

COVID-19 and Sustainable Development Goals (SDGs): Scenario analysis through fuzzy cognitive map modeling

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1 **COVID-19 and Sustainable Development Goals (SDGs): Scenario**
2 **analysis through fuzzy cognitive map modeling**

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14
15 **Abstract**

16 The COVID-19 crisis has immensely impacted the implementation of the 2030 Agenda for
17 Sustainable Development worldwide. This research aims at providing a policy response to support
18 achieving the Sustainable Development Goals (SDGs) taking the COVID-19 long-term
19 implications into account. To do so, a qualitative analytical method was employed in the following

20 four steps. First, a fuzzy cognitive map was developed to specify causal-effect links of the
21 interdependent SDGs in Iran as a developing country in the Middle East. Second, potential effects
22 of the pandemic on the SDGs achievement were analyzed. Third, five strategies were formulated,
23 including *green management, sustainable food systems, energizing the labor market, inclusive*
24 *education, and supporting research and technology initiatives in the energy sector.* And finally,
25 different scenarios corresponding to the five proposed strategies were tested based on the identified
26 interconnections among the SDGs. The analysis showed that applying each of the five considered
27 strategies or their combination would mitigate the effect of COVID-19 on the SDGs only in case
28 of a medium pandemic activation level. Moreover, implementing a single strategy with a high
29 activation level leads to better outcomes on the SDGs rather than applying a combination of
30 strategies in low or medium activation levels during the pandemic situation. The provided insights
31 support stakeholders and policy-makers involved in the post-COVID-19 recovery action plan
32 towards implementing the 2030 Agenda for Sustainable Development.

33 **Keywords:** Pandemic, Sustainability, Fuzzy cognitive map, Scenario analysis, Policy
34 recommendation.

35 1. Introduction

36 The 2030 Agenda for Sustainable Development was adopted by the United Nations (UN) General
37 Assembly in 2015 as a shared plan of action including 17 Sustainable Development Goals (SDGs)
38 for peace and prosperity (General Assembly, 2015), which works for both people and the planet.
39 The 17 SDGs consist of 169 specific targets that can be clustered in three main pillars of
40 sustainability including economic (SDGs 1-3 and SDGs 8-9), social (SDGs 4-5, SDGs 10-11, and
41 SDGs 16-17), and environmental (SDGs 6-7 and SDGs 12-15) pillars (Kostoska and Kocarev,

42 2019). Due to the wide range of SDGs from basic needs and economic growth to innovation and
43 modern infrastructures, and the interdependent nature of the 17 SDGs (Ranjbari et al., 2019), the
44 accomplishment of the 2030 Agenda for Sustainable Development needs a full integration and
45 active collaboration of different sectors and disciplines within a society (Shulla et al., 2020). In
46 order to support the achievement of the SDGs, the interactions among SDGs that make it a complex
47 system have been studied in several research (Singh et al., 2018; van Soest et al., 2019; Weitz et
48 al., 2018).

49 The COVID-19 pandemic implications for the governments, industries, and all business activities
50 across the world have seriously challenged the SDGs' achievement and have added to the
51 complexity of the interacting SDGs. Not only health but almost all sectors of the global community
52 have been significantly affected by the current pandemic crisis. In this vein, the economic activities
53 (Rahman et al., 2020; Sahoo and Ashwani, 2020), education (Iivari et al., 2020), tourism (Sigala,
54 2020), the energy sector (Fell et al., 2020; Rajput et al., 2021), manufacturing activities (Shokrani
55 et al., 2020), transportation (Mogaji, 2020; Ravina et al., 2021), food (Aldaco et al., 2020),
56 healthcare waste management (Ranjbari et al., 2022), air quality (Ambade et al., 2021; Chelani
57 and Gautam, 2021; Gautam et al., 2021), and agricultural sector (Aldaco et al., 2020) are only
58 some examples addressed by the scientific community. Therefore, the long-term effects of the
59 pandemic should be analyzed and managed properly at an appropriate time to ensure successful
60 progress towards sustainable development (Ranjbari et al., 2021c). Consequently, the role of
61 decision- and policy-makers in different sectors of the society for implementing the 2030 Agenda
62 has become much critical due to the panic situation that emerged from this crisis.

63 Although several studies have been conducted to investigate the effects of COVID-19 on the
64 sustainability domain such as sustainability transition (Kanda and Kivimaa, 2020), sustainable
65 supply chain (Majumdar et al., 2020), and ecological sustainability (Zabaniotou, 2020), limited
66 research has been carried out on the sustainable development agenda and especially its SDGs. The
67 research conducted by Alibegovic et al. (2020) in Italy showed that SDG 1, SDG 4, and SDG 8
68 are the most affected SDGs by COVID-19. Barbier and Burgess (2020) proposed subsidy swap
69 and also tropical carbon tax on fossil fuel after COVID-19 as a progress policy for SDGs with a
70 special focus on the energy sector in developing countries. The impact of COVID-19 on SDGs in
71 India was analyzed by Bherwani et al. (2021) with a focus on air quality. Besides, Suriyankietkaew
72 and Nimsai (2021) investigated the challenges and opportunities post COVID-19 for possible
73 sustainable recovery solutions considering SDGs. In the study conducted by Alam et al. (2021),
74 15 challenges were identified for the COVID-19 vaccine supply chain and their implications for
75 SDGs were presented. The importance of government's support and optimal portfolio allocation
76 for SDGs achievement post pandemic was mentioned by Yoshino et al. (2020) in a theoretical
77 analysis. Finally, considering Iran that is also the case of the current research, Ranjbari et al.
78 (2021b) focused on the analysis of SDGs targets at the country level post COVID-19 and
79 concluded that SDG 1.2, SDG 8.3, SDG 3.3, SDG 11.5, and SDG 9.3 are the highest priorities for
80 action in Iran for the post-pandemic recovery agenda.

81 The present research considers all the 17 UN's SDGs and aims at presenting a new insight for the
82 2030 Agenda for Sustainable Development and achieving the SDGs post COVID-19 in Iran, as a
83 developing country. Iran has been infected dramatically by the pandemic with 4,960,744 positive
84 cases, 107,151 death records, and the rank of 9 among all countries in terms of cumulative total
85 death per 100,000 populations by August 31, 2021 (WHO, 2021). Total economic loss resulting

86 from the pandemic restrictions in Iran is estimated to be 47.23 billion dollars (Hemant Bherwani
87 et al., 2021), which can affect the achievement of the UN's SDGs in this country. In this regard,
88 the main questions of the research are formulated as follows. (1) How do SDGs affect each other?
89 (2) How much has COVID-19 affected each one of the SDGs? and (3) What are the proper
90 strategies to approach the 2030 Agenda for Sustainable Development post COVID-19?

91 In order to answer the research questions, Fuzzy Cognitive Map (FCM) modeling is utilized to
92 conceptualize the mental model of a panel of experts. FCM is a method based on the experts'
93 opinion, which have been widely applied in many research within different areas of sustainability
94 context before the pandemic, such as sustainable environment (Kokkinos et al., 2020), sustainable
95 consumption (Morone et al., 2019), and energy sustainability (Pereira et al., 2020). Due to the lack
96 of adequate and reliable data concerning COVID-19, the application of participatory methods
97 informed by a panel of experts and decision-makers has become much highlighted by researchers
98 (Sarzi-Puttini et al., 2020; Sawhney et al., 2020) to overcome this deficit. In this vein, FCM has
99 also been applied in a few studies for predicting the severity level of COVID-19 (Abbaspour Onari
100 et al., 2021), medical diagnosis of COVID-19 (Groumpos, 2021, 2020), and healthcare service
101 quality during the current pandemic (Babroudi et al., 2021). Also for Iran, as a reach country in
102 terms of renewable energies (Fadai et al., 2011), a study was conducted by Ghaboulian Zare et al.
103 (2022), which concluded that the continuation of the pandemic situation can result in the shrink of
104 government budget and abstain private companies from renewable energy projects. However, the
105 literature lacks a study that has applied FCM to analyze strategies regarding the UN's SDGs in the
106 post-COVID-19 era. To the best of the authors' knowledge, this research is the first attempt to
107 employ FCM to identify the causality strength of the links among the SDGs and analyze recovery
108 scenarios considering the COVID-19 pandemic in Iran.

109 The rest of the paper is structured as follows. Section 2 explains the research design and the
110 methodology framework applied in this study. Section 3 provides an overview of the panel experts
111 who participated in this research and presents the main steps to build the FCM model. Strategy
112 formulation and scenario testing, accompanied with the analysis of the test results are provided
113 and discussed in section 4. And finally, section 5 concludes the research and provides future
114 research recommendations for further studies.

115 2. Research design and methodology

116 Applying a mixed-method approach, two main steps were taken in this research as shown in Fig.
117 1. Considering the complex interconnections between SDGs, FCM was applied to draw the
118 causality among the SDGs in the concept mapping stage. Then, recommended strategies by experts
119 were tested in the model and analyzed in the scenario analysis stage.

120 A set of variables and their relevant interconnections, which are derived from the knowledge and
121 experience of experts and key stakeholders, are the two main pillars of a FCM model. On this
122 basis, the main four steps of FCM modeling, adopted from (Kontogianni et al., 2012; Wang et al.,
123 2019) and elaborated for our research, are as follows:

124 **Step 1.** Concept (node) selection: In this step, the 17 SDGs and COVID-19 were considered as
125 nodes in the FCM model, presented by $C = \{c_1, c_2, \dots, c_n\}$.

126 **Step 2.** Fuzzy FCM questionnaire: A questionnaire was designed to capture the experts' viewpoint
127 regarding the existence and the weight of causal relationships between the nodes. A seven-point
128 scale was considered for weights, including "high", "medium" and "low" in either positive or
129 negative directions, as well as "no effect" to show that c_i does not affect c_j .

130 **Step 3.** Building the diagraph and the adjacency matrix: The linguistic terms in the questionnaire
131 were translated into triangular fuzzy numbers (TFNs) based on the experts' opinion reflected in
132 Table 1, transformed into crisp values and then, used to build the adjacency matrix. Besides the
133 weight of the arcs between the identified SDGs, the weights for the COVID-19 level of effect on
134 the SDGs were used to weight the arcs linking COVID-19 to the other nodes.

135 **Step 4.** Specifying the activation level of the driver nodes (COVID-19 and five proposed
136 strategies) and simulating the scenarios: An initial activation vector was applied as an input for the
137 driver components in the model and the values of the ordinary components were simulated. For
138 each component, the activation level was also illustrated by the seven-point scale
139 $\{H^+, M^+, L^+, N, L^-, M^-, H^-\}$, ranging from fully active with a positive relative change to fully
140 active with a negative relative change. The simulation process was conducted repeatedly for each
141 scenario by changing the activation level of the nodes. Finally, based on the simulation of the
142 scenarios, relevant recommendations for the adoption of the proposed strategies by decision-
143 makers and authorities were provided.

