



Assessing resilience of healthcare infrastructure exposed to COVID-19: emerging risks, resilience indicators, interdependencies and international standards

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Abstract

In the moment of preparation of this paper, the world is still globally in grip of the Corona (COVID-19) crisis, and the need to understand the broader overall framework of the crisis increases. As in similar cases in the past, also with this one, the main interest is on the “first response”. Fully appreciating the efforts of those risking their lives facing pandemics, this paper tries to identify the main elements of the larger, possibly global, framework, supported by international standards, needed to deal with new (emerging) risks resulting from threats like Corona and assess the resilience of systems affected. The paper proposes that future solutions should include a number of new elements, related to both risk and resilience. That should include broadening the scope of attention, currently focused onto preparation and response phases, to the phases of “understanding risks”, including emerging risks, and transformation and adaptation. The paper suggests to use resilience indicators in this process. The proposed approach has been applied in different cases involving critical infrastructures in Europe (energy supply, water supply, transportation, etc., exposed to various threats), including the health system in Austria. The detailed, indicator-based, resilience analysis included mapping resilience, resilience stress-testing, visualization, etc., showing, already before the COVID-19, the resilience (stress-testing) limits of the infrastructures. A simpler (57 indicator based) analysis has, then been done for 11 countries (including Austria). The paper links these results with the options available in the area of policies, standards, guidelines and tools (such as the RiskRadar), with focus on interdependencies and global standards—especially the new ISO 31,050, linking emerging risks and resilience.

Keywords Corona · COVID-19 · Resilience · Risk · Indicators

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1 Introduction, what is/was really new about COVID-19?

1.1 COVID-19 as “surprise”?

As of April 2020 COVID-19 has “covered” the world (Fig. 1). More than any other crisis before, the Corona crisis comes as probably the most global one so far, not only in terms of geography. The crisis is unique also because it appears to be one of the first globally experienced emerging risks. Affecting resilience of the world and stress-testing the resilience of both the healthcare system and the society as a whole. Did it come as a surprise? Hardly.

Despite the numerous preceding warnings and mentioning of new kind of pandemic risk in the WEF Global Risk Report starting as early as 2006, and the detailed OECD reports (2011a; b), preparedness level of almost all



Fig. 1 The world on April 2, 2020: firmly in the grip of COVID-19 (<https://www.google.com/maps/d/viewer?mid=1yCPR-ukAgE55sROnmBUFmtLN6riVLTu3&ll=18.683350789325377%2C52.46303051550274&z=2>, accessed on 2 Apr 2020)

healthcare systems around the globe to fight a pandemic outbreak remained insufficient. The critical mix for a “successful pandemic outbreak” is a fast and efficient human to human transfer of the pathogen where, humans have little or no immunity against it, no vaccines currently exist and supply of antiviral drugs is insufficient or not existing. Most of these can now be seen during the current COVID-19 outbreak. In other words, the outbreak of COVID-19 is not a real surprise, the surprise is linked to its extremely high infection rate allowing a very fast worldwide progression. In the Global Risk Report of 2006 (written after the Avian Flu H5N1 Pandemic in 2003), it is mentioned that if the virus can no longer be contained and person to person infection were to become common place, “the vulnerabilities of our interconnected global system would intensify the human and economic impact. The worldwide spread would be facilitated by global travel patterns and insufficient warning mechanisms. Short term economic impacts would include severe travel impairments, tourism and other service industries, as well as manufacturing and retail supply chains. Deep shifts in social, economic and political relations are possible”. What else could one have added? In its voluminous, almost 300 pages long report, OECD (2003, p. 31) has been forecasting this as follows:

As underlying conditions of risk – from climate to pathogen resistance – change, risk management policies based on past records and experience are likely to be increasingly faced with “surprises”. How to account for evolving conditions will become a central issue in the handling of many risks. This will entail, in

particular, a framework for dealing with major uncertainties and gaps in scientific knowledge.

1.2 COVID-19 pandemics as a “global shock”?

Considering pandemics as aspects of public health and infectious diseases as “existential threats” to the society has been embedded already in the United Nations Development Programme (UNDP) of 1994 and reaffirmed in the 2003 UN Commission on Human Security (see OECD 2011b). The report points out, that “survival under a pandemic global shock clearly refers to taking every action to minimize morbidity and mortality *as well as* to minimize the effect of the pandemic on the economic, social and political stability of communities, nations and transnational organizations”. Furthermore, the authors argue, that the global shock to public health in the form of a pandemic is unique among global shocks in having profound positive and negative externalities and interdependencies. But being officially classified as pandemic by WHO,¹ would COVID-19 qualify as “global shock”, too? Table 1 shows that it is clearly the case. But six months after the outbreak of COVID-19, it is rather understood and perceived as a “global threat” and the focus is on monitoring of the threat (e.g. Johns Hopkins²), media

¹ <https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic>

² <https://coronavirus.jhu.edu/map.html>

Table 1 COVID-19 as a global shock—plotted against OECD (2011a) criteria (number of ticks indicating level of applicability: from (✓)—“partly” to ✓✓✓—“fully”)

Characteristics	Routine emergencies	Disasters	Global Shocks	COVID-19
Scale	Scale is modest and well-defined in space and time	Scale may be large, but defined	Scale is large and perhaps ill-defined in space and time. High impact possibly irreversible	✓
Visibility	Event recognized, but low visibility	High visibility	Very high profile, intense and long-lasting political and media interest	✓✓✓
Interaction	Interaction with familiar faces	Interaction with unfamiliar faces	Counterparts unknown	✓✓
Familiarity with procedures	Familiar tasks and procedures	Tasks and procedures sometimes unfamiliar	Tasks and procedures outside previous experience	✓✓✓
Coordination	Intra-organizational coordination needed	Intra- and inter-organizational coordination needed	Multi-layered international coordination needed	✓✓✓
Infrastructure affected	Roads, telephones and facilities intact	Roads may be blocked or jammed, telephones jammed or non-functional, facilities may be damaged	Transport and communication hubs blocked, ports may be damaged (airports, Internet ports, maritime ports), disrupting global supply chains	✓
Communication channels	Communications frequencies adequate for radio traffic	Radio frequencies and mobile services often overloaded	International telecommunications overloaded or disrupted	(✓)
Type of communication	Communications primarily intra-organizational	Need for inter-organizational information-sharing	Need for international information-sharing	✓✓
Terminology of communication	Use of familiar terminology in communicating	Communication with persons who use different terminology	Communication between persons with different language, culture, norms and geo-political perspective	✓✓✓
Press/Media	Need to deal mainly with local press	Hordes of national and international reporters	Media sources incapacitated, social media unmanageable	✓✓
Resources	Management structure adequate to coordinate the number of resources involved	Resources often exceed management capacity	Resources sometimes cannot be accessed for long periods	✓✓✓

focused on response measures and science unable to make reliable predictions, or even provide consistent explanations.

1.3 COVID-19 as an emerging risk

New, previously unknown or not considered, “emerging” risks can pose the greatest challenges to resilience, safety and operational and business continuity. These “new and/or increasing” risks can be related to different areas of activities, such as new processes, new technologies, new types of workplace, or social or organizational change. They can also be some long-standing issue, newly considered as a risk due to a change in social or public perceptions or due to new scientific knowledge. The increasing nature of these risks means that the number of hazards leading to the risk may be growing, or that the exposure to the hazard leading to the risk is increasing, or that the effects/impacts of the hazards are getting worse (e.g. seriousness of effects and/or the number of people affected). These risks will interrelate with the processes like globalization, digitalization, innovation, cross

boundary operations and many others, inextricably, directly or indirectly influencing each other, being interconnected, systemic and/or interdependent.

Starting from the ISO 31000 definition of risk (“effect of uncertainty on objectives”) and understanding risk management as a significant contributor to value creation and preservation, the new "ISO 31050³ Guidance for Managing Emerging Risks to Enhance Resilience", currently under development, will contribute to the further enhancement of integrated governance and management processes that provide insight into how risk may affect the achievement of organizational objectives.⁴ An emerging risk, as

³ <https://committee.iso.org/sites/tc262/home/projects/ongoing/iso-31022-guidelines-for-impl-2.html>

⁴ The development of the standard is assigned to the Joint Work Group ISO/TC 262/JWG 01 "Joint ISO/TC 262—ISO/TC 292 WG; Managing emerging risk" of the Technical Committees TC262 and TC292. The work started in June 2018, taking DIN SPEC 91299 (CWA 16649, 2013), the work of the ISO TC292 (ISO 223xx standards, especially 22300 and 22316) and the works of organizations

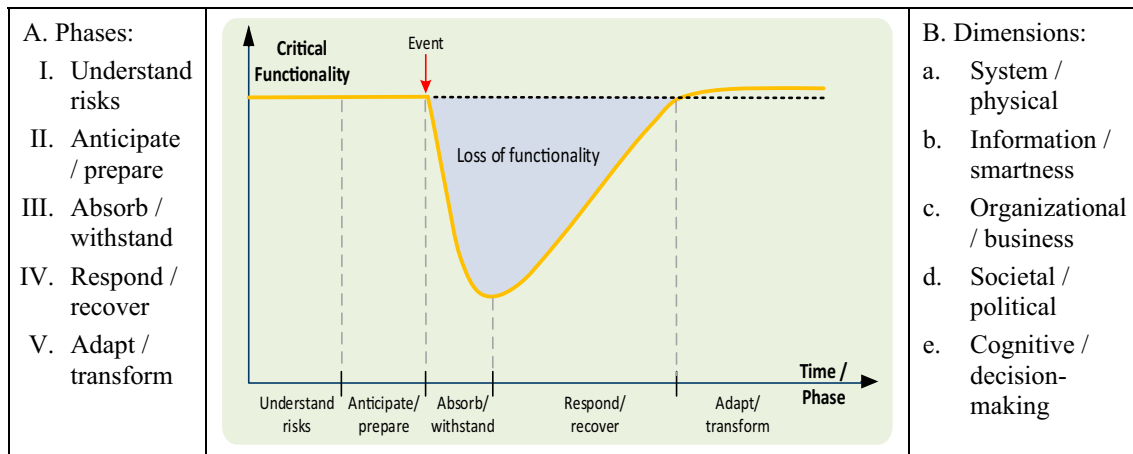


Fig. 2 The resilience matrix based on five phase and five dimensions as adopted in SmartResilience project (2019)

currently discussed at within work at the new ISO 31050 standard, proposes to define it as a highly uncertain risk which is evolving from events with potential for serious consequences/impacts. There, the term “evolving” refers to changes in the risk understanding related to relevant threat sources, events and their effects/consequences, their likelihood and/or level of and uncertainty associated with background knowledge. Obviously, COVID-19 is in the scope of this definition, but primarily in terms of “potential for serious consequences/impacts”, not in terms of awareness that an event like this may occur.

