A Resilience-Based (RB) Methodology to Assess Resilience of Health System Infrastructures to Epidemic Crisis

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Abstract: The assessment of resilience of health infrastructures during an epidemic crisis is a fundamental issue in civil engineering, as shown by the recent COVID-19 crisis. During epidemic crises, health services and infrastructures need to maintain a level of functionality and avoid failures. In addition, it is important to evaluate post-hazard procedures, such as emergency and recovery actions. In this regard, the paper applied resilience as a parameter to assess investments, countermeasures and mitigations. The Resilience-Based (RB) methodology herein proposed was then applied to quantify the resilience of health infrastructure systems by considering the recovery of four European Countries (Germany, France, United Kingdom and Italy) after the first wave of COVID-19. The results demonstrated that the resilience of health system infrastructures (HSI) depends significantly on the policies that every government management applied—these being ultimately responsible for the differences in respective COVID impacts. In particular, the principal advantage of using resilience lies in its readability by many stakeholders, such as health infrastructure managers, government owners and public authorities.

Keywords: resilience; a resilience-based methodology; health system infrastructures; epidemic crisis

1. Background

Civil communities may be severely affected by natural disasters. COVID-19 demonstrated how pandemics may spread globally, severely impacting national economies. In this regard, the crisis extensively impacted European countries with dramatic socioeconomic effects. As shown in [1], during the second part of 2020, both GDP and employment fell by 13.9% and 2.9% respectively, compared with the same period of 2019 in all Europe. In this regard, health service infrastructures were particularly vulnerable to the pandemic and resilience has become a key parameter to study in pre- and post-event decision-making procedures.

In this regard, EU Countries developed several responses to the impacts of COVID-19 [2]. The assessment of health system infrastructures’ (HSI) resilience depends on the peculiarities of every government’s management, since any national government applies its own policies. In particular, this paper considered four countries—Germany, France, the United Kingdom and Italy—during the first wave. That wave had a lesser impact on other countries, such as the Nordic ones (except for Sweden). The four studied countries (plus Spain) were the object of [3], in which the authors analyzed the differences between centralized and decentralized systems and thus the interaction in policy-making processes from the start of the COVID-19 pandemic up to early 2021. In addition, the first wave was also investigated by [4], in which they considered the contextual and government response factors for 25 nations using fuzzy-set qualitative comparative analysis and compared the selected countries in relation to existing welfare typologies. Other studies assessed the effects of the different policies in the COVID-19 prevention. For example, Ref. [5] considered 169 countries by comparing two major policies: contact restrictions and active treatments. In particular, they applied regression and cluster analysis to demonstrate that national policies were responsible for the main differences in the COVID impacts. A more general assessment was proposed by [6]; they applied a mixed-methods approach to propose cross-country comparisons of pandemic responses in several
countries (the United States (US), Brazil, Germany, Australia, South Korea, Thailand, New Zealand, Italy and China), selected on the basis of their income level, relative COVID-19 burden and geographic location. In addition, they considered a list of 14 indicators to assess the countries’ preparedness, actual response, and socioeconomic and demographic profile, and to explain the differences in their vulnerability, preparedness and response.

As expected, a major economic crisis followed the COVID-19 impacts in the second part of 2020 and many countries experienced serious economic contractions and delays in growth. In addition, government strategies based on restrictions (such as lockdowns and closures) contributed to reducing the level of the economy—especially in Europe, as compared with some Asia-Pacific regions (i.e., New Zealand). These depended on several reasons, e.g., the age and density of populations, preexisting health diseases (i.e., obesity, lung cancers, etc.), the relevancy of international tourism and travel and, finally, the fact that European countries (i.e., Italy) had less time to organize strategies because they were hit by the pandemic at earlier times [7].

Resilience has been used in the health sector since the Ebola epidemic in West Africa in 2013–2016, as a key concept, by the 2014 European Commission Communication [8]. In particular, Ref. [9] may be considered a previous attempt in applying resilience in order to compare the national policies of Germany, Austria and Switzerland to the COVID-19 pandemic during the first wave. The same authors [10] considered the importance of novel technologies and new testing strategies in France, Belgium and Canada with several approaches (i.e., purpose of existing beds, equipment and labor resources).