144 3. FCM model building

145 According to the wide range of the SDGs within the 2030 Agenda for Sustainable Development,
146 22 potential experts from different fields of activity were invited to the research. Finally, 9 experts
147 participated in our research. The responses were gathered from the expert panel through
148 questionnaires to build the FCM model from May 5, 2021, to June 28, 2021. However, formulating
149 the scenarios and identifying their effect on each SDG was conducted based on an interview with
150 3 experts. Table 2 reports the characteristics of the expert panel in our research.

151 The FCM diagraph was constructed based on the SDGs and their existing relationships specified
152 by the experts. Each SDG was added to the model as a component. Then the weights of the arcs,
153 stated by the experts, were used to construct the FCM adjacency matrix. COVID-19 was also added
154 to the model as a driver component affecting the SDGs, and the weights of their linking arcs were
155 used to complete the adjacency matrix. Then, five strategies proposed by the experts were added
156 to the model as five driver nodes. The weights of the arcs from these strategies to the SDGs affected
157 by them were also specified and added to the model.

158 Fig. 2 illustrates the FCM diagraph constructed in the Mental Modeler software. The blue arcs
159 with '+' signs demonstrate a positive magnitude in the causal relationship between the nodes (an
160 increase of concept C_j when C_i increases), while the red arcs with '-' signs indicate a negative one
161 (a decrease of concept C_j when C_i increases). Moreover, the thicker the arc, the higher the
162 relationship weight. The developed diagraph contains 23 components and 205 connections, leading
163 to 8.9 connections per component. The number of existing connections compared to the number
164 of all possible connections is 0.4, which shows the density of the model. Table 3 presents the
165 metrics for the model components, including indegree index (the sum of the weights of the
166 component's entering arcs), the outdegree index (the sum of the weights of the component's
167 leaving arcs), and the centrality index (the sum of incoming and outgoing connections) (Santoro
168 et al., 2019). To validate the model, sensitivity analysis was conducted by considering different
169 activation levels for the nodes, and the output was presented to and confirmed by a group of 3
170 experts.

171 4. Strategy formulation and scenario analysis

172 The strategies considered in the model are introduced in section 4.1 and the potential scenarios
173 regarding different activation levels of these strategies are tested and analyzed in section 4.2.

174 4.1. Strategy formulation

175 Given the experts' opinion, five strategies, including *green management*, *sustainable food systems*,
176 *energizing the labor market*, *inclusive education*, and *supporting research and technology*
177 *initiatives in the energy sector* were selected to be considered in the model. These strategies are
178 described in the following.

179 *Strategy A: Green management*

180 *Green management* is a comprehensive strategy referring to the utilization of water, energy, and
181 other resources and their effects on the environment. In addition to the changes in the resource
182 consumption behavior of households and organizations (Abulibdeh, 2021; Baker et al., 2020; Liu
183 et al., 2020; Ranjbari et al., 2021a), the pandemic can be an opportunity to encourage people and
184 organizations to try and continue working from home during and after the pandemic, which may
185 result in lower time and energy consumption (Kylili et al., 2020). During the pandemic, the Iranian
186 government should try to build the essential infrastructures for digital government services and
187 other similar facilities to reduce the need for the presence of workers at their workplace, and at the
188 same time, try to promote sustainable consumption of resources. Therefore, this strategy entails a
189 variety of activities to be conducted by the government and authorities to make the transition
190 towards comprehensive green management possible. These activities may include but are not
191 limited to the following: (1) providing the require infrastructure for information and

192 communication technologies, and support high-speed internet all over the country, especially in
193 outlying and rural areas, (2) building and supporting sharing platforms for information technology
194 equipment, such as laptops and tablets, to enable poor and vulnerable people to follow the changes
195 happening in the lifestyle and workstyle post pandemic, (3) making public services online and
196 reducing in-person services as much as possible, (4) reducing the use of papers in public and
197 private organizations by improving online systems and integrating and linking data bases, (5)
198 implementing systems to increase efficiency in water consumption, reduce waste of water in
199 governmental organizations, and encourage private sectors and households to save water, (6)
200 improving energy efficiency and utilizing clean and renewable energy resources, (7) facilitating
201 teleworking and providing regulations for both public and private organizations in this regard, and
202 (8) implementing systems to improve waste sorting and recycling in public and private sectors as
203 well as households.

204 *Strategy B: Sustainable food systems*

205 Research shows that the COVID-19 pandemic has affected food security in Iran (Rad et al., 2021)
206 and worldwide (Niles et al., 2021; Sreenonchai and Arunrat, 2021). Strategy B (*Sustainable food*
207 *systems*) concentrates on providing a sufficient food supply for the whole population in Iran,
208 aiming at providing access for all people to healthy food and nutrients, which can be achieved by
209 providing the required financial support and subsidies as well as strengthening the food supply
210 chain in this country. The main suggested activities required to fulfill the implementation of this
211 strategy are as follows: (1) providing comprehensive databases on all food supply chain sectors
212 and stakeholders, (2) establishing a strong and transparent communication network among food
213 supply chain stakeholders to balance supply and demand, and to prevent disorders caused by

214 profiteers, (3) improving food supply chain management to increase efficiency and reduce the cost
215 of food production and distribution, (4) using methods, tools, and information to improve
216 efficiency and reduce food losses and waste, and (5) providing sufficient financial and non-
217 financial support to farmers to reduce the effect of the pandemic on their activities, and to
218 consumers in vulnerable situations to help them access their required food and nutrition in the
219 wake of the pandemic.

220 *Strategy C: Energizing the labor market*

221 The pandemic has affected the labor market in developing countries both in terms of income and
222 job loss (Bottan et al., 2020) and mental health (Radulescu et al., 2021). To support the labor
223 market in Iran, which is highly affected by the pandemic, *energizing the labor market* was
224 suggested as a strategy to focus on the financial and non-financial support for the creation of new
225 jobs and attempts to maintain current jobs by supporting their relevant activities. Critical
226 components of this strategy include: (1) financial and non-financial support to workers and the
227 self-employed to overcome the economic pressure resulting from their lower income during the
228 pandemic, (2) providing more support for social security and unemployment insurance of workers,
229 (3) facilitating work from home where possible, (4) recovery plans for small and medium
230 enterprises and supporting them to adopt digital technologies, and (5) extending tax payments by
231 institutions and small and medium enterprises.

232 *Strategy D: Inclusive education*

233 Iran is facing various challenges regarding distance learning during the pandemic due to the lack
234 of network infrastructure, access of all students to the required digital devices, and internet access,

235 like other developing countries (Tadesse and Muluye, 2020). The strategy *Inclusive education* was
236 proposed aiming at the development and enhancing of the required platforms to provide fair
237 education to all children, and to improve work conditions and opportunities in poor regions by
238 providing sufficient facilities for parents in order to allow their children to study. The main
239 elements of this strategy are as follows: (1) providing access to electricity, internet, computers,
240 and other digital communication tools for education and training of children and also university
241 students especially in faraway and poor regions, (2) trying to minimize child labor despite the
242 economic pressure of the pandemic situation on poor people and providing the opportunity for all
243 children to study school lessons, (3) providing the students in poor regions with food and nutrients
244 at schools, and (4) providing basic sanitation facilities at schools and educate children, especially
245 girls, in terms of hygiene and sanitation.

246 *Strategy E: Supporting research and technology initiatives in the energy sector*

247 Although Iran is a rich country in terms of both renewable and non-renewable energy sources
248 (Fadai et al., 2011), renewable sources of energy do not play a significant role in the energy supply
249 in this country (Solaymani, 2021). Research shows that Iran is facing several challenges for
250 knowledge creation and diffusion of renewable energy technologies (Fartash et al., 2021), and the
251 post-pandemic era is worse than the pre-pandemic regarding the development of renewable
252 energies in this country (Ghaboulian Zare et al., 2022). Strategy E targets *research and technology*
253 *initiatives in the energy sector* and concentrates on financial support for research on renewable
254 energies. The main components of this strategy are as follow: (1) removing subsidies from fossil
255 fuels and instead, providing subsidies for renewable energy resources consumption by public and
256 private sectors, (2) devoting financial support and funds to support the development of renewable

257 energy infrastructures and to foster technological innovation through research collaborations, (3)
258 supporting start-ups and venture capital financing in the field of renewable energies, and (4)
259 promoting innovation through competition among research institutions and also research and
260 development departments of public and private companies.

261 4.2. Scenario analysis and discussion

262 Before analyzing the implementation of the proposed scenarios, the effect of the COVID-19
263 pandemic on the achievement of SDGs is simulated in this section. Two different activation levels
264 of $L_{\text{COVID-19}}^0 = M^+$ and $L_{\text{COVID-19}}^0 = H^+$ are considered for COVID-19 node in the built FCM
265 model, representing middle and high relative change in the current situation of the pandemic,
266 respectively. These activation levels, which refer to the worsening of the pandemic situation, have
267 been considered based on the opinion of experts believing that with respect to vaccination rate and
268 new virus variants, the pandemic or its consequences will last long in Iran. As can be seen in Fig.
269 3, by changing the activation level of COVID-19 from medium to high, (i) more SDGs would be
270 affected, and (ii) the negative impact on different SDGs would increase. SDGs 1, 5, 6, 8, 9, 10, 12,
271 14, 15, and 17 would be affected negatively even with a medium level of worsening the pandemic
272 situation. The most drastic impact is on SDG 17 (Partnerships for the goals), followed by SDG 9
273 (Industry, innovation, and infrastructure). As the governments around the world are struggling
274 with the COVID-19 pandemic, it is trivial to allocate most of their resources to overcome the
275 pandemic and its effects, and helping other countries or considering environmental and social
276 programs are a lower priority. Besides, some SDGs are difficult to be achieved in Iran even in the
277 absence of the pandemic, and there is not a properly defined program for them. Therefore, the

278 pandemic would not significantly affect these SDGs and even by deactivating the COVID-19 node,
279 the achievement of these SDGs would not improve.

280 In order to analyze the effects of the proposed strategies on the UN's SDGs achievement in the
281 post-COVID-19 era, potential scenarios based on different activation levels of the mentioned
282 strategies are tested. Besides, the implementation of a combination of two and three proposed
283 strategies is also tested and analyzed in this section. The results of these tests are discussed in the
284 following sections.

285 4.2.1. Activation of Strategy A: Green management

286 Activation of Strategy A in the designed model considering $L_{\text{COVID-19}}^0 = M^+$ leads to the changes
287 shown in Fig. 4. Three different activation levels are considered for Strategy A in this figure. Fig.
288 4 (a) refers to the low activation level of Strategy A ($L_A^0 = L^+$) and shows the negative impact on
289 eight SDGs. By changing the activation level of Strategy A to medium level ($L_A^0 = M^+$) in Fig. 4
290 (c), the number of SDGs with negative relative change reduces to six, and finally, with a high
291 activation level of Strategy A ($L_A^0 = H^+$) as illustrated in Fig. 4 (e), the number of SDGs with
292 negative relative change remain unchanged but their relative change declines. In addition, by
293 implementing this strategy, eight SDGs would have a relative positive change. As can be seen,
294 SDG 17 (Partnerships for the other SDGs) experiences the highest relative change in the negative
295 direction by implementing Strategy A.