2 Risk and resilience analysis

The ISO (22300:2018(E)) meta definition of Resilience is *ability to absorb and adapt in a changing environment*. In the context of critical infrastructures and the SmartResilience project (2016), the definition was first extended to resilience as *the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruption* (Linkov 2014, NAS 2012) and then, with inclusion of the ability to understand risks (current and emerging), as *the ability to understand risks, anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruption* (Øien et al. 2010). SmartResilience project adopted concept of resilience of an infrastructure (Jovanović et al. 2019a, b) as *the ability to understand and anticipate the risks – including new/emerging risks – threatening the*

critical functionality of the infrastructure, prepare for anticipated or unexpected disruptive events, optimally absorb/withstand their impacts, respond and recover from them, and adapt/transform the infrastructure or its operation based on lessons learned, thus reducing the critical infrastructure fragility (Russoa, Ciancarinia, 2016). This conceptual framework, as an extension of the one of Fox-Lent et al. (2015 and 2018) and Linkov (2018), yields the following main additional advantages:

- Including understanding of risk (including emerging risks),
- Including optimization, adaptation and transformation,
- Allowing to naturally include phases of the resilience cycle and the indicator-based approach within the resilience matrix.

The definition allows analysing behaviour of an infrastructure exposed to an adverse event both during the operation time (e.g. a year) and over the “scenario time” (e.g. during the adverse event, Figs. 2, 3). The approach allows to decompose the overall resilience problem and focus on single relevant resilience issues described by relevant resilience indicators, the values of which allow to quantitatively assign an aggregated value to each “cell” of the resilience matrix (Fig. 4).

Phase I *Understand risks*, is applicable prior to an adverse event. It emphasizes emerging risks and includes their early identification and monitoring; e.g. what could the “adverse event” be?

Phase II *Anticipate/prepare*, also applicable before the occurrence of an adverse event. It includes

Footnote 4 (continued)

such as OECD, SRA, WEF and EU (projects iNTeg-Risk, SmartResilience and ResiStand) as main references.

Fig. 3 Possible outcomes in the case of an infrastructure exposed to an adverse event: between improvement and complete failure, e.g. in the case of COVID-19

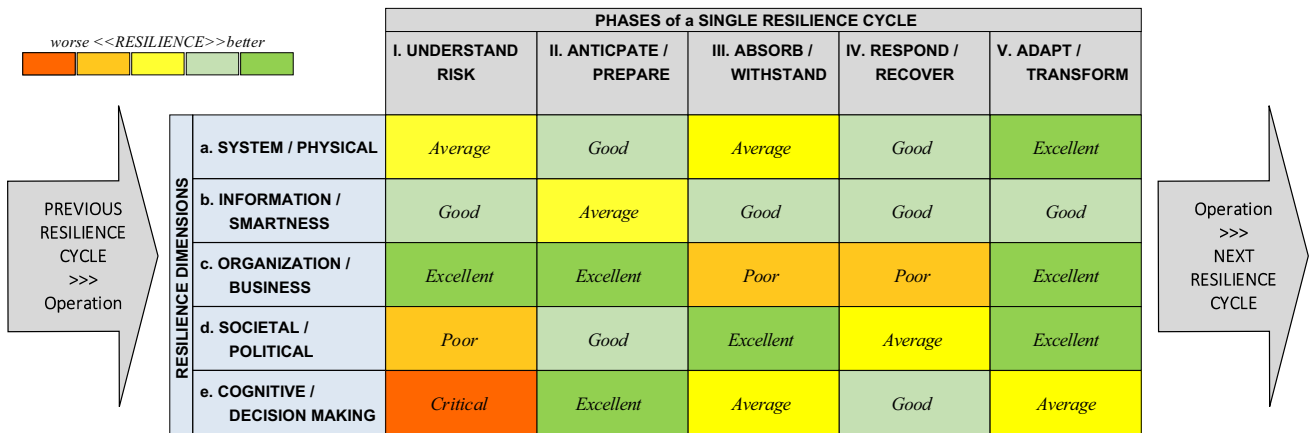
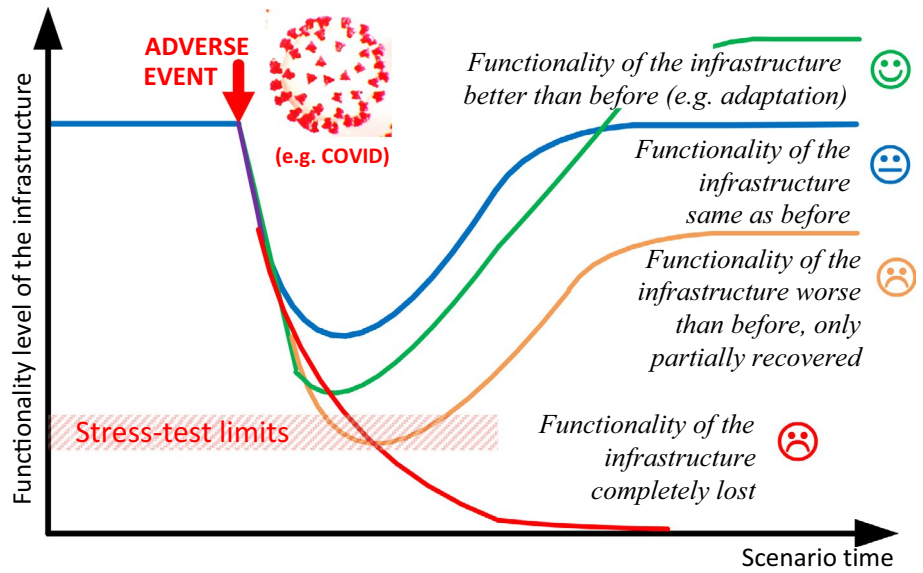


Fig. 4 Example of a resilience matrix showing the resilience level in each cell of the matrix (NOT related to any particular case and not to COVID-19; examples of issues and indicators defining the resilience level are given in 4.2)

- planning and proactive adaptation strategies, possibly also “smartness in preparation”.
- Phase III** *Absorb/withstand*, comes into action during the initial phase of the event and shall include the vulnerability analysis and the possible cascading/ripple effects; e.g. “how steep” is the absorption curve, and “how deep” down will it go?
- Phase IV** *Respond/ recover*, is related to getting the adverse event under control as soon as possible, influencing the “how long” will it last, question. Further, it includes the post-event recovery; e.g. “how steep up” is the recovery curve for normalization of the functionality?
- Phase V** *Adapt/transform*, which encompass all kinds of improvements made on the infrastructure and its environment; e.g. affecting “how well” the

infrastructure is adapted after the event, and whether it is more resilient and “sustainable”. The activities in this phase also lead to preparation for the future events and hence, this resilience curve also exhibits a reoccurring cycle.

For each phase, one can define dimensions of the resilience, such as state of physical characteristics, information flow, organization, policies, etc. While defining the “phases” of the resilience cycle (“A”), is usual straight-forward, the decomposition over dimensions (“B”) might be more difficult, as these may overlap very much in practical cases (Fig. 4).

The dimensions help in categorizing the indicators. Dimension (a), system/physical, includes technological aspects of the given infrastructure, as well as the physical/

technical networks being part of a given infrastructure, and interconnectedness with other infrastructures and systems. Dimension (b), information/data, is also related to the technical systems but is dealing with information and data, specifically. Further, dimension (c), organizational/business, covers business-related aspects, financial and HR aspects as well as different types of respective organizational networks. Dimension (d), societal/political, encompass broader societal and social context, also stakeholders not directly involved in the operation and/or use of the infrastructure (e.g. social networks). Lastly, dimension (e), cognitive/decision-making, accounts for perception aspects (e.g. perceptions of threats and vulnerabilities, Jovanović et al. 2016).

3 Analysing resilience by means of resilience indicators

In the indicator-based concept (Fig. 5), an "issue" is a general term referring to anything that is important in order to be resilient against severe threats such as terror attacks, cyber threats and extreme weather. It is telling what is important, e.g. it can be "training" performed in the anticipate/prepare phase. Obviously, the more indicators one chooses, the better the "coverage" of an issue is going to be, but it is also obvious that the larger the number of indicators, the more complex their handling is going to be. The "way out" has two components and these would be:

- finding the "right number" of indicators properly describing given resilience problem tackled (in the usual engineering practice, managed by humans, 120–150 indicators are usually a maximum—the more critical the situation, the smaller the number; in absolute emergency situations humans can hardly look at more than 3 indicators), and
- allowing to "drill-down" in cases when one or more indicators need further explanation.

The resilience indicators are mainly taken from current practices (standards, guidelines, reports, etc.) within safety and risk management, emergency preparedness, business continuity, etc. and in most cases, they exist already as safety indicators, risk indicators, or similar. Collecting the indicators and applying the approach, the theoretical framework for variable selection, weighting, and aggregation must be defined and the basis for this is the context of the assessment, or scenario.

The value of an indicator can come from, e.g.:

- Expert opinion (e.g. during a table-top exercise)
- Measured value (e.g. from a monitoring system)
- Analysis of big data.

Once in the model, they are, in a general case, normalized and used as scores.

There are two principally different ways (methods) of measuring resilience using indicators as illustrated in Fig. 6.

Method 1 treats the resilience cycle indirectly, as a conceptual model where indicators are used to measure the resilience in each phase indirectly, i.e. without considering the curve describing functionality of the system by means of the resilience curve.

Method 2 models of the shape of the resilience curve (FL-t curve) directly and looks for "macro-indicators" (e.g. maximum loss of functionality, downtime, etc.). In this method, the event is described as an exact scenario, and the time may be referred to as scenario time, as described further below. The model behind the method is illustrated in Fig. 7.

3.1 Analysing resilience over operating time ("indirect resilience assessment")

In the SmartResilience approach applied in the research behind this paper, the values of the indicators (at the time of measurement) are based on, e.g. data from monitoring systems, expert opinions and big data analysis. The approach is based on several previous methods, notably the ANL/Argonne method (Fischer 2010), the Leading Indicators of Organizational Health (LIOH) method and the Resilience-based Early Warning Indicator (REWI) method (Øien et al. 2012).

The indicators can be of any type, e.g. yes/no questions, numbers, percentages, portions, or some other type. They are transformed to an equal scale, i.e. a score on a scale from 0 to 5. The indicator scores are aggregated upwards in the six-level hierarchical model ending with an overall resilience level (RIL) of a critical infrastructure (e.g. healthcare system) or an entire area (e.g. a city or a country). If the assessment is repeated (regularly, e.g. annually), the trend curve (RL-T) is obtained. This time (T) may be referred to as operational time and the details on the underlying levels can be drilled-down using visualization (Jovanović et al. 2017).

The calculations are performed bottom-up, but the main part of the assessment is carried out top-down, starting with defining the scope, e.g. a city, region or country (level 1), one or more smart critical infrastructures (SCIs), e.g. the healthcare system (level 2), one or more threats, e.g. pandemic (level 3). The phases (level 4) are fixed as described in Sect. 2. The remaining two levels, issues (level 5) and indicators (level 6) are core concepts in the resilience assessment method.