The present paper aimed to study health systems’ vulnerability to epidemic crises, with particular focus on the proposal of recovery functions on the basis of the data registered in several EU Countries during 2020. The principal objective consisted of proposing a new methodology that applied the concept of resilience to assess the impacts of COVID-19 or future pandemic crises. The ultimate novelty consisted of proposing a methodology that applied the concept of resilience (commonly applied for structural estimations) to decision-making considerations. In this regard, the proposed methodology was applied at a national level instead of the more typical level of single buildings (hospitals), infrastructures or communities. The methodology was applied to investigate the recovering efficiency of some European countries by considering the national ICU occupancy during the recovery phase that followed the first wave of COVID-19 with the aim of comparing the recovery processes of different health systems. In particular, the countries were selected on the basis of several reasons. First of all, their similarities in terms of geography made it possible to consider similar disspreading of the virus. Then, because of similar cultural backgrounds, the social approaches, technological knowledge and human factors (i.e., education, skills and knowledge of medical personnel) were considered similar. Finally, coherency between the four official databases allowed us to deduce the percentage of the ICU capacity during the first wave of COVID-19. On the other side, the differences among the countries consisted, essentially, of the policies that each national government management adopted, and this paper aimed to apply the presented RB methodology to discuss such parameters. It is worth noting that other countries (such as Nordic countries or international ones, such as China and USA) were considered too diverse to be included in the study.

Specifically, several novelties were herein considered: (1) covering a relatively unexplored issue such as the assessment of the pandemic crisis; (2) developing a resilience-based (RB) approach for decision-making procedures and pre- and post-event procedures; (3) the management of pandemic crisis, based on quantifying resilience as a readable parameter for decision-makers; (4) the multi-disciplinary dimension of resilience, which may consider inputs from several disciplines, such as civil engineering, social sciences, management and economics.

The organization of the paper is as follows: Section 2 explains the proposed methodology, while Section 3 shows the data and the applications to the selected European case studies (Germany, France, UK and Italy). The results are shown in Section 4, where the discussion of the main outcomes is also presented.
2. Resilience-Based (RB) Methodology

This paper applied the concept of resilience to study health systems’ vulnerability to epidemic crisis by following the previous contributions from [11,12]. In particular, the resilience-based methodology consisted of considering resilience as a parameter to quantify the rapidity of a system to return to pre-disaster levels of performance. The RB methodology aims to be a credited state-of-the-art approach that may help health systems administrators and owners to establish priorities and operational planning procedures. In this regard, the OECD’s New Approaches to Economic Challenges (NAEC) is a methodology that considers the mutual interaction between resilience and efficiency for several vulnerable systems [11].

Resilience is a powerful concept that may summarize several aspects: “Resilience acknowledges that massive disruptions can and will happen—in future, climate disruption will likely compound other shocks like pandemics—and it is essential that core systems have the capacity for recovery and adaptation to ensure their survival, and even take advantage of new or revealed opportunities following the crises to improve the system through broader systemic changes . . . The new approach to resilience will focus on the ability of a system to anticipate, absorb, recover from, and adapt to a wide array of systemic threats.” [12]. In addition, [13] showed another resilience-based approach, named Health Systems Performance Assessment (HSPA), that “describes the capacity of a health system to (a) proactively foresee, (b) absorb, and (c) adapt to shocks and structural changes in a way that allows it to (i) sustain required operations, (ii) resume optimal performance, (iii) transform its structure and functions to strengthen the system, and (possibly) (iv) reduce its vulnerability to similar shocks and structural changes in the future”.