296 While considering a high activation level for COVID-19 ($L_{\text{COVID-19}}^0 = H^+$), activation of Strategy A
297 at low, medium, and high levels are illustrated in Fig. 4 (b), (d), and (f), respectively. As expected,
298 the number of the SDGs with a negative relative change would increase if the pandemic situation

299 worsens. Again, SDG 17 shows the highest negative relative change in terms of all the considered
300 activation levels of Strategy A.

301 Activating Strategy A has an upper-medium relative impact on SDGs 7 (affordable and clean
302 energy), 11 (sustainable cities and communities), and 13, a lower medium relative impact on SDGs
303 3 (good health and well-being), 6 (clean water and sanitation), 10 (reduced inequalities), and 12
304 (responsible consumption & production), and a low relative impact on SDGs 14 and 16. Therefore,
305 the achievement of these SDGs improves by activating Strategy A. A notable result is that although
306 SDGs 6 (referring to clean water and sanitation) and 14 (referring to life below water) are slightly
307 affected by this strategy, they have a high positive relative change in practice. In addition, SDGs
308 6, 7, and 13 with the highest positive relative change remain constant even with the high activation
309 level of the COVID-19 pandemic. The following reasons can describe the obtained results: (i)
310 SDGs 6 (Clean water and sanitation), 7 (Affordable and clean energy), and 13 (Climate action),
311 are mostly affected by government policies rather than COVID-19. Therefore, increasing the
312 activation level of COVID-19 may not change these SDGs significantly; and (ii) both SDG 6 and
313 14, which are less affected by Strategy A, are about water resources. Although the direct effects
314 of other SDGs on SDGs 6 and 14 are low, their cumulative low indirect effects lead to a significant
315 positive change in these two SDGs.

316 4.2.2. Activation of Strategy B: *Sustainable food systems*

317 Implementing Strategy B at a low level ($L_B^0 = L^+$) while assuming that the pandemic situation
318 improves at a medium level ($L_{\text{COVID-19}}^0 = M^+$), leads to relative changes in the SDGs as illustrated
319 in Fig. 5 (a). In this case, eight SDGs would experience a negative relative change among which
320 SDG 17 would face the highest level of change. Applying Strategy B at the medium level reduces

321 the number of SDGs with negative change and only by considering a high level of activation, six
322 SDGs would experience positive relative changes. Moreover, applying this strategy in the high
323 and medium levels of pandemic and in case of worsening the situation, as illustrated in sections
324 (b), (d), and (f) of Fig. 5, respectively, would affect almost all SDGs negatively.

325 This strategy has an upper-medium relative impact on SDG 2 (Zero hunger) (upper medium
326 relative impact), a medium relative impact on SDGs 3, a lower medium relative impact on SDGs
327 10, 12, 13, 14, and 15, and a low relative impact on SDGs 4 and 16. As shown in Fig. 5, activation
328 of this strategy enhances the achievement of SDGs 10, 13, 14, and 15. These SDGs are not subject
329 to negative effects even in the presence of COVID-19 at the high activation level, which
330 corresponds to strongly worsening the pandemic situation. Furthermore, although implementing
331 Strategy B directly affects SDG 2 with a medium to high relative impact, no effect on this SDG
332 can be seen in Fig. 5. This may be because SDG 2 on one hand is mostly affected by SDGs 1, 8,
333 10, and 16 with an upper-medium level of relative impact, by SDGs 4 and 12 with a medium level
334 of relative impact and eventually, by SDGs 3, 9, 13 and 17 with a low level of relative impact.
335 This SDG on the other hand is imposed to a high negative impact from the pandemic, since the
336 negative impacts of the COVID-19 on the economy affect both the purchasing power of the people
337 and the activities related to the food supply chains. In addition, SDGs 1, 8, and 10, which have the
338 greatest impact on SDG 2, are almost neutral against Strategy B (SDGs 1 and 8) or slightly
339 impacted by this strategy (SDGs 10). Therefore, the accumulation of these effects leads to not
340 observing a significant effect on SDG 2 by implementing Strategy B.

341 4.2.3. Activation of Strategy C: *Energizing the labor market*

342 As can be seen in sections (a), (c) and (e) of Fig. 6, by implementing Strategy C while the pandemic
343 situation experiences a medium improvement, a lower number of SDGs would face a negative
344 relative change. Besides, Fig. 6 (b), (d), and (f) indicate that more SDGs would be affected
345 negatively even by implementing this strategy if the pandemic situation becomes worse.

346 SDGs 1, 5 (Gender equality), 8, 10, and 16 are affected positively by applying Strategy C.
347 Interestingly, positive relative changes are observed in the SDGs that have been directly addressed
348 by this strategy, except SDGs 2 and 3. This result may not be unexpected for SDG 3, since it is
349 weakly influenced by Strategy C. However, it is unexpected regarding SDG 2, which is moderately
350 influenced by Strategy C. The reason for such a result may be the high vulnerability of SDG2
351 originating from both the pandemic and other political and economic policies. Another notable
352 point regarding this strategy is that SDG1 experiences a positive relative change, which is only
353 achieved by applying Strategy C among all proposed strategies. Therefore, if SDG1 is a priority
354 for policy-makers, special attention should be devoted to implementing Strategy C.

355 4.2.4. Activation of Strategy D: *Inclusive education*

356 Sections (b) and (d) of Fig. 7 indicate that all the SDGs experience negative relative changes in
357 the presence of Strategy D ($L_D^0 = L^+$) or $D(L_D^0 = M^+)$, however Strategy D ($L_D^0 = H^+$) leads to
358 positive relative changes in SDGs 4 and 5. The medium level of COVID-19 affects the SDGs more
359 slightly and lets Strategy D change four SDGs positively, including SDGs 4, 5, 10, and 16. This
360 strategy mainly addresses SDG 4 and to a lesser extent SDGs 5, 10, and 16. As can be seen in Fig.
361 7, activation of this strategy at the high level leads to positive relative changes in all the mentioned

362 SDGs. It is noticeable that although SDG 5 is moderately affected by Strategy D, it shows the most
363 positive relative change among the addressed ones. This can be explained by the fact that although
364 Strategy D has the most direct impact on SDG 4 and weak impacts on SDGs 5, 10, and 16, SDGs
365 4, 10, and 16 have high impacts on SDG 5, which refers to gender equality. Thus, SDG 5 is subject
366 to the direct impact of the inclusive education strategy and the indirect impact received from other
367 addressed SDGs in this strategy. Other mentioned SDGs are weakly influenced by Strategy D and
368 also the other addressed SDGs. Furthermore, the COVID-19 pandemic slightly affects SDG 5
369 while it has a high negative impact on other SDGs.

370 4.2.5. Activation of Strategy E: *Supporting research and technology initiatives in the energy*
371 *sector*

372 Strategy E is the only strategy among the implemented strategies, which can cause a positive
373 relative change in the SDGs even with a medium activation level (see section (c) of Fig. 8). This
374 strategy leads to a positive relative change in six SDGs, including SDGs 7, 9, 10, 11, 12, and 13 in
375 both medium and high activation levels of COVID-19 (see section (e) and (f) of Fig. 8).

376 Eventually, this strategy results in a positive relative change in SDG 9, which always suffers from
377 negative relative change even in case of implementing Strategies A to D. Also, the positive relative
378 change of SDG 9 against other SDGs with positive relative change (SDGs 7, 9, 10, 11, 12, and 13)
379 is noteworthy. The main reason may be that SDGs 7 and 13 (with high impacts), SDG 9 (with
380 upper medium impact), and SDGs 10, 11, and 12 (with low impacts) are directly influenced by
381 Strategy E. Furthermore, the high impact of SDG 9, which is focussed on the industry, innovation,
382 and infrastructure, from SDG 7 that targets affordable and clean energy intensifies the impact of
383 SDG 9 from the implementation of this strategy.

384 4.2.6. Activation of a combination of the proposed strategies

385 In this section, different possible combinations of strategies A, B, C, D, and E are analyzed.
386 Hereon, the M^+ activation level of COVID-19 is considered to test different scenarios
387 (combinations of strategies). First, the activation level for all the five strategies is set to be $L^0 =$
388 L^+ . This is because activating each strategy needs a sufficient budget and government
389 supervision and therefore, it is not possible to activate all the strategies simultaneously at the
390 high or medium levels. Activating all the outgoing arcs from the strategy nodes leads to relative
391 changes in the SDGs as shown in Fig. 9. As illustrated in this figure, only the relative change of
392 SDG 13 turns positive and SDGs 1, 8, and 17 remain unchanged. Moreover, a relative
393 improvement is observed in SDG 9, and the negative relative changes of SDGs 5, 6, 10, 12, 14,
394 and 15 disappear. In the next step, all combinations of two strategies are tested for M^+ and H^+
395 activation levels. As stated previously, it is not possible to activate more than one strategy at a
396 high level. Scenarios based on Strategy A are examined in detail, as an instance to show the
397 analysis approach. Table 4 shows the results of tests for implementing Strategy A and also a
398 combination of Strategy A with other strategies. Results indicate that SDG 1 always experiences
399 a negative relative change except in case of implementing Strategy C ($L_C^0 = H^+$) and also in case
400 of the implementation the combination of Strategy A ($L_A^0 = M^+$) and Strategy C ($L_C^0 = H^+$).
401 Moreover, Table 4 shows that applying the single Strategy A ($L_A^0 = H^+$) affects most of the
402 SDGs. Applying the combination of two strategies that include Strategy A may on one hand
403 cause some positive relative changes to disappear, and on the other hand, eliminate some
404 negative relative changes. Therefore, it can not be concluded that a given scenario is absolutely
405 better than the others. Besides, no synergetic or redundancy relationships are observed between
406 the scenarios presented in this table.

407 The results of similar tests for the combination of all the proposed strategies are illustrated in Fig.
408 10. As can be seen in various sections of this figure, the combination of Strategies D and B are not
409 satisfactory in comparison with the other tested strategy combinations. However, the combinations
410 of Strategy A with Strategy B or E are more satisfactory than the others in terms of the
411 improvements in achieving more SDGs. As can be seen, by implementing each combination, the
412 achievement of some SDGs is improved, some are unchanged, and some are worsened. Therefore,
413 policy-makers should select the combination that has the highest favorable effect on the prioritized
414 SDGs with respect to national/international interests.