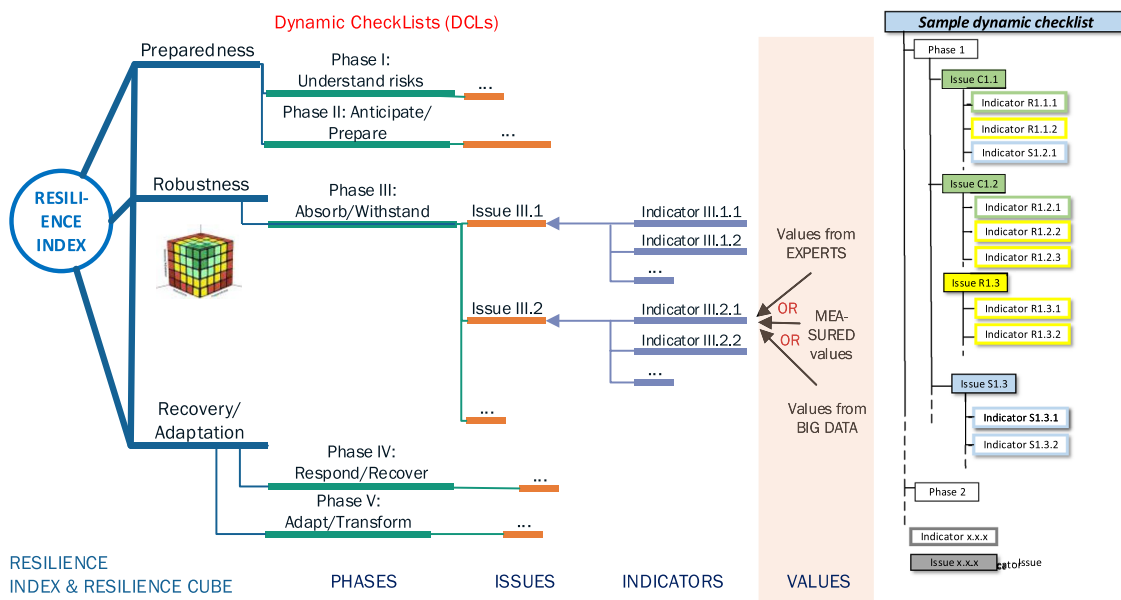


Fig. 5 Issues measured by indicators, allow to make the bridge between a given, e.g. measured value of an indicator, and the overall, final Resilience Index & Resilience Cube

An "issue" is a general term referring to anything that is important in order to be resilient against severe threats such as a pandemic. It is telling what is important, e.g. it can be "understanding of the threat/ pandemic", "learning from others about COVID-19, e.g. China", "doctors and nurses", "intensive care beds", "respirators", "test equipment", "infection control equipment", "plans for increasing capacity", "plans for restrictions such as quarantine and isolation", etc. The issues can, if necessary, be categorized in various ways, e.g. according to the dimensions in Fig. 2 or some subcategories. Computationally, this can be solved by weights. One or more indicators are used to measure each issue, e.g. "number of intensive care beds available", "number of respirators operational", etc. The issues and indicators for any resilience assessment have to be tailored for a given assessment, e.g. in the case of a pandemic in general, or COVID-19 in specific.

One of the strengths with this method is that every measure (or at least the most important measures) taken before and during (and eventually after) COVID-19 can be described as issues/indicators in the resilience matrix and made more transparent (see Annex 1). The preference for certain measures will of course vary between countries due to, e.g. political, cultural, social, financial and other differences.

3.2 Analysing one resilience cycle ("direct resilience assessment")

One challenge with this approach is that no matter how intuitively one might say that the critical functionality of an infrastructure is easy to define, in practical terms, especially quantitative, it is usually not. In the case of COVID-19, the healthcare system's critical functionalities are, e.g. to hospitalize all infected persons in need of healthcare, to provide intensive care for those who need this, and to provide respirators for the most critical patients, but also, e.g. continuing to provide adequate care to non-COVID-19 patients. In the SmartResilience concept, these are the functionality elements (corresponding to the "issues" in the indirect method), which can be assessed by functionality indicators, just as in the indirect method based assessment (e.g. the "number of intensive care beds available" can be such an indicator). Defining the functionality this way enables to quantitatively define the resilience curve in scenario time, e.g. for the main characteristic points in time.

Based on the resilience curve (or functionality curve), it is then possible to define the resulting macro-indicators, such as Robustness, Absorption time, Downtime, Loss of Functionality, Fragility (loss of functionality rate × Loss of functionality), Recovery time, Recovery rate, Disruption time, and Adaptation/transformation (Jovanović et. al 2018a, b, c). The resulting macro-indicators (not the input indicators) can also be used for "stress-testing", in which case these can be

Fig. 6 Indirect and direct measurement of resilience

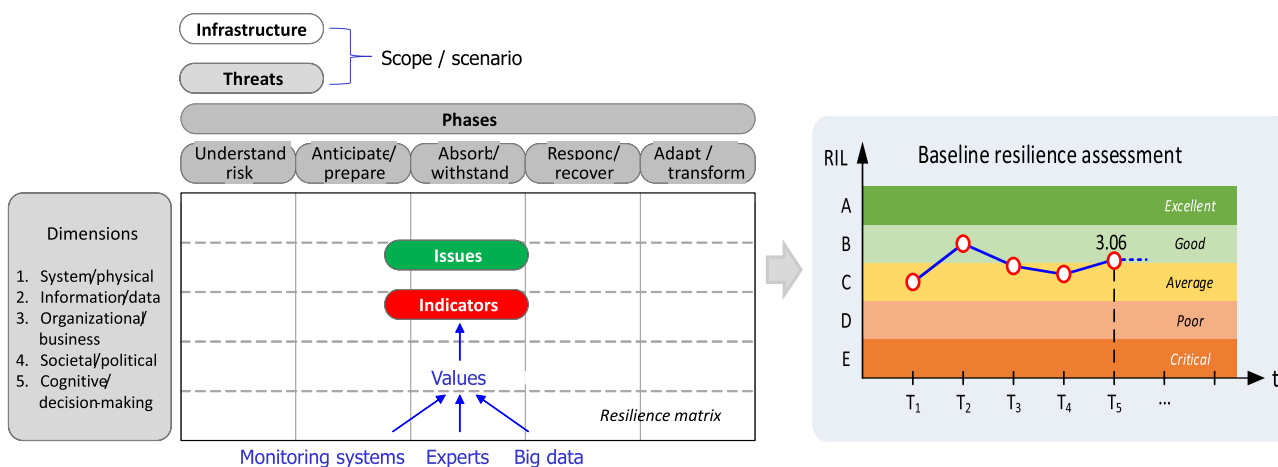
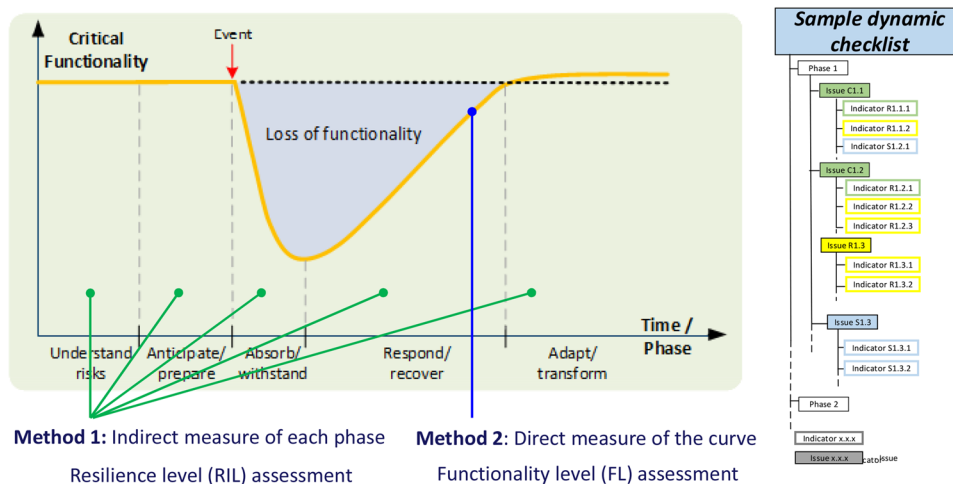


Fig. 7 The hierarchical model in method 1

compared with the critical thresholds, e.g. for the maximum loss of functionality, duration or a combination of these, etc.

A special characteristic of a pandemic like COVID-19, compared to other extreme events, is that it is gradual, long-lasting and may involve several dips in functionality level. This gradual increase in infected population, i.e. the infection rate, is critical to control in order not to overwhelm the healthcare system, i.e. it is necessary to "flatten the curve", as illustrated in Fig. 8. The figure also illustrates that during the preparation phase, the critical functionality (critical resources) can be increased, since all but the first country (China) know that the virus is on its way. In addition, the phases "absorb/withstand" and "respond/recover" are not as clear-cut as in sudden and concentrated events. The same type of representation can also be used to look at the gradual and long-lasting impact of COVID-19 pandemic onto infrastructures (health and others) including the, e.g. multiple shocks of varying degrees of severity occurring to the

system over time with different recovery responses (e.g. the often discussed "second wave").

4 Application of the approach to assess resilience of a healthcare infrastructure

The approach assumes that the resilience of the healthcare system plays a key role in assessing the overall resilience of other related critical infrastructures. In this sense, looking at healthcare infrastructure means also looking at the society in terms of infrastructure-of-infrastructures, i.e. as an "integrative" case study. The scenario was analysed before Corona (COVID-19) crisis, but de facto considering many its elements. It assumed a threat of a sudden and/or unexpected surge of patients or injured people due to either a mass casualty incident (e.g. water contamination, disasters), or a health problem like epidemic (pandemics such as COVID-19 in an

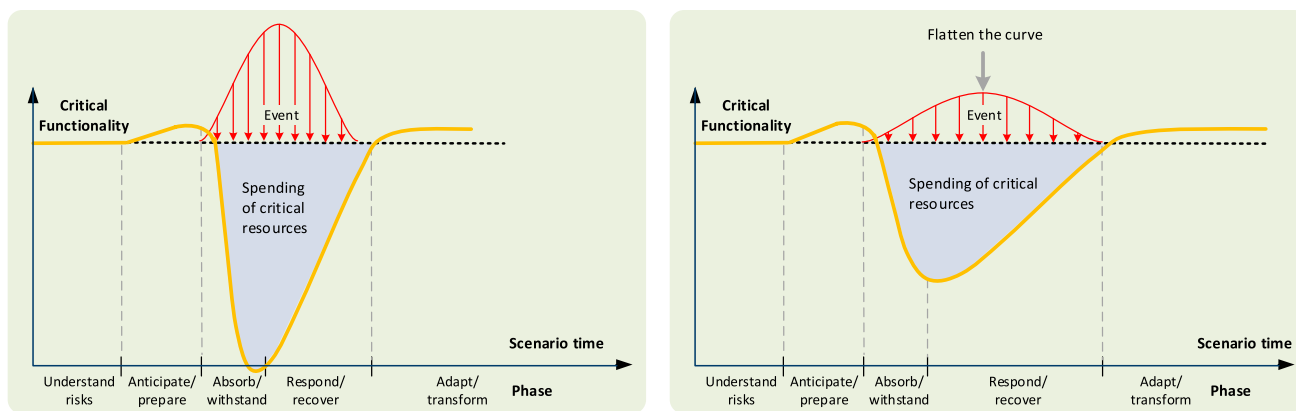


Fig. 8 Flattening of the curve to not overwhelm the healthcare system

extreme case), or due to an event that renders a substantial fraction of healthcare providers inoperable. The healthcare system of Austria is used as a test case. Experts from the technical direction of Europe’s largest hospital, as well as experts for a data-driven and evidence-based benchmarking and performance measurement of healthcare systems evaluated the threats and provided advice.