In the last decades, resilience has been defined in several ways, from the first definition in 1988 by Wildavsky: “the capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back.” This definition expressed two important concepts: (1) prevention from damages and (2) learning for future events [14]. Holling et al. (1997) proposed a more specific definition: “the buffer capacity or the ability to a system to absorb perturbation, or magnitude of disturbance that can be absorbed before a system changes its structure by changing the variables.” Their definition expressed the principle of a change of the structural configuration of the system [15]. Horne and Orr (1997), in the same year, extended the definition to “individuals, group and organizations, and systems”, generalizing the application of resilience to a larger scale [16]. In 1998, Mallak applied the concept to health care provider organizations by defining resilience as “the ability of an individual or organization to expeditiously design and implement positive adaptive behaviours matched to the immediate situation, while enduring minimal stress.” [17]. The originality of this definition consisted of the introduction of recovery inside resilience. Mileti (1999) proposed to consider the possibility of an “amount of assistance from outside the community.” [18]. This definition was novel for two points of view: (1) considering eventual help from the outside and (2) extending the concept of resilience from systems to community. Comfort and Waugh (2002) extended the concept of resilience to “the capacity to adapt existing resources and skills to new systems and operating conditions.” [19]. The key words in this definition were capacity and adaptation, meaning that resilience was intended as the possibility of an effective answer to changes due to an external event. Paton et al. (2000) described resilience as “an active process of self-righting, learned resourcefulness and growth the ability to function psychologically at a level far greater than expected given the individual’s capabilities and previous experiences” [20]. This definition extended the original definition considerably by (1) considering resilience as a process, (2) introducing the psychological contribution and (3) referring to individuals.

In the early 2000s, other definitions were proposed (such as [21–23]). These authors proposed an interrelated concept of resilience that considered technical, organizational, social and economic dimensions that could assess the performance of critical systems (i.e., electric power, water, road infrastructures and critical structures) and the social and economic dimensions of communities. The most comprehensive definition may be considered the one presented by UNISDR (2015) in the so-called Hyogo Framework, [24]. Resilience
was defined as “the capacity of a system, community or society potentially exposed to
hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level
of functioning and structure. This is determined by the degree to which the social system
is capable of organizing itself to increase this capacity for learning from past disasters for
better future protection and to improve risk reduction measures.” This modern definition
took into account several contributions from previous works, in particular, by underlining
the importance of the social dimension and the role of learning from the past and future
protection actions. [25–27] developed an analytical formulation to quantitatively calculate
resilience by including recovery time (the period necessary to restore the functionality of
the system to a desired level).

In the structural arena, [28] proposed a formulation that quantified resilience by
applying it to a series of hospital buildings. Several assumptions were made to establish
the retrofit strategies: “No Action”, “Retrofit to life safety level” and “rebuild option”,
corresponding to code levels: “low”, “intermediate”, “high”, respectively. In particular, [28]
investigated the case of earthquake scenarios, by considering four hazard levels and
adapting earthquakes with 2%, 5% 10% and 20% probability of exceedance (PE) over
50 years.

In the present paper, several hypotheses were considered. First, (1) the occupancy
of intensity care units (ICU) was taken as the reference parameter for the assessment of
losses. (2) The functionality was calculated as the percentage of the emptiness of the ICU,
considered as the most representative parameter to model recovery. (3) Resilience was
calculated in order to define the rapidity rate for the health infrastructure to recover to
pre-event levels of functionality—thus facilitating discussions and considerations on the
vulnerability of HSI.

In particular, Figure 1 shows the national HSI capacities, in terms of ICU, before the
COVID-19 crisis. The year inside the brackets indicates the latest data available [7] while
EU14 means the mean values among the considered European Countries. It is worth noting
that ICU capacity varied among the various countries due to several related parameters
such as national policies, health infrastructural management and national economies. In
particular, the mean value was 12.9 and, among the considered countries, two were above
the mean (Germany and France at 33.9 and 16.3, respectively) and two were lower (United
Kingdom and Italy at 10.5 and 8.6, respectively). The occupancy rates of ICUs during the
months that followed the peak of the first wave were deduced from the databases that
every country published in their respective official web sites.

![Figure 1. Intensive care capacity—ICU beds before the COVID-19 crisis, latest year available (per
100,000 population) [7].](image-url)

This paper proposed to consider the percentage of ICU capacity with respect to the
peak value reached during the first wave of COVID-19. It is worth noting that these peaks
were not reached at the same time (even with small differences around the spring of 2020). Recovery function $Q(t)$ represents the recovery process to return to the pre-event level and was calculated as:

$$Q(t) = 1 - \frac{\text{Occupancy (t)}}{\text{Peak Occupancy}}$$

(1)

In the last 10 years, resilience has been applied with many definitions [29,30] and is graphically designed as the normalized area below $Q(t)$ ([28,31,32]). Therefore, its quantification depends on the definition of a loss model that describes the decrease of functionality consequent to the events. In addition, recovery models depend on many factors that are typical of certain regions and communities and are used to describe the processes and actions to enhance the capacity of an affected system or a community [30].