415 The effects of implementing a combination of three strategies on the SDGs are also analyzed in
416 this section to provide a clearer picture of the effect of the proposed policies on the SDGs
417 achievement in Iran. In this regard, the implementation of a combination of a given strategy at the
418 medium activation level and two other strategies at the low activation levels are studied to account
419 for the limitations of budget and the government supervision capacity. Table 5 shows the results
420 of simulating the effect of implementing a combination of strategies, which include $A(M^+)$. As
421 can be seen, scenarios $A(M^+)/B(L^+)/C(L^+)$, $A(M^+)/B(L^+)/D(L^+)$ and $A(M^+)/D(L^+)/E(L^+)$
422 are dominated by other scenarios and should be eliminated from more considerations. Other
423 scenarios reported in the table are temporarily kept to be compared with scenarios analyzed
424 regarding the other strategies. In Table 6, the results of simulating different scenarios comprising
425 of three strategies including Strategy $B(M^+)$ are presented. Only two scenarios are non-dominated
426 in this case, which include $B(M^+)/E(L^+)/A(L^+)$ and $B(M^+)/C(L^+)/D(L^+)$. Scenarios
427 $B(M^+)/E(L^+)/C(L^+)$ and $B(M^+)/A(L^+)/C(L^+)$ show the same results as $B(M^+)/E(L^+)/D(L^+)$
428 and $B(M^+)/A(L^+)/D(L^+)$, respectively. However, all of them are dominated scenarios. Table 7
429 shows the simulation results for the scenarios composed of three strategies including $C(M^+)$. As

430 can be seen, scenarios $C(M^+)/A(L^+)/B(L^+)$, $C(M^+)/A(L^+)/E(L^+)$ and $C(M^+)/B(L^+)/E(L^+)$
431 are non-dominated. This indicates that combinations of Strategy D do not result in positive
432 changes. In table 8, simulation results are provided for scenarios composed of three strategies
433 based on $D(M^+)$, where scenarios $D(M^+)/A(L^+)/B(L^+)$ and $D(M^+)/A(L^+)/E(L^+)$ are non-
434 dominated. And finally, Table 9 presents scenarios that are composed of three strategies
435 considering $E(M^+)$. Scenarios $E(M^+)/A(L^+)/B(L^+)$ and $E(M^+)/D(L^+)/C(L^+)$ are non-
436 dominated ones based on the results of this table. According to the analyses results provided in
437 Tables 5-9, most scenarios are dominated and should be eliminated from further considerations.
438 Non-dominated scenarios obtained from each table are collected and compared with each other to
439 find ultimate non-dominated scenarios, which include $D(L^+)/C(L^+)/A(M^+)$,
440 $C(M^+)/B(L^+)/A(L^+)$, $A(L^+)/C(M^+)/E(L^+)$, $E(L^+)/C(M^+)/B(L^+)$, $E(M^+)/B(L^+)/A(L^+)$, and
441 $E(M^+)/D(L^+)/C(L^+)$. Analysis of the results obtained from the simulation of scenarios
442 comprising of three strategies shows that the scenarios based on Strategy $B(L_B^0 = M^+)$ or
443 $D(L_D^0 = M^+)$ are totally dominated by other scenarios, while the ones based on Strategy
444 $C(L_C^0 = M^+)$ have the most non-dominated outcomes.

445 Comparison of the results obtained from the analysis of the implementation of one, two, and three
446 strategies in the presence of the COVID-19 pandemic shows that activating two strategies at high
447 and medium levels instead of one strategy at the high level does not necessarily lead to a significant
448 improvement. This is also true about the results of combining three strategies in comparison with
449 single strategy implementation. Moreover, the results of implementing a combination of three
450 strategies are poorer than the implementation of two strategies or a single one. More specifically,
451 the analysis in this section revealed that Strategy E has a crucial effect on the achievement of SDG
452 9 (Industry, innovation, and infrastructure), while other scenarios can not make any changes in the

453 achievement of this SDG. Applying Strategy $E(L_E^0 = M^+)$ improves the achievement of SDG 9,
454 but the relative change of this SDG remains negative. To achieve a positive relative change in this
455 SDG, only the single Strategy $E(L_E^0 = H^+)$ should be implemented. Therefore, results confirm
456 that focusing on the implementation of a single strategy provides better performance in the
457 achievement of SDGs post COVID-19 pandemic in comparison with the combination of two or
458 three strategies at low levels.

459 5. Concluding remarks

460 Implementation of international agreements such as the UN's 2030 Agenda for Sustainable
461 Development needs cooperation between different sectors of societies within a system as a whole.
462 Due to the significant effects of the COVID-19 restrictions on the 2030 Agenda and the
463 achievement of its associated SDGs, this research was carried out to support the SDGs
464 achievement post COVID-19 in Iran, as a developing country. Applying a qualitative FCM-based
465 method, the following steps were taken and results were obtained. (1) the key interconnections
466 among the SDGs were specified; (2) potential effects of COVID-19 on the SDGs achievement
467 were synthesized; (3) five strategies were considered, and for each strategy, three scenarios
468 considering different levels of COVID-19 effects were simulated aiming to reduce the negative
469 effects of COVID-19 on the SDGs achievement. Many other scenarios were also considered by
470 combining two or three of the proposed strategies with different activation levels. These strategies
471 include *green management, sustainable food systems, energizing the labor market, inclusive*
472 *education, and supporting research and technology initiatives in the energy sector.* Simulations
473 showed that applying each of the five considered strategies or their combination would mitigate
474 the effect of COVID-19 on the SDGs just in case of the medium pandemic level. The outcome of

475 applying these strategies would be more challenging if the pandemic crisis level goes up
476 drastically. Findings also illustrate that implementing a single strategy at a high activation level
477 leads to better outcomes on the SDGs achievement rather than activating the combinational
478 strategies in low or medium activation levels. Applying a combination of two or more strategies,
479 having a predetermined and restricted budget and governmental supervision, results in less
480 influence on the SDGs. The outcomes of our study, contribute remarkably to the post-COVID-19
481 recovery action plan for the 2030 Agenda for Sustainable Development in Iran, with a special
482 focus on the SDGs.

483 Nevertheless, our research comes with some limitations. First, due to the lack of reliable
484 quantitative data, a qualitative simulation modeling approach was adopted. Therefore, conducting
485 quantitative and mathematical modeling with adequate and reliable data is recommended for
486 further studies. Second, this research focused on the 2030 Agenda for Sustainable Development
487 only at the SDGs level of analysis. Further research is recommended to be carried out on the targets
488 and their specific indicators, as well. Third, the case of our study was Iran, as a developing country
489 in the Middle East. The same research for the other developing countries or even less-developed
490 countries is recommended for making a comparison between the results and evaluating the
491 generalizability of the considered policies in our research. Finally, the scope of our research was
492 the whole 17 SDGs to identify SDGs affected by COVID-19. More in-depth studies on the effects
493 of the pandemic on each one of the identified SDGs affected by COVID-19 in our research are
494 encouraged to be conducted to provide a better understanding and develop suitable recovery
495 strategies.

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686

687 Figure Captions

688 **Fig. 1.** Research framework

689 **Fig. 2.** The designed FCM diagraph

690 **Fig. 3.** Relative change of SDGs considering different levels of activation for COVID-19

691 **Fig. 4.** Relative changes of SDGs considering different activation levels for COVID-19 and

692 Strategy A

693 **Fig. 5.** Relative changes of SDGs considering different activation levels for COVID-19 and

694 Strategy B

695 **Fig. 6.** Relative changes of SDGs considering different activation levels for COVID-19 and

696 Strategy C

697 **Fig. 7.** Relative changes of SDGs considering different activation levels for COVID-19 and

698 Strategy D

699 **Fig. 8.** Relative changes of SDGs considering different activation levels for COVID-19 and

700 Strategy E

701 **Fig. 9.** Relative changes of SDGs considering $L_{\text{COVID-19}}^0 = M^+$ and $L^0 = L^+$ for the strategies

702 **Fig. 10.** Relative changes of SDGs considering $L_{\text{COVID-19}}^0 = M^+$ and combinations of two

703 strategies with different activation levels

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708 Table Captions

709 **Table 1.** Linguistic terms and corresponding TFN for the weight of relationships between each
710 pair of SDGs

711 **Table 2.** Expert panel characteristics

712 **Table 3.** Type and metrics of the model components

713 **Table 4.** Summary of the SDGs relative changes in the studied scenarios involving Strategy A

714 **Table 5.** Applying Strategy A at the medium level and two other strategies at the low level

715 **Table 6.** Applying Strategy B at the medium level and two other strategies at the low level

716 **Table 7.** Applying Strategy C at the medium level and two other strategies at the low level

717 **Table 8.** Applying Strategy D at the medium level and two other strategies at the low level

718 **Table 9.** Applying Strategy E at the medium level and two other strategies at the low level

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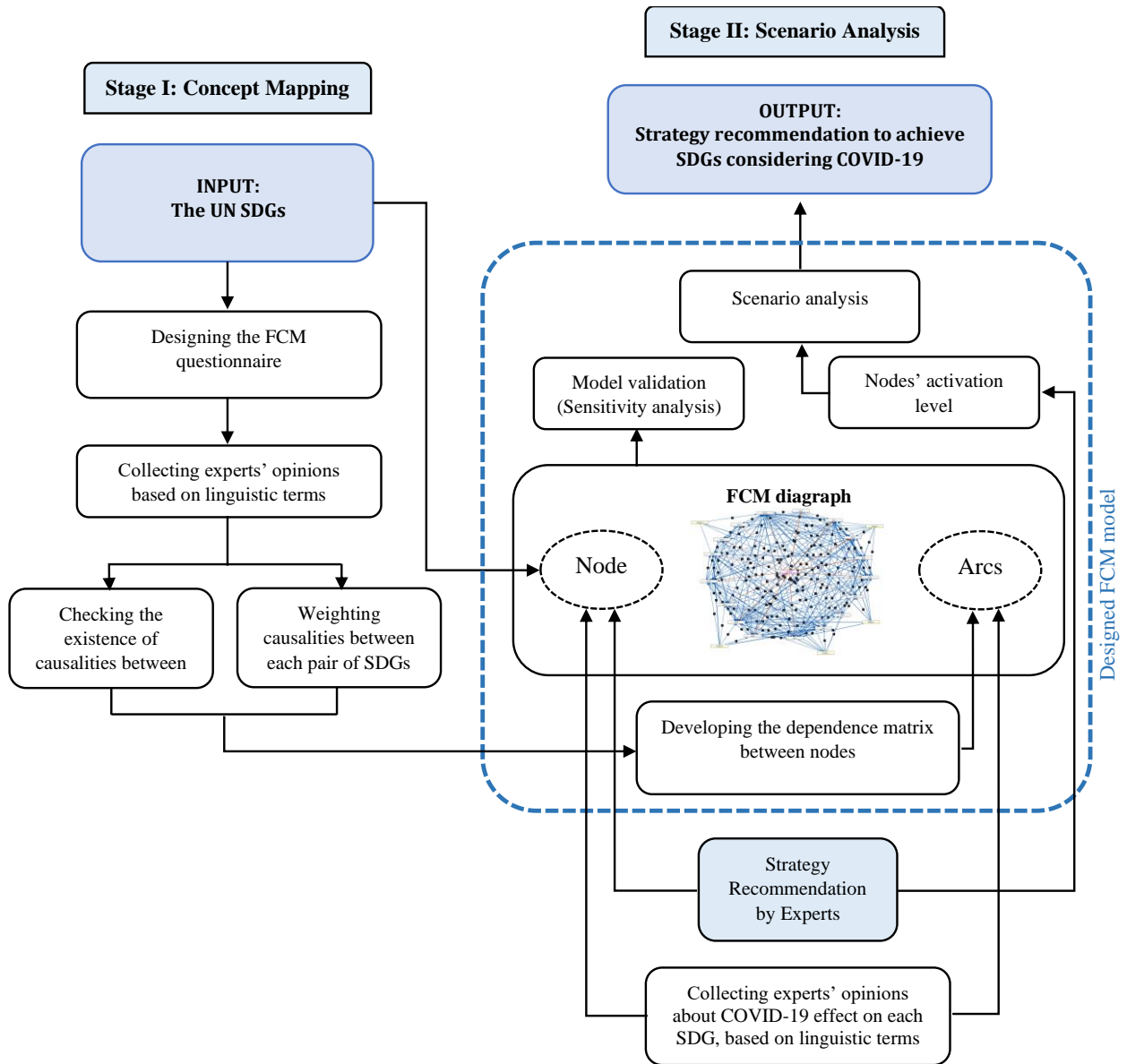