4.1 General description of the assessed critical healthcare infrastructure

The Austrian healthcare system encompasses about 20,000 different healthcare providers with services that accounted for 39.6 billion € or 11.2% of the Austrian GDP in 2016. Among these providers are 122 hospitals throughout the country and about 5000 primary care providers that provide services covered by the mandatory social insurance in Austria. The focus is on the General Hospital of Vienna, the largest hospital in Europe and employing about 9000 people and treating around 95,000 inpatients annually (Fig. 9).

The Austrian healthcare system is highly segmented with responsibilities being split up between various regional or national organizations in different health sectors. For instance, responsible for outpatient care in Austria are mostly more than 20 different social security institutions that have recently been restructured into only five institutions. In the inpatient sector, hospitals are managed by regional carrier organizations, next to some exceptions of hospitals that are managed directly by the Republic of Austria. From this fragmentation (presumably an issue in other countries, too) arises the challenge of harmonizing and integrating data from all of these institutions, which is necessary to give a comprehensive picture of the efficiency and resilience of healthcare in Austria. In practical terms, this means that there are databases that integrate these heterogeneous data sources. They include all relevant inpatient and outpatient services (which allows connecting activities in the health

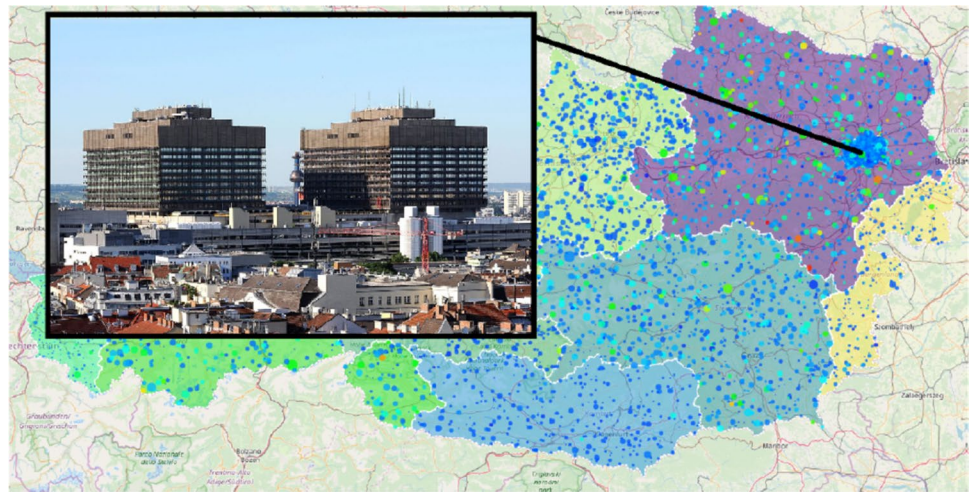
sector to other sectors, such as transportation). But, there is no real-time monitoring on a comprehensive, nation-wide scale of such activities and, therefore, no (non-)automatic adaptations to events observed in real time.

Almost all European countries face the challenge of an unsustainable healthcare system. That is, health expenditures typically grow faster than national incomes, which means that on the long run there is only a limited set of options: one either cuts back on medical services provided to the population or cuts back in other sectors, unless dramatic technological developments reduce the future demand for health services. As a consequence of these pressures, healthcare systems are constantly pushed towards operating at their maximal capacity, e.g. in terms of patients treated at hospitals and the occupancy of hospital beds. If the system is already close to its maximum capacity in the normal mode of operations, how will it react in the situations of severe shocks such as COVID-19? How resilient will the system be with respect to sudden and unexpected surges in patient numbers if waiting rooms in outpatient wards and doctor offices are already full? Relevant threats on the routine level (Table 1) therefore include cyber-attacks (rendering some providers non-operational) and natural threats (e.g. urban flooding), yet the methodology that has been developed can be generically applied in all situations where a specific type of healthcare providers faces a sudden and unexpected increase, such as COVID-19 in the number of patients to be treated within a given time span.

4.2 Applying the resilience indicator-based approach

In the particular case, the resilience matrix (5×5) was applied taking into account the main issues shown below (per each dimension of the resilience matrix Fig. 2, Tables 1 and 2).

Fig. 9 Map of Austria with healthcare providers shown as circles (inset: General Hospital Vienna)



4.2.1 System/physical

- **Understand risks** The physical dimension that is relevant for a resilience assessment of the healthcare system corresponds to a city-spanning network of different types of healthcare providers—from hospitals over physicians and medical specialists to pharmacies. In order to provide effective care for patients, multiple of these healthcare providers need to coordinate themselves in their treatments.
- **Anticipate/prepare** In the normal mode of operation this system can be characterized by flows of patients between their homes or work places and through different types of providers. To understand risks for such a system means to understand how such these flows change under the particular scenario. Anticipation and preparation on this dimension means to adjust the densities of certain types of provider in specific regions such that the system has a sufficient capacity to provide for the population even in the case of adverse events.
- **Absorb/withstand and respond/recover** In the case of emergency response this requires an effective system for triaging patients and routing them according to their level of urgency through the healthcare system following the rules implemented in a so-called patient guidance system.
- **Adapt/transform** The procedures in this system need to be continuously adapted and adjusted in order to reflect the “lessons-learned” from past events.

4.2.2 Information/data

- **Understand risks** For a quantitative and data-driven understanding of risks in a regional healthcare system, the implementation of a shared, nation-wide system for electronic healthcare records is necessary.

- **Anticipate/prepare** This allows to anticipate and to prepare for adverse events through a moment-by-moment quantification of population health and the characterization of the status quo of the utilization of certain types of healthcare providers. From this it is possible to derive key performance indicators that are informative on where potential vulnerabilities exist in the system.
- **Absorb/withstand and respond/recover** In the case of an event itself, a permanent monitoring of patient flows at the sites of individual healthcare provider, in particular those involved in emergency response, is key.
- **Adapt/transform** These experiences can then be used to refine and update the performance indicator in order to have a “smart” and resilient healthcare system.

4.2.3 Organizational/business

- **Understand risks** On an organizational level, such quantitative approaches to risk analysis need to be complemented by suitable qualitative approaches, in particular scenario analysis.
- **Anticipate/prepare** In order to anticipate and prepare it is crucial to formulate a plan of action that clearly assigns roles, competences and also hierarchies to different organizations as well as key staff within these organizations. In case of an event the personnel need to follow the procedures set out in the corresponding plan of action.
- **Absorb/withstand** In these plans, response measures are typically implemented through extensive checklists.
- **Respond/recover and adapt/transform** Regular training and simulation exercises for the key staff are necessary for an adaptive and in this sense learning system.

Table 2 Basic 5 × 5 matrix for the Austrian case

Phases → Dimensions ↓	Understand risks	Anticipate/prepare	Absorb/withstand	Respond/recover	Adapt/transform
System/physical	Treatment pathways of patients. System given by transport flows of patients between different types of healthcare providers (physicians, hospitals, pharmacies)	Adjust the density of certain types of provider in a certain region to ensure that needs of the population are met in case of an event	Triaging of patients to distinguish between different levels of urgency	Care and transport of the patients following the patient guidance system for patients with a given triage level	Review of the management system and adjust plans of action
Information/data	Implementation of a nationwide shared system of electronic health records	Moment-by-moment quantification of population health as a function of demographic variables and place of residence	Permanent monitoring of patient flows on HCP level	Permanent monitoring of patient flows on HCP level	Continually update relevant key performance indicator—"smart critical infrastructure";
Organizational/business	Quantitative and qualitative risk analysis	Assign roles, competences, and hierarchies to the involved organizations and their key staff	Implementation of a plan of action on the level of individual healthcare provider (internal events) and on a regional level (external events)	Follow checklists	Regular scenario exercises and training for key staff
Societal/political	investments in infrastructure, political discussions and negotiation among different stakeholder	Formulate joint plans of actions and provide resources necessary for their execution	Distribute relevant information to media, relatives, and staff	Distribute relevant information to media, relatives, and staff	Redistribute funds and investments
Cognitive/decision-making	Understand differences between emergency procedures and the routine mode of operation	Anticipation of events that have the potential to either lead to mass casualties or to reduce the number of operational healthcare provider drastically	Identify relevant threats	Follow checklists and agreed-upon procedures	Increase coordination between different healthcare provider and other, relevant organizations

4.2.4 Societal/political

- **Understand risks** To ensure an efficient and suitable allocation of resources and investments in relevant infrastructures is fundamental in the societal/political dimension. An important characteristic of the healthcare system is that a large number of stakeholders are involved on this level (representatives of the inpatient and outpatient sector on a state and federal level, private companies, social security institutions, public and private carrier organizations for hospitals, and so on).
- **Anticipate/prepare** In order to understand the risks and prepare plans of action accordingly it is therefore necessary to coordinate all these involved stakeholders.
- **Absorb/withstand and respond/recover** In the case of an event and in its wake one of the main priorities for this dimension is to efficiently distribute information to the media, medical staff, but also to relatives.
- **Adapt/transform** An adaptation and learning on this level can only be achieved through a redistribution of -mostly public- funds.

4.2.5 Cognitive/decision-making

- **Understand risks** The first step in understanding risks is to note that there are crucial differences between the routine mode of operation in the healthcare system and procedures in the case of adverse events.
- **Anticipate/prepare** In anticipating and preparing for such events this means to understand which types of mass casualties or disruptions in the operation of certain types of healthcare providers are to be expected.
- **Absorb/withstand** In the case of an event the first priority is to identify the relevant threats and then follow the checklists and agreed-upon procedures.
- **Respond/recover and adapt/transform** Increased adaptability and learning can be achieved through increasing the coordination between different healthcare provider and stakeholder organizations.

The approach was used in the Austrian federal state (Vorarlberg) with outpatient care provider placed at random locations within their districts (show on map in Fig. 10). The figure (a) shows for one selected provider its dependence relations to other providers as blue lines. The thickness of these blue lines gives estimates for how likely it is that services provided by the selected provider can be substituted by services from the linked providers (which is estimated from the data based on factors like geographic proximity, overlap in patients, type of services provided, etc.). A surge in the number of patients at this provider will overload its capacity and cause secondary effects for the other providers (b), where the levels of redness indicate how much of

the initial shock each provider is expected to absorb. As a result, tertiary cascades might occur (c). This kind of assessment can either be done directly “by hand” in the healthcare assessment module developed within the project, or automatically for each doctor and district in Austria. A more detailed description of this stress test of a healthcare system can be found in Lo Sardo et al. (2019). The approach is comparable to those applied to other critical infrastructures (e.g. transportation, Ganin (2017) or epidemic outbreaks (Massaro et al. 2018)). For the inpatient setting, i.e. hospitals, we developed a different assessment module that is, however, based on the same functioning principles and the same indicators. As a concrete scenario here we consider an urban flooding event in Vienna. The initial event is a surge in the number of patients to be treated as an initial impact of the flood (in the current scenario, it was assumed that the subway system is flooded in the morning close to rush hour leading to the load of an entire subway train needing to be transported to the hospital). The assumed situation was further that the flood cuts off access to hospitals at the other side of the Danube, that only become accessible again later in the day, see also Fig. 11.