Resilience was then calculated (see Section 4 below) as:

$$R = \int_{t_{0E}}^{t_{0E}+T} \frac{Q(t)}{T} dt$$

(2)

where $t_{0E}$ is the time of occurrence of the event $E$, $T$ is the time frame (or recovery time) necessary to restore the functionality of the health infrastructure.

It is worth considering that, in Equation (2), resilience is calculated as the ratio between the functionality and the time frame. Therefore, this choice allowed us to apply resilience as an a-dimensional parameter to make comparisons among the various European countries (see Section 4 for more details).

3. Database

This paper proposed to calculate the recovery function from the percentage of emptiness in ICUs as a representative parameter. In this regard, Figure 2 shows the number of COVID-19 patients in ICUs for the United States, Spain, Germany, France, United Kingdom, Italy, Canada, the Netherlands, Belgium and Israel from 1 March 2020 to 26 February 2021. It is worth noting that, even if the peak values were not reached simultaneously, they occurred around the beginning of April 2020 for all the considered nations. The values registered just after the peak value (around the beginning of August 2020) were herein considered in order to represent the recovery phase after the first wave (see Section 4). In particular, the present paper considered four European states (Germany, France, United Kingdom and Italy) and derived the relationships on the basis of information from official websites. In particular, data showed that France had 107 cases per 100,000 people, compared to 150 per 100,000 in Germany and 250 per 100,000 in Italy.

![Figure 2](image-url)
3.1. Germany

In Germany, the first peak of people being treated for the coronavirus in intensive care facilities occurred on 18 April 2020 (2933), according to the DIVI register of German ICU capacity [33]. The data covered the period from 1 March 2020 to 15 October 2020 (Figure 3a). The time frame (130 days) to calculate the recovery function of the health infrastructure was considered to be between 18 April 2020 to 1 September 2020. Figure 3b shows the application of Equation (1) to calculate the functionality $Q$ for Germany, and thus to derive the recovery curve that was necessary for the calculation of resilience, as detailed in the previous section. It is worth noting that the recovery trend began linearly, while at around day 40 it began increasing faster. This was probably due to weather conditions (summer time) that seemed to reduce the spread of the virus. The results demonstrated that the national policy played a significant role in reducing the COVID impact, as demonstrated by [3], which considered that the long traditions of central government (allowed to act as a coordinator and mediator and promoter of convergence) were fundamental to reduce the impacts.

![ICU occupancy (Germany)](a)

![Functionality (Germany)](b)

**Figure 3.** (a). Number of COVID-19 patients in ICU in Germany from 1 March 2020 to 26 February 2021. Source: DIVI Intensivregister. (b). Health Infrastructure functionality vs. days in Germany ($T = 130$ days).
3.2. France

Figure 4a shows the COVID-19 occupancy in intensive care units from 7 April to 7 December in France. In particular, on December 10th, across France, one COVID-19 patient was admitted to hospital every minute, and one patient admitted to intensive care every seven minutes [34]. Since the spring, the decreasing number of hospital patients who end up in intensive care was attributed to improvements in treatment of the illness. In addition, at the end of October, France was seeing some of the highest case numbers per capita of the population in the world, significantly worse than Spain, Italy, the USA and Germany. The time frame (123 days) considered was 7 April 2020 to 7 August 2020, when the first wave could be said to have concluded. On the basis of the period, the recovery function of the health infrastructure was calculated. In particular, Figure 4b shows the functionality trend. Both curves showed that the trends were similar to those registered for Germany (compare with Figure 3); this was probably due to the similar initial conditions (in terms of ICU resources and economies) among the two countries. Moreover, Ref. [3] showed that the centralized system allowed the establishment of a hierarchical system of crisis management in which national authorities took over all relevant decisions. This was fundamental for the French government to enhance emergency policies and recover from the pandemic crisis.