Figure 1

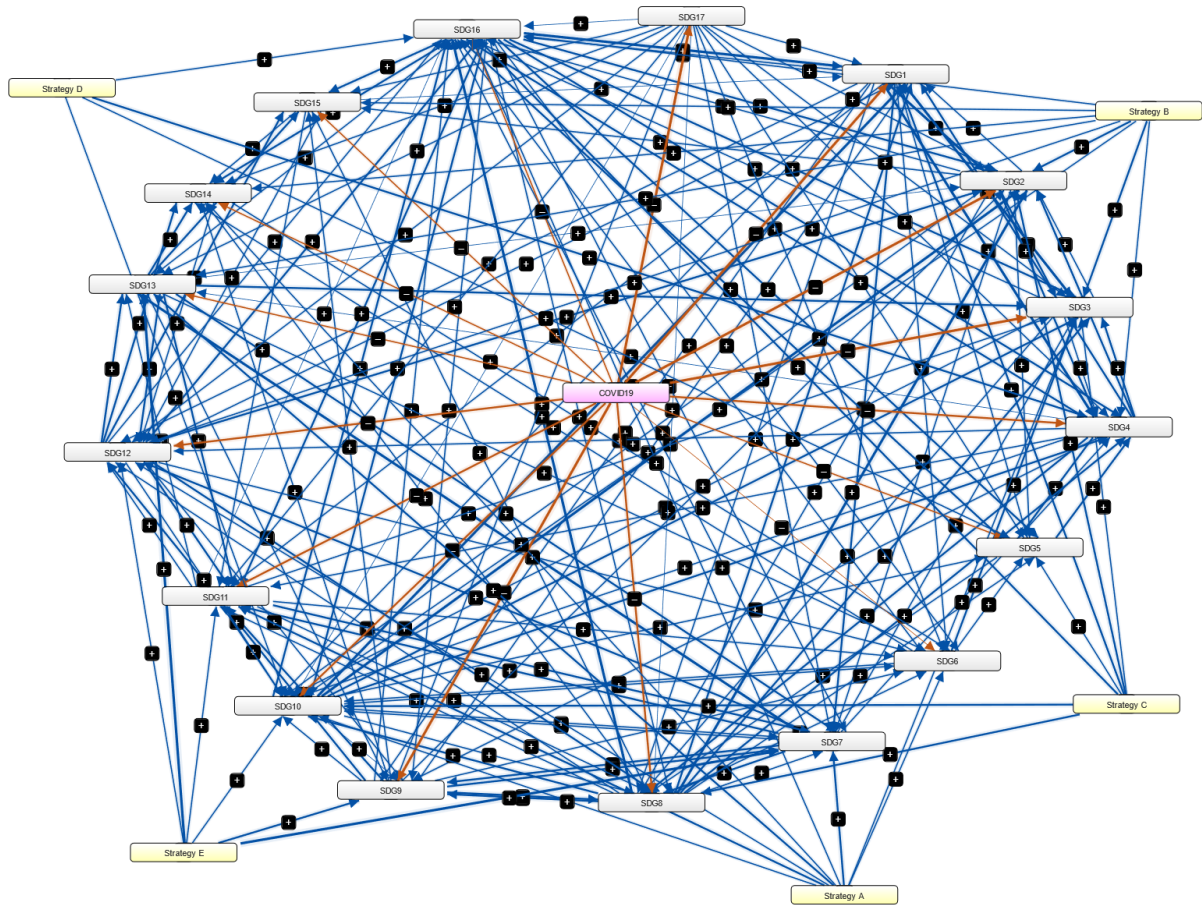
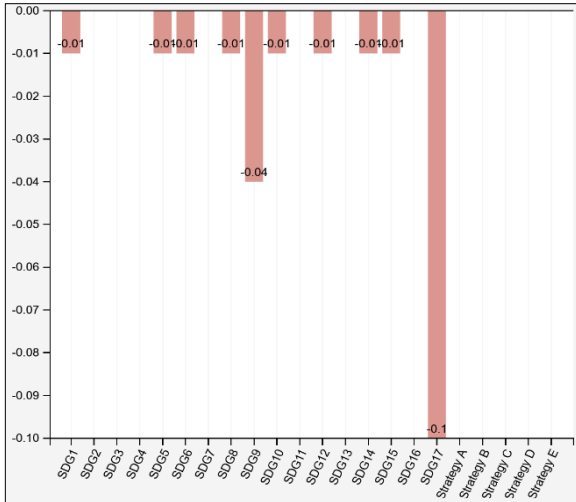
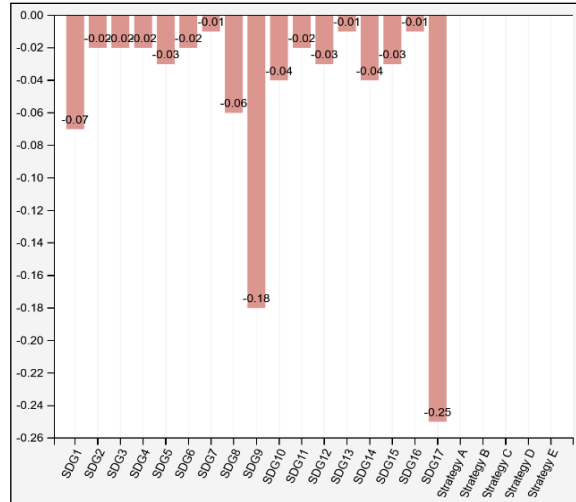


Figure 2

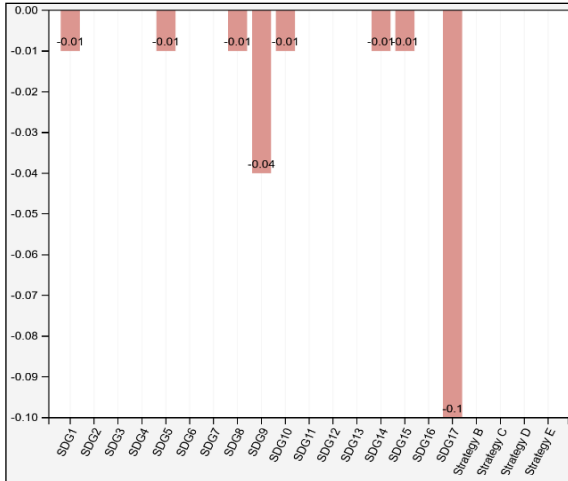


(a) $L^0_{\text{COVID-19}} = M^+$

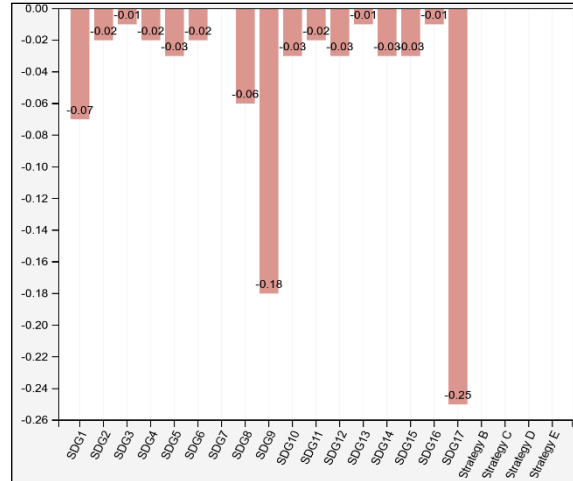


(b) $L^0_{\text{COVID-19}} = H^+$

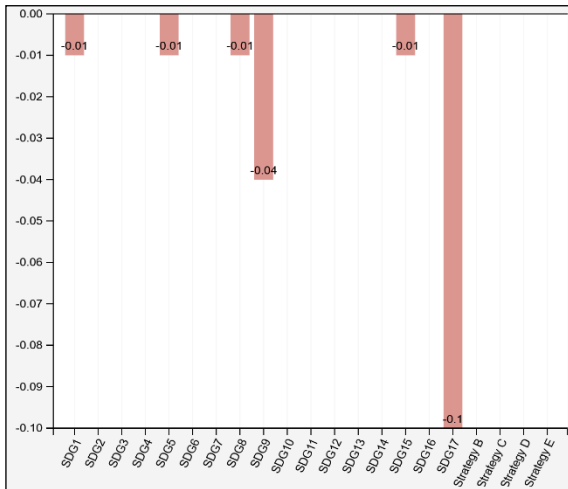
Figure 3



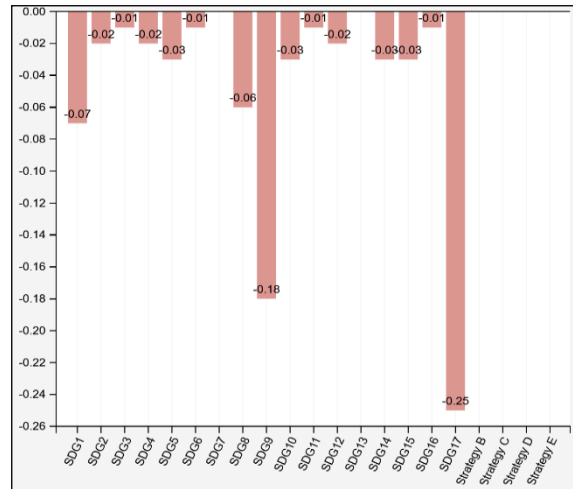
(a) $L^0_{\text{COVID-19}} = M^+, L^0_A = L^+$