4.3 The exercise

A list of indicators that underlies the above exercise scenario have been developed over multiple workshops and bilateral meetings with key stakeholders in the Austrian healthcare system. During these interactions, the issues and conventional resilience indicators to be used were defined and evaluated, and also the “inner workings” of the healthcare assessment module of the tool assessed. This included the comparison of districts with respect to their Resilience Index Level as well as a more detailed investigation of changes in the functionality level of Vienna’s hospital in the case of a large event (see the Functionality Level assessment).

For the development of the assessment module and a proper formulation of the indicators, an end-user driven approach was followed in a series of joint meetings and workshops. One of these specific characteristics of this exercise was the use of a GIS-based assessment module in order to compare all 122 Austrian districts with respect to their resilience levels in the inpatient and outpatient sectors. In particular, based on needs and requirements communicated by the end users, iterative versions of the assessment module were developed, including its underlying data sources, and respective issues and indicators. After an updated version was built, another meeting to discuss progress was set up and further expert input on how to refine the assessment module until a satisfactory state of the tool was achieved as a basis for the assessments. The final scenario was then selected in a table-top meeting exercise where the corresponding numerical simulations were carried out Fig. 12.

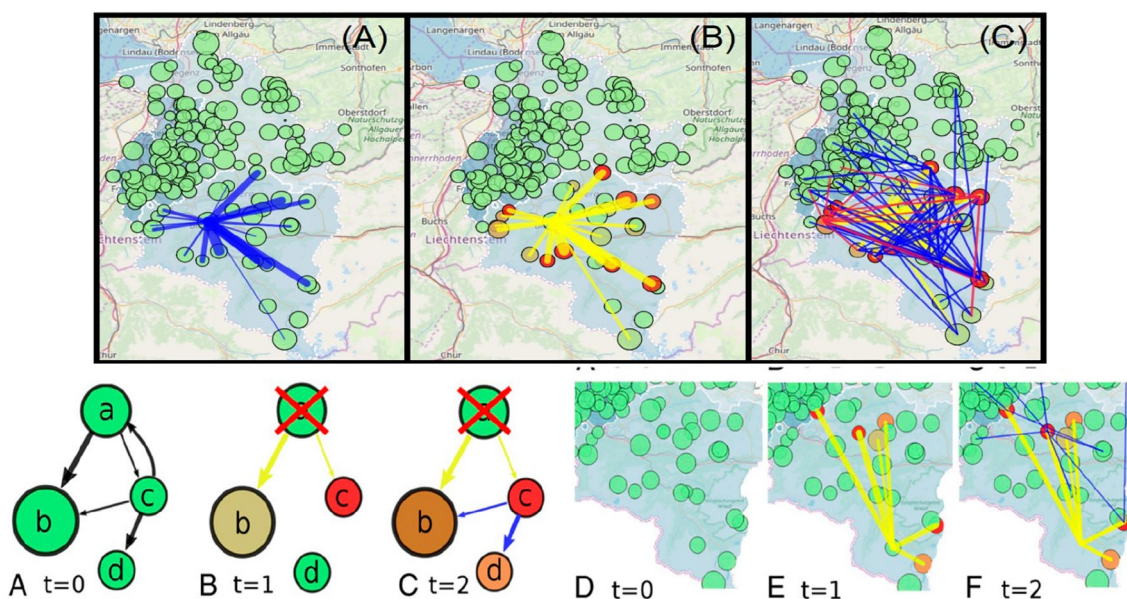


Fig. 10 Test scenario for outpatient care providers: Schematic representation of patient displacement dynamics. **a** Doctors are represented as nodes (size represents the number of patients treated per year). They are linked if they share patients in the patient sharing network, **a** (black arrows). The colour represents their current capacity; green means that they have capacity, and red means that they can no longer accept new patients. **b** Doctor “a” retires at time step 1; his/

her patients are distributed to other doctors according to the weights of the links from “a” to “b” and from “a” to “c” (yellow arrows). This, in turn, changes the capacity of the other doctors. **c** As **c** has reached its capacity limit (red), he/she must send patients to other doctors (blue arrows from “c” to “b” and “d”). This creates a cascade of patient displacements of size 2

4.4 Main results of the exercise (general case)

The main result of the comparison of all districts of Vienna with respect to their Resilience Index Level is summarized in the Fig. 13. The Resilience Index Level for each district is colour coded on a scale from 0 to 5. Note that the 23 districts of Vienna have been aggregated into a single district for purposes of the visualization, the individual assessment reports of these districts can be accessed via the resilience dashboard. It is evident from the picture above that the resilience level is confounded by geographic proximity, i.e. districts that are close to each other tend to have comparable resilience levels. There is one outlier in terms of low resilience, which is a district in lower Austria with a comparably low healthcare coverage index (i.e. density of primary care provider) that is coupled with a sudden loss in accessibility of primary care services in case of an increased medical needs of the population.

The indicators used include the “unsupervised”, big-data-driven indicators that have been evaluated using the assessment modules described above. While a substantial amount of resources went into the exact formulation of these indicators, they have the advantage that they can easily be applied to all Austrian districts once their methodology has been fixed. In order to comprehensively quantify all relevant aspects of resilience as defined by the SmartResilience

approach, these big data indicators were complemented with more conventional, “supervised” suitable indicators. Most of these indicators apply across all districts, as the healthcare infrastructure (in particular in the inpatient sector) is operated by a small set of carrier organizations. The most important regional variations however, such as healthcare coverage indicators, numbers of cases, number of available hospital beds, population density in affected areas and such are evaluated in an unsupervised way from big data sources. Only the results from one specific district (Vienna 9th district that contains the country’s largest hospital, the General Hospital of Vienna), out of 122 evaluated districts are shown here (Fig. 14, 15). For the remaining districts, the assessment reports containing the data-driven indicators are available in the ResilienceTool.⁵

A further study has been performed by Sardo et al. (2019) looking for the answer to the question, is there a point beyond which these pressures will severely impair the quality of care? Resilience captures how fast and the extent to which it is possible to deliver adequate healthcare services to the entire population in the wake of such an assumed shock (“stress-test”). The questions like the one above were, at the time of working at the study, the assumptions

⁵ <https://www.resiliencetool.eu-vri.eu>

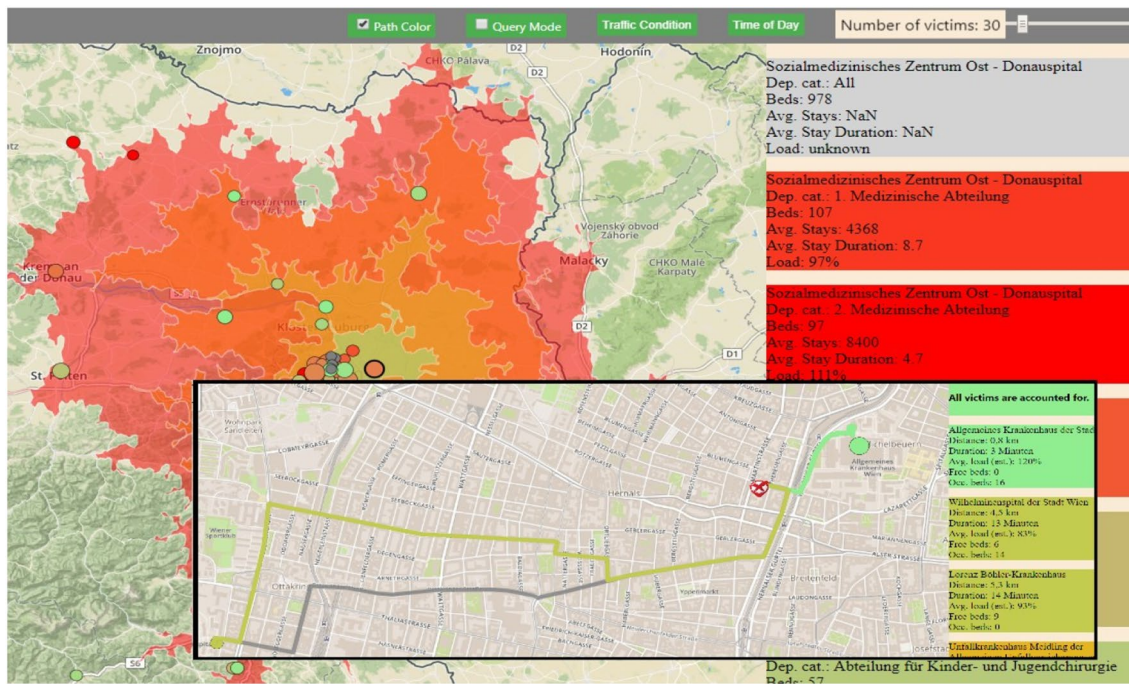


Fig. 11 Snapshot of the hospital assessment tool. Hospitals are shown as circles with colours that indicate their free numbers of beds. The shaded areas give regions of equal time to travel to one specific hospital. The tool allows one to simulate an event in a specific place (specified by the time of day, traffic conditions, and the number of injured

people) and computes how long it takes to bring each of those people to a free hospital bed. Inset: example of how a scenario can be implemented. By clicking on a specific location and specifying the number of injured people there, the tool estimates the resulting changes in indicator levels for all hospitals

for hypothetical scenario, similar to the COVID-19 one. Although the assumptions for the stress-test were by far less severe than those of COVID-19, the results are showing quite a different picture than the one in Fig. 13.

4.5 Recommendations

The lowest indicator scores, i.e. the largest potential for improvement, can be identified in the use of real-time monitoring tools that aid decision-making, in particular in the response and recover phase. As already mentioned, the healthcare system is particularly robust with respect to the adoption of new technologies. In some areas in healthcare, paper-based record keeping is still the de facto standard, with digital data imputation only occurring as an afterthought in order to claim financial compensation from the social security institution. The consequence is a lack of real-time information on how the current "load" (numbers of patients at specific providers in a given region—a serious problem in COVID-19 pandemic) is distributed at any given time. Rather, one has to infer this knowledge in the simulations from historical data. The main conclusion of this exercise is therefore the need to reinforce investments into developing information flows to ensure that patient-level information is channelled efficiently to all necessary healthcare providers

in order to improve the resilience of healthcare systems. This recommendation has been fully confirmed by COVID-19 in Austria.