Figure 4. (a) Number of COVID-19 patients in ICU in France from 7 April 2020 to 7 December 2020. Source: Health Ministry and Santé Publique France. (b) Health Infrastructure functionality vs. days in France (T = 123 days).
3.3. United Kingdom

In the United Kingdom the management policy was different from the other considered countries. In addition, the definition of ICU changed over the period [35]. For example, the first definitions were: “COVID daily confirmed on admission” and “COVID-19 confirmed on admission”, considering the COVID-19 daily admissions diagnosed within 24 h. Even so, it was not clear whether ‘admission’ meant “admitted to hospital with COVID”, “admitted and diagnosed with COVID while in a hospital” or “infected with COVID while an inpatient” [35]. Figure 5a shows the occupancy trend from 1 April 2020 to 26 October, following [35]. It is worth noting that the data were available only for the period that immediately followed the peak (day 11, 3239) and that the decrease was more rapid than those shown for Germany and France. As a consequence, the recovery trend (Figure 5b) for the time frame (133 days, between 14 April 2020 to 18 August 2020) was faster than the previous ones, especially in the first 40 days. In particular, [3] considered the different instances of coordination and competition between the four nations of the union that were at the base of the responses defined by the authors as inconsistent.
3.4. Italy

Figure 6a shows the Italian cases of COVID-19 patients in ICU between 18 February 2020 and 3 January 2021. It is worth noting that the pandemic crisis in Italy was detected from the middle of February, when the first European case was monitored. The data were taken from the Aggiornamento Nazionale 29 Dicembre 2020, by the Istituto Superiore di Sanità (ISS) [36]. At that time, the situation was still severe, due to its impact on health infrastructure. However, fewer contractions occurred between 14 December and 27 December (305.47 per 100,000 inhabitants) than in the previous period, 7 December to 20 December (329.50 per 100,000 inhabitants). It is also worth noting that the trend of decrease was the fastest among all considered countries, especially at the beginning of the period (first 40 days). This confirmed that the recovery phase could be driven significantly by national climate conditions. As a consequence, Figure 6a shows that Italian functionality was completely recovered in 70 days, half of the considered time frame (140 days, between 29 March, 2020 to 15 August 2020). This also showed that ICU occupancy was nearly zero at the beginning of the summer season. In addition, Italy may have been affected by the territorial fragmentation that caused local resistance to centralization; more details in [3].

![ICU occupancy (Italy)](image)

![Functionality (Italy)](image)

**Figure 6.** (a). Number of COVID-19 patients in ICU in Italy from 18 February 2020 to 3 January 2021. Source: Ministero della Salute/Protezione Civile italiana. (b). Health Infrastructure functionality vs. days in Italy (T = 140 days).
4. Resilience

The previous sections showed the occupancy and the functionality trends for the selected European countries by considering national data (sources: national websites). Functionality curves were interpolated with polynomial curves to define analytical relationships between the time frame and the functionality. Recovery functions $Q(t)$ were calculated for each country:

$$Q(t) = A \times T^3 + B \times T^2 + C \times T$$

where $A$, $B$, $C$ are the coefficients of the interpolating curves (see Table 1). $R^2$ was used to assess the quality of correlations. The selected European countries were compared in order to assess the different strategies and management procedures.

Table 1. Interpolation values.

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>France</th>
<th>UK</th>
<th>Italy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A$</td>
<td>$1.00 \times 10^{-6}$</td>
<td>$8.00 \times 10^{-7}$</td>
<td>$7.00 \times 10^{-7}$</td>
<td>$3.00 \times 10^{-7}$</td>
</tr>
<tr>
<td>$B$</td>
<td>$-3.00 \times 10^{-4}$</td>
<td>$-2.00 \times 10^{-4}$</td>
<td>$-2.00 \times 10^{-4}$</td>
<td>$-1.00 \times 10^{-4}$</td>
</tr>
<tr>
<td>$C$</td>
<td>0.0320</td>
<td>0.0268</td>
<td>0.0262</td>
<td>0.0225</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.994</td>
<td>0.998</td>
<td>0.990</td>
<td>0.979</td>
</tr>
<tr>
<td>Time Frame (days)</td>
<td>130</td>
<td>123</td>
<td>133</td>
<td>140</td>
</tr>
<tr>
<td>Resilience</td>
<td>0.94</td>
<td>1.01</td>
<td>0.93</td>
<td>1.05</td>
</tr>
</tbody>
</table>

The results of the analyses in terms of resilience are shown in the last row of Table 1. It is worth noting that the values did not differ significantly, with a more rapid recovery for Italy (1.05) and France (1.01). This could be attributed to several factors, such as the warm climate conditions of the Mediterranean basin in the summer.