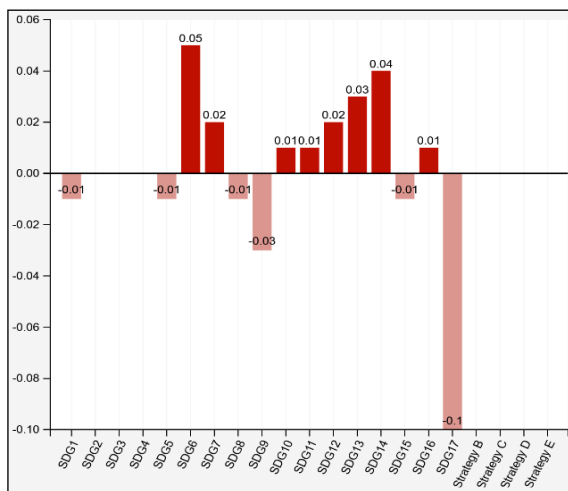
(b) $L^0_{\text{COVID-19}} = H^+, L^0_A = L^+$



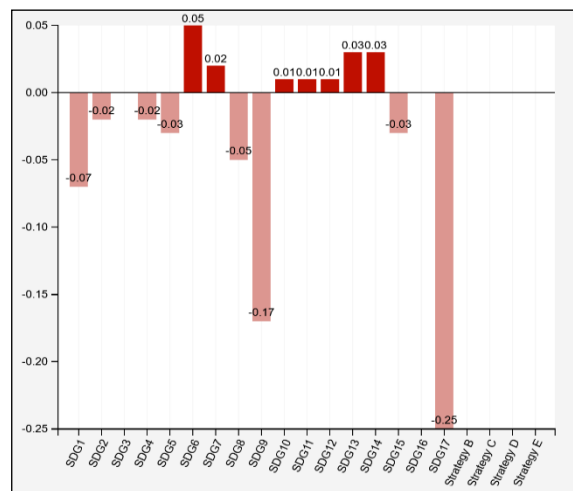
(c) $L^0_{\text{COVID-19}} = M^+, L^0_A = M^+$



(d) $L^0_{\text{COVID-19}} = H^+, L^0_A = M^+$

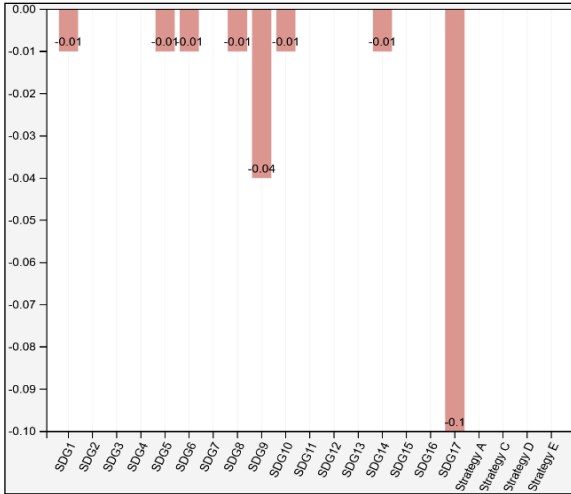


(e) $L^0_{\text{COVID-19}} = M^+, L^0_A = H^+$

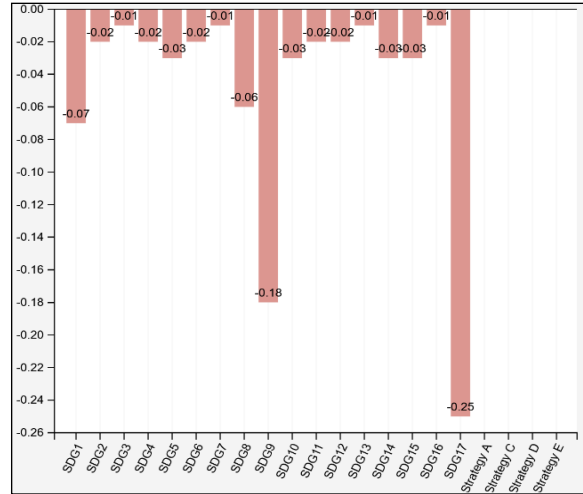


(f) $L^0_{\text{COVID-19}} = H^+, L^0_A = H^+$

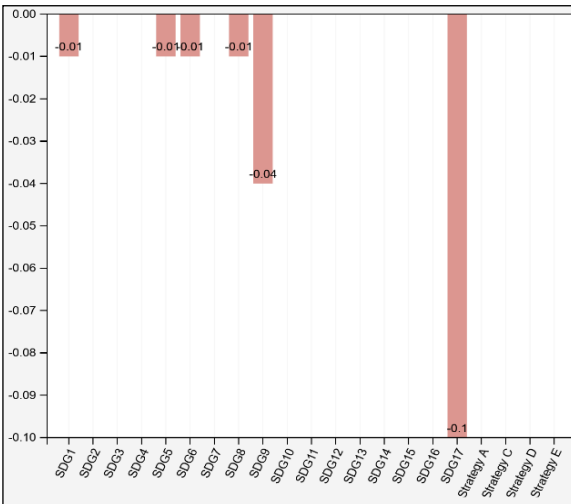
Figure 4



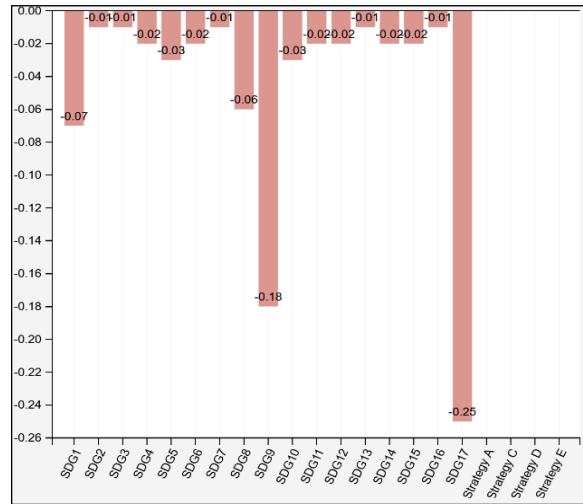
(a) $L_{\text{COVID-19}}^0 = M^+, L_B^0 = L^+$



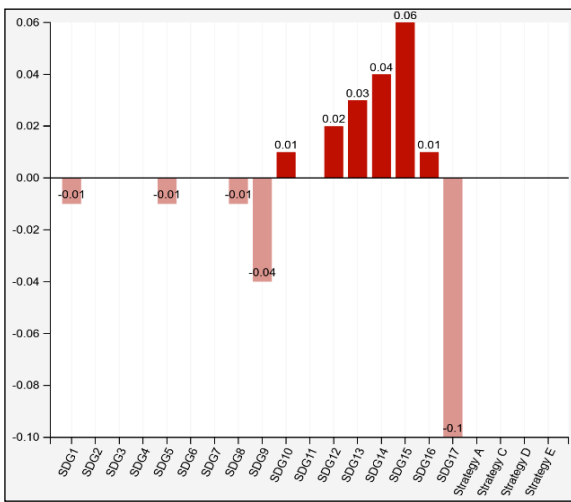
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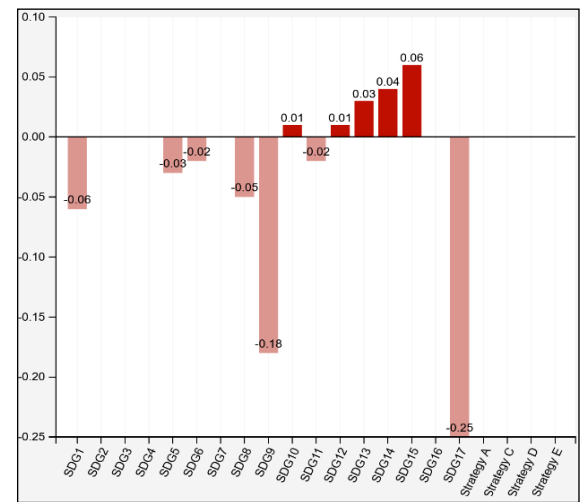
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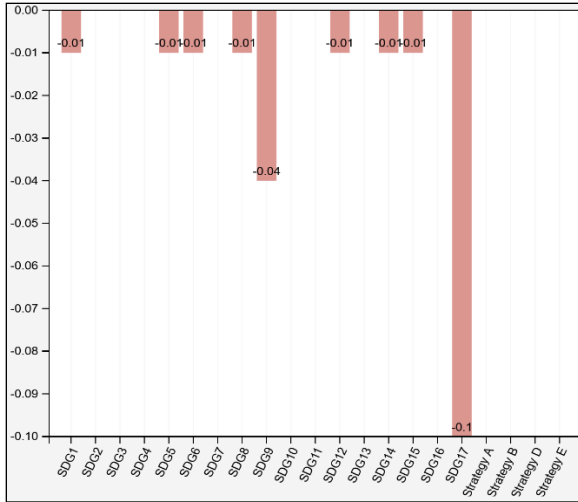


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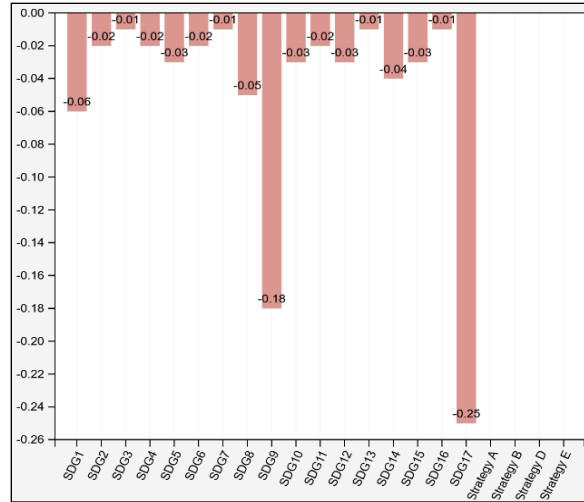