As the Austrian healthcare system is undergoing a major restructuring, one of the incentives of which is the need to harmonize the provision of medical services across the country. This offers the opportunity to rethink the current processes of collecting and sharing data. In particular, it would be necessary to break up the currently existing silos of data and to enable a comprehensive real-time mapping of activities in the healthcare system. How many beds are right now free in department X within hospital Y? What is the waiting time for treatment Z in region U? While it is beyond doubt that such kind of information is vital to improve resilience of the healthcare system, it must at the same time be taken into account that healthcare data is highly sensitive and needs to be processed accordingly. It therefore requires a unique set of skills to be able to (i) appropriately handle the high-volume dynamic and sensitive data that healthcare systems produce and (ii) have the required domain knowledge to transform this data into actionable knowledge this can ultimately be used to improve population health. A new kind of institutional setup is therefore needed to simultaneously fulfil both needs, as current institutions either lack

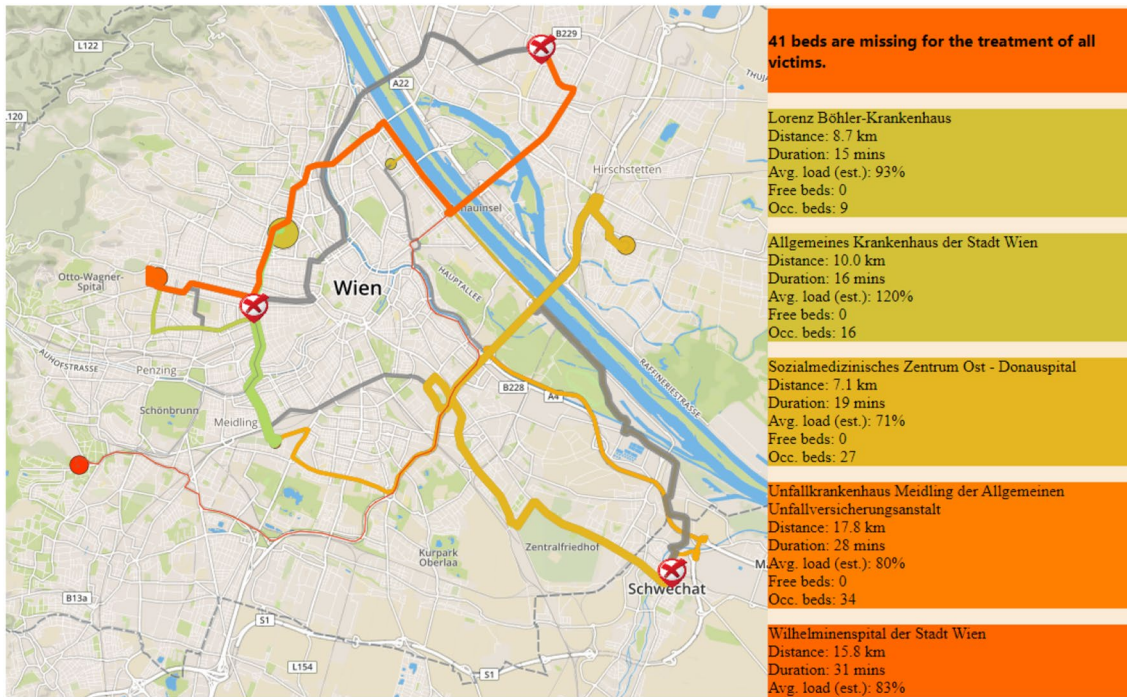


Fig. 12 Snapshot of the hospital assessment tool. Simulates an event of three concentrations of an adverse event, roughly simultaneous and their impact on possible patient routing to healthcare providers, easily overcoming the normal capacity of the assigned providers

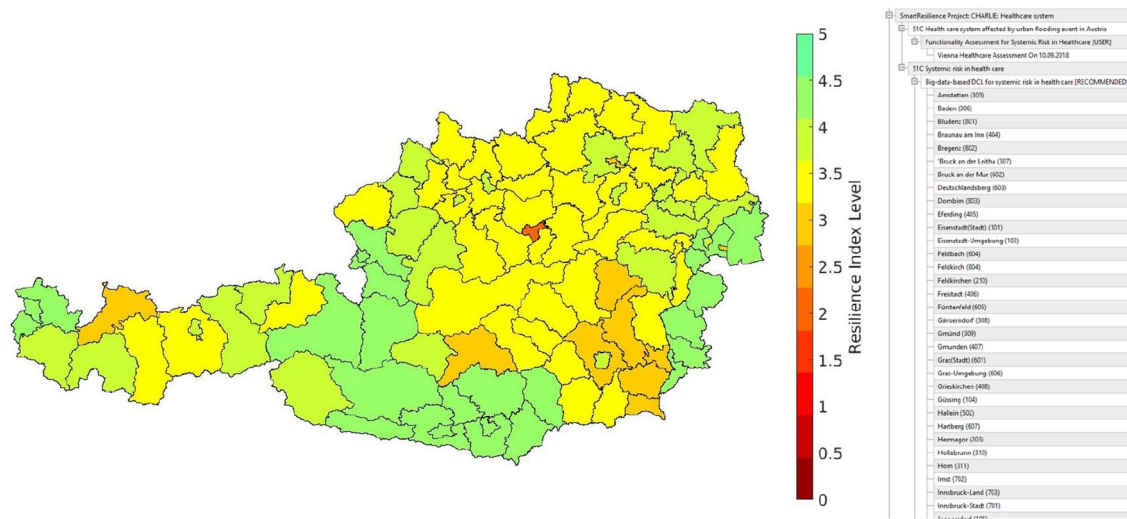


Fig. 13 Main result of the first exercise. For each district of Austria (the “tree” on the right side), the resulting score of the resilience assessment exercise is shown on the scale from 0 (red) to 5 (green)—“routine emergencies” (Table 1)

medical domain knowledge or the skills to handle large-scale dynamic data.

The stress-testing exercise clearly show that the resilience of healthcare systems cannot be described by trivial summary statistics, such as physician density. The resilience can be quantified, e.g. by set of appropriate indicators, and used to aid decisions on optimal allocations and how investments

for the increase of regional primary (health)care provide (PCP) densities would be most beneficial. One can estimate the systemic relevance of individual providers and therefore, identify which providers it would be particularly important to keep in place or support immediately (e.g. in the case of COVID-19, the PCPs who have succumbed the infection.

Interactive map of assessments

Visualize resilience > Interactive map of assessments

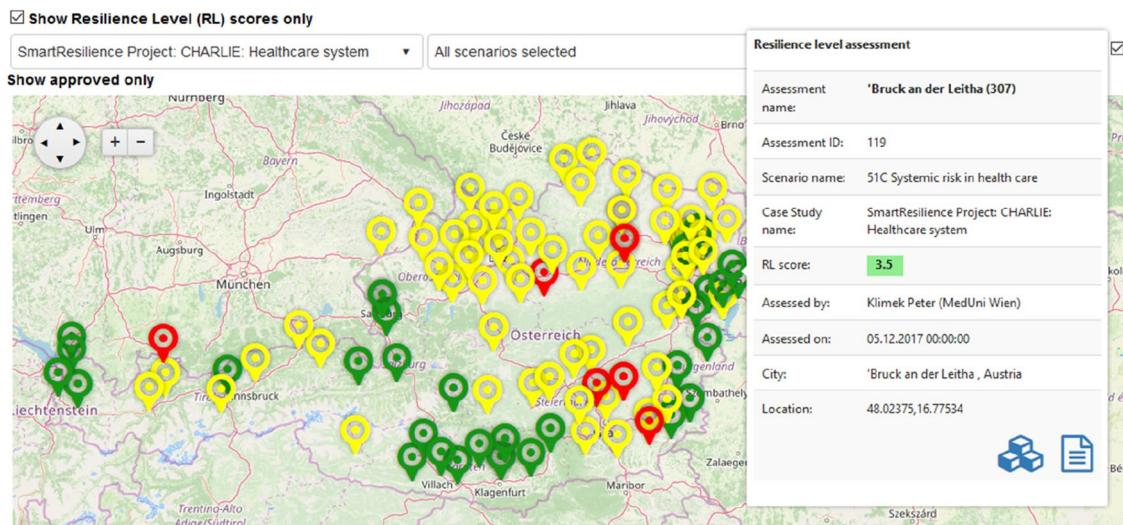


Fig. 14 The 122 evaluated districts in the healthcare system of Austria

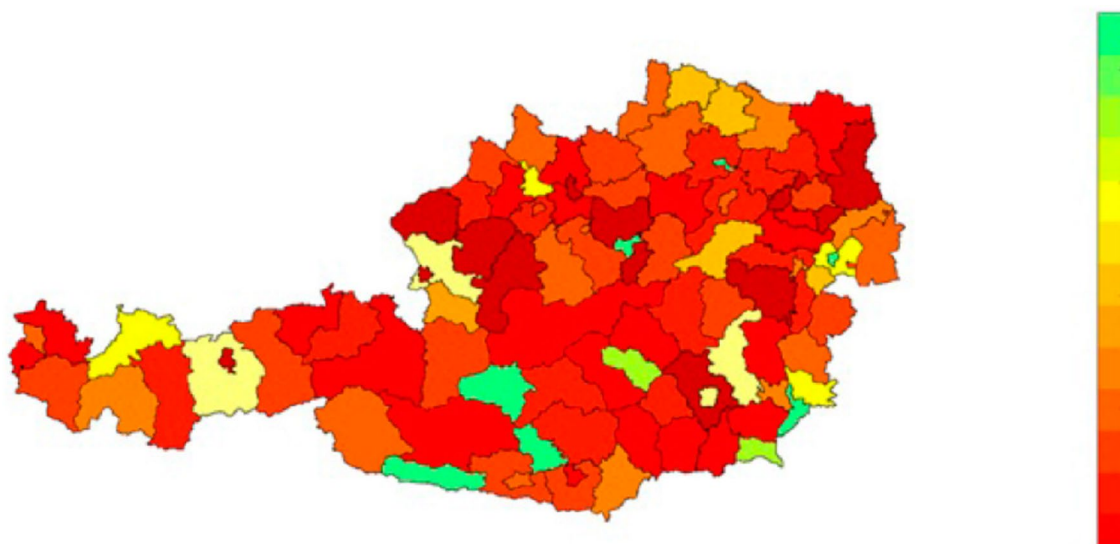


Fig. 15 One of the results of the stress-test (Sardo et al. 2019): Map of Austria showing the upper bound of the resilience indicator for all districts for a very challenging stress-test scenario. Districts coloured in green (red) have a particularly high (low) resilience: that is, critical

removal fractions (Fig. 10)—the map shows significant change compared to the scenario in Fig. 13; note that the stress-test scenario was not of the scale of the COVID-19 one

Finally, the analysis confirms in the quantitative terms the common sense knowledge saying that current health systems are designed to deliver more of the “continuous service” than prevention and match for extreme events such as pandemic.

5 Comparing practices in the COVID-19 crisis by means of resilience indicators

5.1 Countries selected for comparison

The countries selected for the comparison were selected based on the importance of their situations, including

precautionary and response measures, and based on the availability of data⁶—it is common knowledge that the numbers related to COVID-19 are collected in different ways and formats, and cannot be compared directly; these arrive with different time delays and all together, are yet to be consolidated for the full-scale scientific analysis. Hence, for the preliminary analysis performed here, the data were collected primarily from online sources, including media. For the sake of traceability, main sources of information are stored in the ResilienceTool (Jovanović et al. 2019a, b, Fig. 16).

5.2 Results per country

In the ResilienceTool, the countries are set up as one COVID-19 case study, following the project scenario. So far, all the countries (Fig. 17) follow the same scenario, while country specific variances may be set up in the future, as more information becomes available. For the selected scenario, a dynamic check list of 57 indicators was established. Again, as for the selection of countries, it was not always possible to use the most interesting indicators (e.g. number of doctors and medical staff affected or dead)—the data for the values of these were simply not available. The sources consulted were taken as available. The results are organized on several levels per country:

- Level 0 RLI-based (resilience level indicator)—Fig. 17
- Level 1 Resilience phase indicators based—Fig. 18
- Level 2 Resilience matrix based—Table 3 and Annex 1
- Level 3 Detailed description Table 4 and Annex 2 (example China)
- Level 4 Full reports—Fig. 19 and Table 5

6 Identifying and understanding emerging risks related to COVID-19

COVID-19, as discussed in chapter 1.3, cannot be considered as a “pure breed” emerging risk. But as a phenomenon and cause of further emerging risks, it affects the global risk and resilience management by:

- changing both the internal and external context,
- exposing huge lack of valid relevant information and knowledge, the potential for established information to become invalid as the context changes and the possibility of misinformation becoming common in the new context,

- causing impact that the new context may have on the control environment, specifically noting that an emerging risk may jeopardize the current control environment (e.g. the healthcare infrastructure in case COVID-19), or require new thinking in terms of controls that must be applied,
- being systemic in its nature and multidisciplinary in its character, and
- being of transnational or sector or system transgressing nature.