The policies that each national government management adopted were of great importance, confirming what was presented extensively by [3]. The authors showed the role of multi-level politics and public policy. In particular, in France, a hierarchical system of crisis management was quickly established. In Germany, centralization was achieved by building coordination between the federal and regional governments. Italy was affected by weak centralization over the first few weeks (especially for the health sector) and an absence of coordination mechanisms that caused a first phase of severe impacts. The United Kingdom presented a mixed picture, where a system of cooperation seemed to prevail and facilitated the creation of a hierarchical system; more details in [3].

However, other variables needed to be considered (i.e., economic indicators, frequency and length of lockdowns) to realistically assess the values of resilience. In addition, considering that every country had a different history, approach and management of the crisis was also fundamental. In particular, the results showed that the various national strategies made all the difference in our assessment of resilience. Therefore, an inter-national plan of emergency would have been particularly useful to coordinate the various strategies and unify the European response to global pandemic crises such as COVID-19.

In this regard, [12] demonstrated the importance of a multidimensional approach based on international cooperation and mutual relationships between authorities and sectors. In addition, [7] recommended some actions to improve resilience (i.e., transfer of patients from hospitals, collaborations among national R&Ds). It is worth noting that having more resilient health systems could allow nations to avoid huge economic consequences. In addition, fragmentation in nations made Europe particularly vulnerable, and this new methodology could help to improve more comprehensive approaches among countries, enhancing their preparedness, surveillance and recovery.

5. Discussion

The present paper showed that the RB methodology may be applied to compare the recovery process of different health systems at various levels (i.e., single hospitals, regional infrastructures or national health systems). It has been demonstrated here that the new
approach may study the recovery functions on the basis of the data registered in several EU Countries during the first wave in 2020 (March–October). In particular, it was assumed that the occupancy of intensity care units (ICU) was taken as the reference parameter for the assessment of losses. Then, the functionality was calculated as the percentage of the emptiness of the ICUs. Finally, resilience described the rate at which the health infrastructure was able to recover to pre-event levels of functionality.

Therefore, the presented case study demonstrated how the methodology may be applied on a national scale to compare the capacity of health systems to remain functional in cases of emergency operation. It is important to note that the presented case study aimed to show the application of the methodology without the intention to produce significant output, since the pandemic crisis is still ongoing as of the time of this writing. In this regard, more specific-oriented calibration of parameters will be set up on the basis that more data will be available in the future. However, outcomes showed that health system infrastructure (HSI) resilience significantly depended on the policies that government management applied, as demonstrated in [6], with the indicator 5 named “leadership, governance and coordination of response”. In addition, confirming what was presented in [5], the main policy (contact restrictions) adopted by the selected countries was shown to be of great significance as a base for enhancing the national policies responsible for the observed differences in COVID-19 impacts. Overall, the presented framework may benefit a wide range of actors that could apply the readable findings to multidisciplinary analyses and assessments, thereby helping nations to recover from natural hazards such as epidemic crises.

6. Conclusions

Quantification of health systems is a fundamental issue, particularly during epidemic crises. This paper proposed a resilience-based methodology that could be applied to compare the recovery processes of different health systems at various levels. The data were taken from four European Countries (Germany, France, United Kingdom and Italy) to derive loss models and quantify resilience. The results compared different levels of resilience that could be easily understood by many actors, such as governments, administrations, HSI owners and decision-makers. Considering that the pandemic crisis is ongoing, more comparisons (among individual hospitals and/or infrastructures) will be possible as further data are made available. Applying the RB methodology to the data that will be available in the future could be important for (1) many interdisciplinary assessments to include future perspectives for designs and recovery solutions, (2) developing parametric case studies that will select the most proper indicators to define resilience, (3) positive involvement of all stakeholders, promoting better preparedness for future pandemic crises and health emergencies, (4) feedback for the evaluation of the government policies that have been applied in different countries and (5) the proposal of a comprehensive parameter that could synthetize the information and drive decision makers to the optimal investments and approaches (i.e., global public health governance, health information systems, digitalization of health systems, and their important benefits on communities and societies). Overall, the presented RB methodology did not consider long-term variables, such as economic indicators or the frequency and duration of lockdowns, that could improve the assessment of resilience. Future parametric studies will be carried out at the end of the epidemic in order to validate the RB methodology and to include more realistic parameters inside the framework.

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