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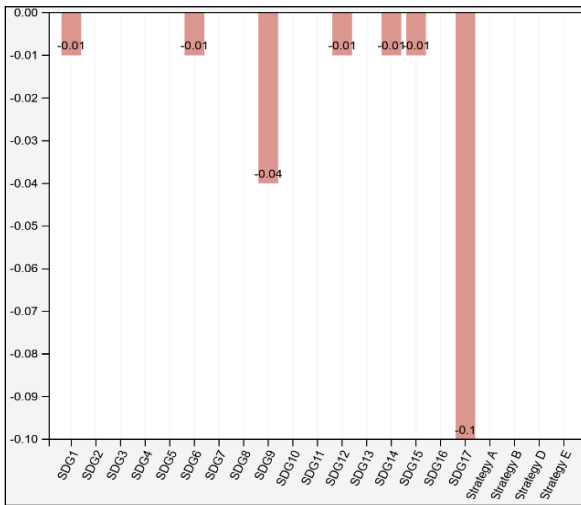
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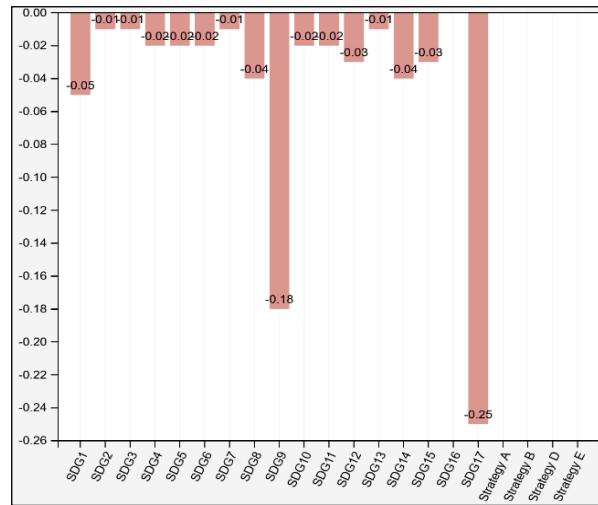
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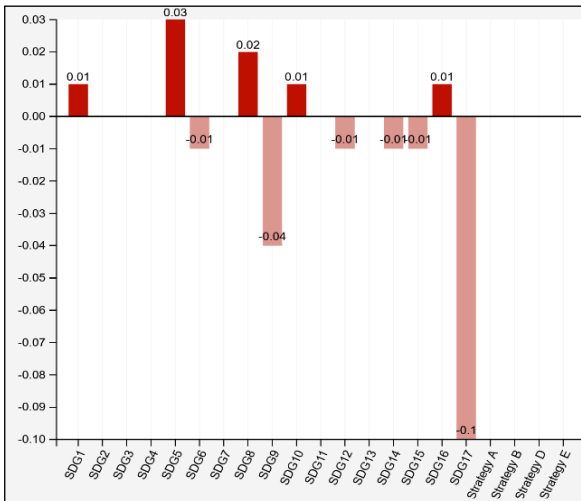
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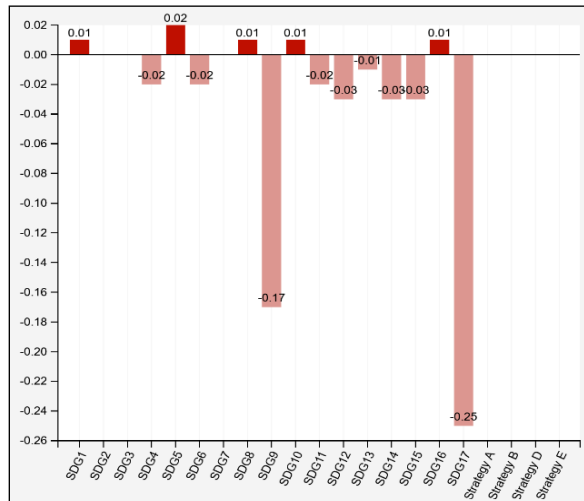
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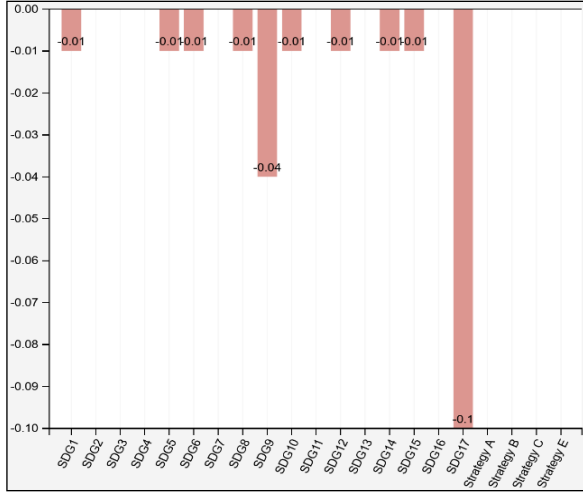


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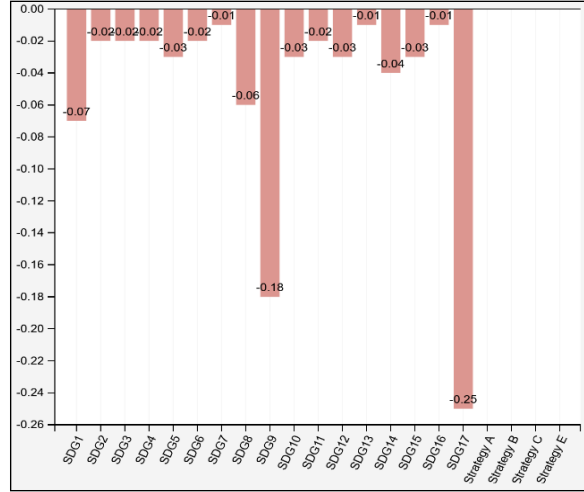


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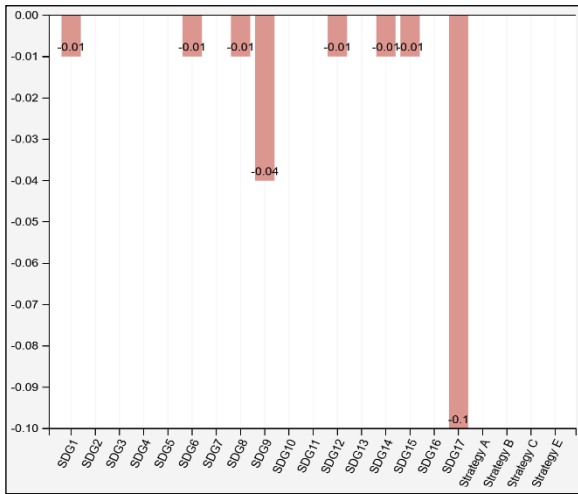
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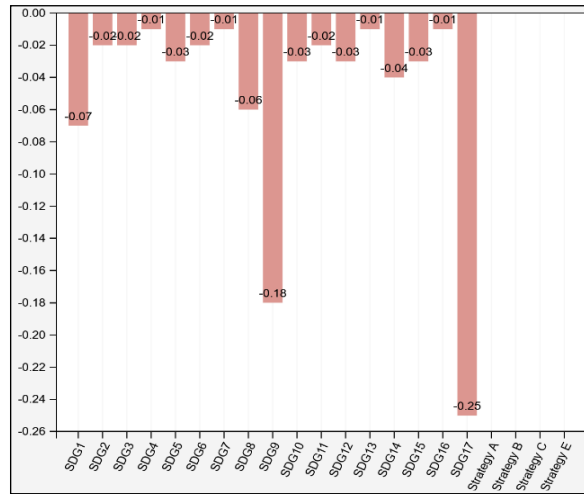
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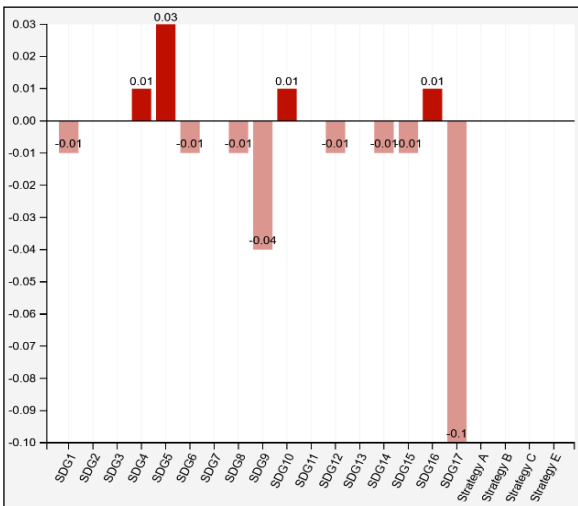
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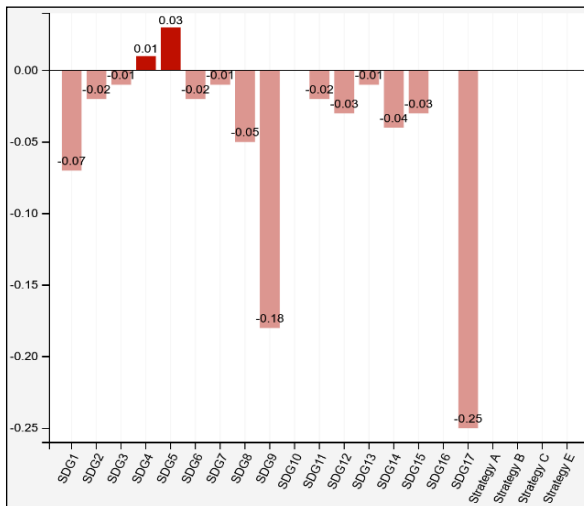
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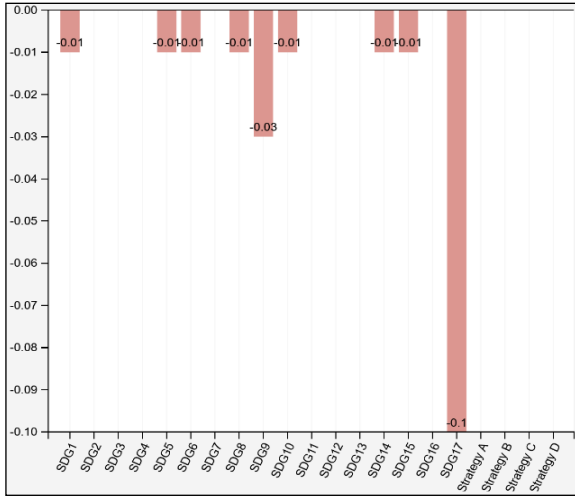


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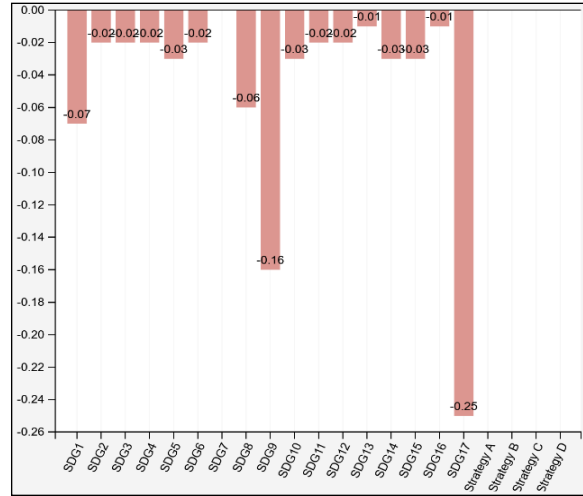


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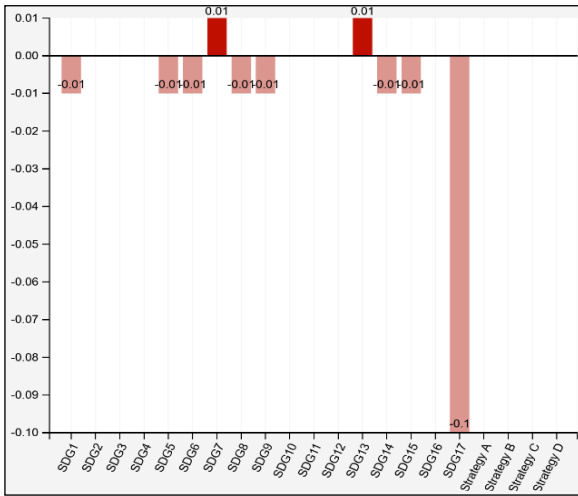
Figure 7