As a risk with low likelihood (frequency), but high impact on human health, safety security, the environment or the resilience of the society, and as summarized in Table 6, it fits the criteria specifying differences between a risk that is already subject to appropriate control and an emerging risk. The process of “maturation” of emerging risks shows that the organization should look at the emerging risks initially, looking at weak signals and giving due consideration to the potential for future impact and speed of change rather than fixate on current impact.

For an emerging risk, it is necessary to consider the main characteristics describing its emerging character: the accumulation of the available knowledge/information about it, i.e. its maturation with time. In most of the cases, the evidence collected will be heterogeneous and incomplete, often contradicting, and it is therefore necessary to ensure that each piece of evidence is stored in a structured manner, in order to obtain a meaningful and consistent picture of an emerging risk as soon as possible.

Practically, it is assumed that a risk “starts” as an emerging risk, when the first indication (e.g. a “weak signal”) is recorded for the first time. After that, any new evidence (notion), further early warnings, indications, signals, precursors, incidents, etc., recorded and processed will contribute to the process of maturation of an emerging risk.⁷ This may lead to first anticipated scenarios, usually formulated by potentially involved stakeholders, who start to feel threatened by these scenarios. If these scenarios start to materialize more frequently, further development (maturation) might lead to the creation of interest groups leading to actions to clarify and/or prevent the emerging risk. Once this process leads to, e.g. new or changed regulation, legal decisions and similar, one can talk about fully emerged risk, fully included into the scope of known, and thus conventional, risks.

Although the maturation of an emerging risk does not necessarily need to have a constantly ascending character and the initial indication may end up by becoming false (e.g. no occurrences happen or counter evidence becomes

⁶ An interesting point could be if the availability of data in itself is an indicator of how resilient the country might be to pandemic, reflecting the state of healthcare informatics accuracy and flow?

⁷ <https://committee.iso.org/sites/tc262/home/projects/ongoing/iso-31022-guidelines-for-impl-2.html>

COVID-19 Country Assessments	Case Study	57	JET Report Full JET report Benchmark
COVID19 Resilience	Scenario	210	Info
COVID-19 Resilience assessment DCL [USER]	Resilience level	192	Info TreeMap Compariso
COVID-19 Assessment for Austria	Assessment RL	538	Result Report TreeMap
COVID-19 Assessment for China	Assessment RL	537	Result Report TreeMap
COVID-19 Assessment for France	Assessment RL	527	Result Report TreeMap
COVID-19 Assessment for Germany	Assessment RL	520	Result Report TreeMap
COVID-19 Assessment for Israel	Assessment RL	521	Result Report TreeMap
COVID-19 Assessment for Italy	Assessment RL	525	Result Report TreeMap
COVID-19 Assessment for Norway	Assessment RL	530	Result Report TreeMap
COVID-19 Assessment for S. Korea	Assessment RL	522	Result Report TreeMap
COVID-19 Assessment for South Africa	Assessment RL	529	Result Report TreeMap
COVID-19 Assessment for Switzerland	Assessment RL	524	Result Report TreeMap
COVID-19 Assessment for USA	Assessment RL	523	Result Report TreeMap
System analysis facing COVID-19 [COMPLETED]	Functionality level	194	Info Comparison
Financial System	Assessment FL <input checked="" type="checkbox"/>	535	Result Report TreeMap
Health System	Assessment FL <input checked="" type="checkbox"/>	534	Result Report TreeMap
Social Infrastructure	Assessment FL <input checked="" type="checkbox"/>	536	Result Report TreeMap

Fig. 16 Countries analysed by the ResilienceTool

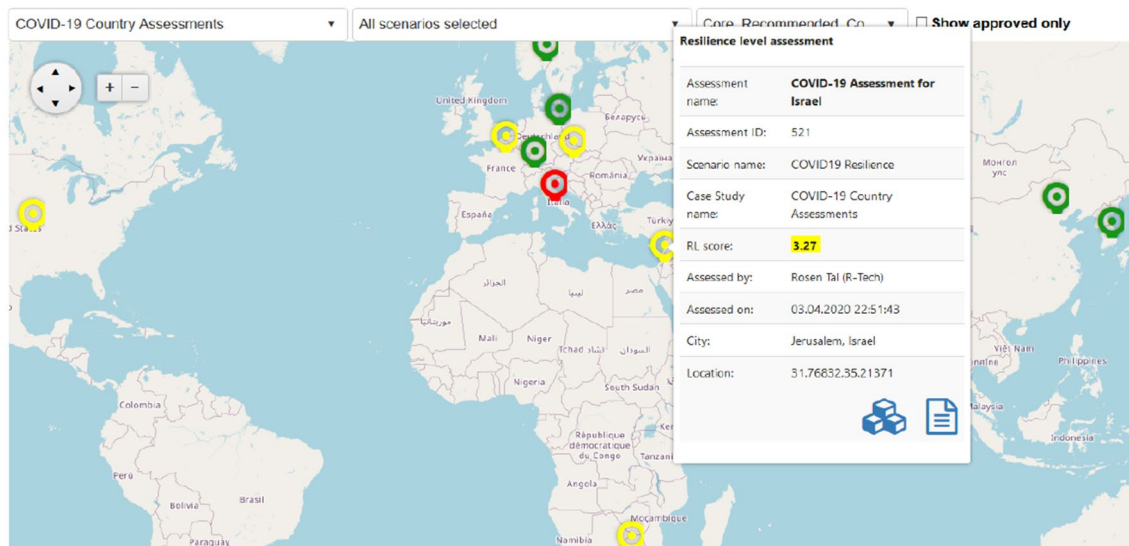


Fig. 17 Countries covered by this resilience analysis (“level 0”)

available, the maturation process starts decaying and the emerging risk, eventually, disappears), the early identification of early warnings is extremely important. One way of capturing these early warnings, is the risk radar (Fig. 20), as applied to COVID-19. The COVID-19 related events should be monitored in order to ensure business continuity and the respective warnings properly aggregated, classified and visualized for the stakeholders. Thus, it enables stakeholders to

discuss early on, what the intended and unintended effects of the developments may be.

The Risk Radar tool has been applied to scan, monitor and visualize the ever-growing volume of online data on COVID-19. The tool utilizes a purely content-based methodology to rank a set of publicly available documents (news articles, blog posts, abstracts from scientific journals etc.) according to their potential to generate impact. The tool considers the textual data over a period of time for a

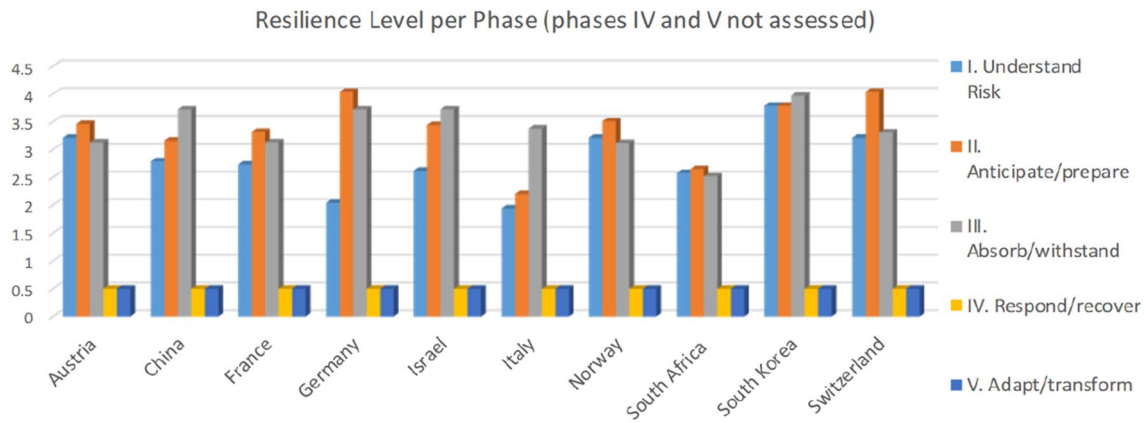


Fig. 18 The resilience phase results (“level 1”) per country

Table 3 Resilience matrix based (“level 2”) results per country (example of Austria, full report in Annex 1, the RLI is given in the matrix)

Resilience Level Overview		Comment				
Austria		Weaknesses: - Preparedness level not sufficient related to medical equipment/intensive care equipment				
Strength: - Good monitoring of situation - Fast implementation of measures - Good coverage of medical equipment						
Resilience level (RL) matrix						
PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform	RL per dimension
a. System / physical	-	3.33	3	-	-	3.16
b. Information / smartness	3.5	-	2.67	-	-	3.08
c. Organization / business	3.33	3.5	3.07	-	-	3.3
d. Societal / political	3	3.5	3.36	-	-	3.29
e. Cognitive / decision-making	3	3.5	3.56	-	-	3.35
RL per PHASE	3.21	3.46	3.13	-	-	3.33

given topic, uses this information to perform data analytics to rank the relevance or importance of the documents and related keywords based on document centrality. Centrality is a simple indicator for gauging the impact of the document that captures the frequency of the terms, but also how these terms are related to each other. The tool yields the Radar and a Network map. The former includes a list of risks-related keywords on a radar-like widget, along with the list of sources used for extracting and ranking these keywords. The position of the keywords (shown in yellow dots) on the radar indicates its importance where the closer to the centre the term is, the more “relevant” a keyword is in documents related to the COVID-19 coronavirus analysis. The Network map includes a short description of the topic (shown in green circle) connected to the most common keywords (shown in blue circles) and the articles (in colours of red, orange and yellow). The colour and size of the collected articles are designated based on their relevance; the larger circle has the highest applicability to the topic.

By looking at different sources (e.g. “science (Fig. 20), “media” and “public” (Fig. 21)) the system identifies the topics of interests in the information parsed (web pages, blogs, publications, reports...) and assigns them the respective risk scores according to the criteria set (e.g. sentiment,

credibility of source, context, etc.). The early warning is identified on the basis of the relation of the terms in search, not on simple “word bagging”. The radar-like visualization is based on the semantic network in the background allowing user to drill-down to the initial source of information and obtain the background information (e.g. the full-text report). An example is shown in Fig. 22, accidentally showing the predictive character of the methodology and the tool: the screen shot made on March 30, 2020 was identifying as risk, which in fact materialized 7 days later.

7 Interdependencies and scenarios: COVID-19, health, economy, society, acceptance...

As shown by Klimek et al. (2019) modern macro-economic theories can be of limited usability to predict the duration and the recovery rate of a crisis (Fig. 23). Predicting the outcomes and recovery from COVID-19 global crisis will be an even greater challenge.

