine for families that represent the normal players in-game. Finally, we introduced the NSGA-II in this paper to help achieve the Nash equilibrium point for the optimized costs for the normal players as well as the special player that represents the government. Moreover, the data sets for this paper were based on the public data sets but not all the cost detail enough due to privacy. Solving the costs is a win-win, optimum solution for all players of the game is a difficult barrier that the government encountered, but GA is the beneficial approach to solve it. In the future, the focus was on how to apply the NSGA-II in finding the optimal Nash equilibrium for solving cost problems.

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