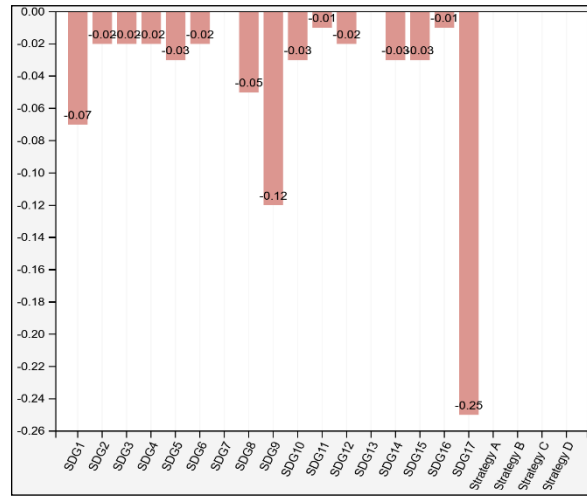
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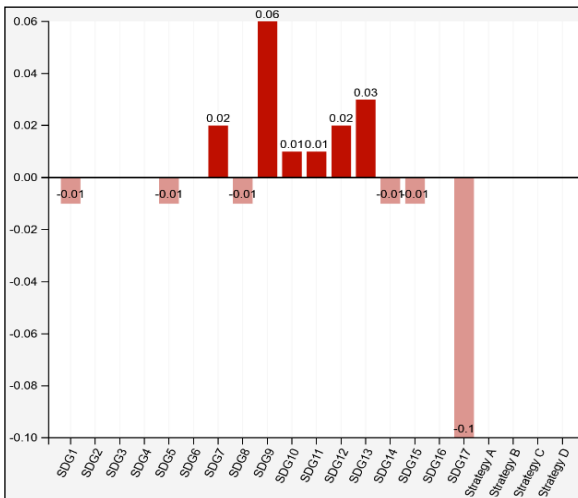
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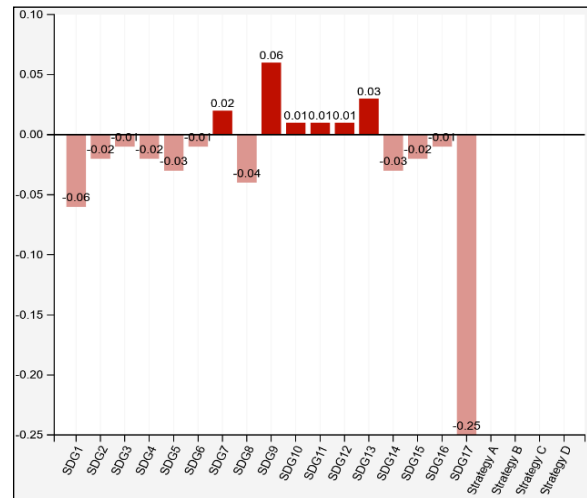
(c) $L^0_{\text{COVID-19}} = M^+, L^0_E = M^+$



(d) $L^0_{\text{COVID-19}} = H^+, L^0_E = M^+$



(e) $L^0_{\text{COVID-19}} = M^+, L^0_E = H^+$



(f) $L^0_{\text{COVID-19}} = H^+, L^0_E = H^+$

Figure 8

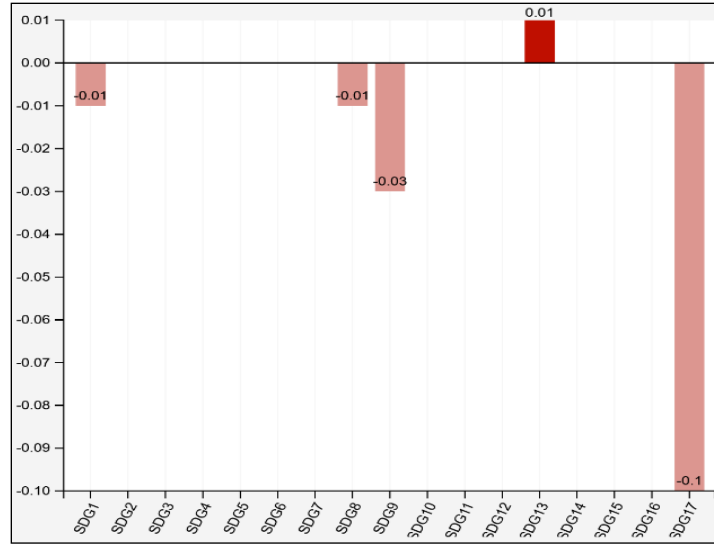


Figure 9

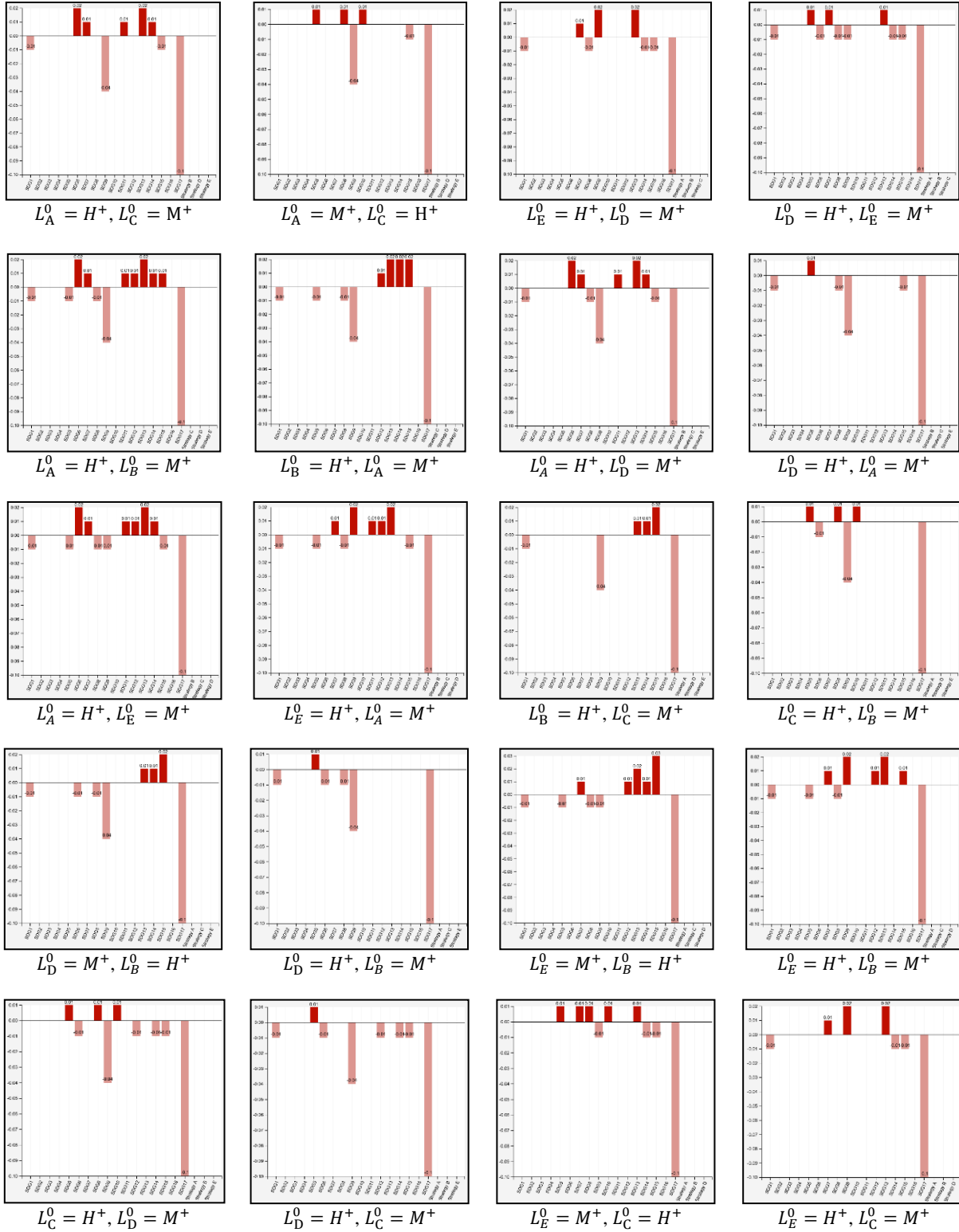


Figure 10

Table 1

Linguistic term	Corresponding TFN	TFN for the considered seven-point scale questionnaire
High- negative (H^-)	$(-1, -1, -0.75)$	
Medium- negative (M^-)	$(-0.75, -0.5, -0.25)$	
Low- negative (L^-)	$(-0.5, -0.1, 0)$	
No effect (N)	$(-0.1, 0, +0.1)$	
Low- positive (L^+)	$(0, +0.1, +0.5)$	
Medium- positive (M^+)	$(+0.25, +0.5, +0.75)$	
High- positive (H^+)	$(+0.5, +1, +1)$	

Table 2

Field of activity	Academia/ research center	Industry / NGOs	Social media	Government sector	Average years of work experience
Environment	1		1		14.5
Energy		1		2	13.3
Economy	1		1		8.5
Education				1	8
Women's rights	1				6
No. of experts	3	1	2	3	

Table 3

Component	Type	Indegree Index	Outdegree Index	Centrality Index
SDG1- No poverty	Ordinary	6.10	5.70	11.80
SDG2- Zero hunger	Ordinary	8.00	3.00	11.00
SDG3- Good health and well-being	Ordinary	8.10	1.20	9.30
SDG4- Quality education	Ordinary	6.70	4.4	11.10
SDG5- Gender equality	Ordinary	3.55	1.50	5.05
SDG6- Clean water and sanitation	Ordinary	3.29	1.70	4.99
SDG7- Affordable and clean energy	Ordinary	5.10	4.80	9.90
SDG8- Decent work and economic growth	Ordinary	5.49	7.30	12.80
SDG9- Industry, innovation, and infrastructure	Ordinary	4.80	4.20	9.00
SDG10- Reduced inequalities	Ordinary	6.60	4.79	11.39
SDG11- Sustainable cities and communities	Ordinary	5.70	2.40	8.10
SDG12- Responsible consumption & production	Ordinary	5.50	4.80	10.30
SDG13- Climate action	Ordinary	5.00	4.99	10.00
SDG14- Life below water	Ordinary	3.90	0.40	4.30
SDG15- Life on land	Ordinary	3.30	0.70	4.00
SDG16- Peace, justice & strong institutions	Ordinary	6.39	7.80	14.20
SDG17- Partnerships for the goals	Ordinary	0.90	3.60	4.50
COVID-19	Driver	0	9.75	9.75
Strategy A- Green management	Driver	0	3.35	3.35
Strategy B- Sustainable food systems	Driver	0	3.45	3.45
Strategy C- Energizing the labor market	Driver	0	3.40	3.40
Strategy D- Inclusive education	Driver	0	1.60	1.60
Strategy E- Supporting research and technology initiatives in the energy sector	Driver	0	3.59	3.59