This analysis has to focus on resilience as a non-equilibrium property of networked complex systems (example: the system looking simultaneously at health, economy/

Table 4 An example of the summary report per country (“level 3 report”): example of two countries, two indicators, <https://www.e19hsrcm.org/searchandcompare.aspx>

	Italy	France
Monitoring and surveillance	<p>For surveillance purposes, Italy adopts the European Centre for Disease Prevention and Control (ECDC) definition, which describes a case as a person who is confirmed as having the virus that causes COVID-19 through lab testing, regardless of signs or clinical symptoms</p> <p>The government is also evaluating digital “contact tracing” solutions, which would allow the detection of the infected person’s movements. Concerns about privacy, however, remain a focal point</p> <p>A National Surveillance System, coordinated by the ISS, was activated on 27th February and oversees the daily gathering of data from regions and from ISS’s National Laboratory for SARS-CoV-2 through a dedicated web portal reporting infographics (graphs, maps and tables), describing the diffusion in space and time of the spread of the disease across the country and providing a brief description of infected cases</p>	<p>The monitoring and surveillance of the epidemic is integrated in a prevention and management plan with four stages</p> <ul style="list-style-type: none"> • The first stage consists in limiting the introduction of the virus on the national territory (from February 23) • the second stage (reached on February 29) consists in limiting the spread of the virus on the national territory • the third stage (reached on March 14) consists in reducing the effects of the epidemic; and • the fourth stage consists in going back to the baseline situation before the start of the epidemic. However, surveillance measures were implemented in France from January 10
Physical distancing	<ul style="list-style-type: none"> • Italy was the first country in Europe to adopt restrictive physical and social distancing measures • Although introduced incrementally, the nation transitioned to full lockdown in a very short period • Government decrees released from 9th to 22nd March have: • Banned any movement except for proven working requirements, situations of necessity and health reasons. Citizens must carry a signed self-declaration explaining the reason for their movement or risk criminal charges <ul style="list-style-type: none"> • Prohibited any form of mobility for those in quarantine or who have tested positive to the virus • Closed all schools and universities, requiring educational activities to take place solely through online teaching • Suspended all forms of gatherings, including sport competitions and cultural, recreational, religious or trade-fair events • Suggested salaried workers resort to days of paid leave or to work remotely • Discontinued civil and religious ceremonies, including funerals 	<ul style="list-style-type: none"> • The first global measure was limited to the interdiction of large public meetings of more than 5000 persons first (on March 4), then of more than 1000 persons (on March 8) and then of more than 100 persons (on March 13) • Concurrently, on March 11, visits to all residential nursing homes were stopped to protect the older population. • Closing of all schools and universities by a decree dating from March 13. all public places, except essential shops such as supermarkets, were also closed • the president announced a total lockdown (stay-at-home) policy from March 18 onwards • All employers were asked to put in place teleworking for their employees whenever possible • Only people who cannot work remotely and provide essential services (including health, medical research, production of essential goods...) are allowed to go to work • Others are only allowed to go out for getting food, for medical reasons or for short recreation activities in the immediate vicinity of their place of residence

production and social acceptance) and develop a response model including all relevant factors, similarly to the framework based on the theory for input–output economics. In the example of such a model calibrating the framework to data from 56 industrial sectors in 43 countries between 2000 and 2014 (Fig. 23), it was possible to model the susceptibility of individual industrial sectors to economic shocks across countries, sectors, and time. In this work we proposed an analytic approach to compute the susceptibility of a given sector in a country to shocks from other countries and sectors. Predictions based on these susceptibilities outperformed thus, by far, standard macro-econometric time series models. They are analytically more rigorous, empirically more testable, and flexible enough to address even highly

uncertain non-linear policy-relevant scenarios, as shown at the example of the impact of the, in 2019, imposed tariffs on US imports (steel and aluminium) on specific sectors across European countries. This clearly speaks for use of these methods also in the prediction of interdependencies (e.g. those among health, economy and society) in the prediction of the COVID-19 related recovery. In the same context, the recovery will obviously be part of the resilience cycle, involving the phases described in chapters 2 and 3. Applying the method described in chapter 3.2 and assuming the values of some of the (currently extremely volatile) indicators, one can model the scenarios and the interdependencies as shown in Fig. 24 and 25.

Fig. 19 An example of sites putting together full-scale sources (e.g. full reports—“level4”) related to COVID-19 (here: the EU The Health System Response Monitor (HSRM) <https://www.c19hsrm.org/searchandcompare.aspx>)

The Health System Response Monitor (HSRM) has been designed in response to the COVID-19 outbreak to collect and organize up-to-date information on how countries are responding to the crisis. It focuses primarily on the responses of health systems but also captures wider public health initiatives. This is a joint undertaking of the WHO Regional Office for Europe, the European Commission, and the European Observatory on Health Systems and Policies.

Click here for policy recommendations and technical guidance from the WHO Regional Office for Europe on how to strengthen the health systems response to COVID-19 and click here for the EU coronavirus response in the area of public health.

IMPORTANT REFERENCES

Important links and articles related to the COVID-19 crisis.

LINKS AND DOWNLOADS All | Tools and Dashboards | Response Monitors | Research | International Resources

- 📄 Cochrane library_ Content from the Cochrane Library relating to the COVID-19 pandemic
Cochrane library
- 📄 ECDC_ COVID-19 resources
ECDC
- 📄 Elsevier_ COVID-19 health and medical research
Elsevier
- 📄 EPPI-Centre_ COVID-19: a living systematic map of the evidence
EPPI-Centre
- 📄 ETUC (Labour, workers rights) COVID-19 Watch briefing notes
ETUC

In all scenarios and considerations, one will certainly have to take into account the acceptance levels (equalling to the limits in the stress-tests) and modelling these will be a challenge of its own. The acceptance analysis will have to take into account the risk perception aspects, as an issue playing an ever increasing role in all the considerations to COVID-19, too. The question remains: what is needed to make early warning and risk perception a better tool for disaster prevention? Or why do leaders, during an event, announce quickly that more investments are needed, but as the effects of the outbreak fade original plans fade as well.

Taking the example of Switzerland, each of its 26 Kantons is supposed to do disaster planning based on the risk report and the scenarios issued by the federal Bundesamt für Bevölkerungsschutz (BABS). Key elements to support the transition of risk analysis to disaster prevention is the risk dialogue among the involved parties on all the political level as well as on the expert and citizen level. Based on the risk analysis and the risk dialogue capacity planning, on the

community, canton and state level, as well as on a company /SME level, should be conducted. Thereby the threat of a pandemic spread is one of the biggest risks, but by far not the only risk, that requires preparation. Therefore, each of the disaster prevention plans should be aligned with Safety policy and strategy of the Swiss Government. In the case of COVID-19, it is apparent that the virus does not stop at national borders and joint multinational efforts are needed to generate the necessary capacities to prepare and fight the virus. But, all disaster prevention measures come at a price. In this context, the returns on safety investments are hard to quantify and most often do not generate a return within a short time frame. Creating /engineering more resilient systems, cities, societies, healthcare systems require a political discussion about how much safety does one want and how much is it going to cost.

Table 5 An example of the summary report per country (“level 3 report”: the list composed out of 57 indicators; no values for the indicators covering recovery and adaptation phases provided)

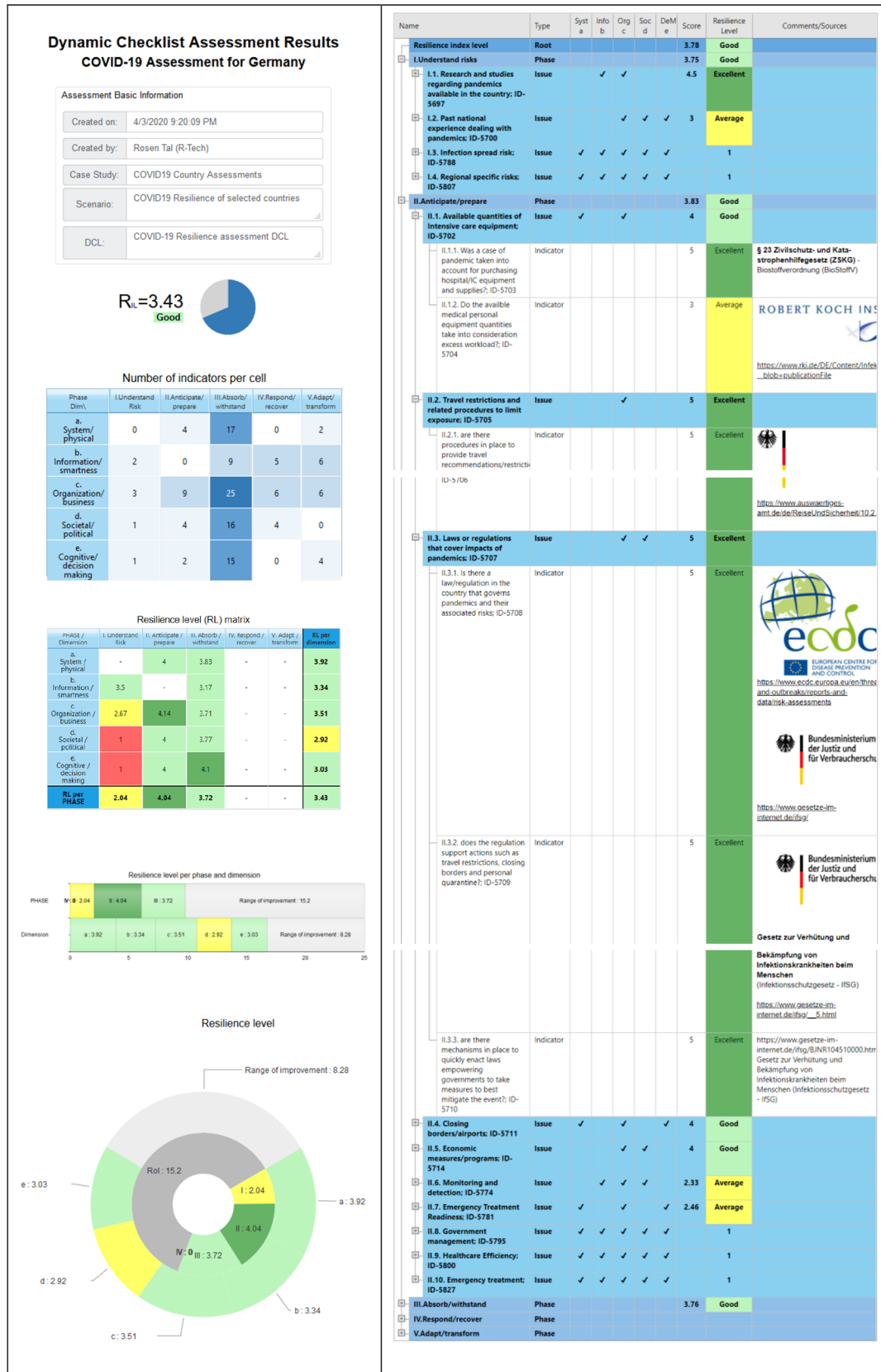


Table 6 Emerging risks are risks characterized by inadequate understanding and ineffective control environment of sound management practice as the quality of information improves

Elements of maturation:	Emerged risk	Emerging risk	COVID-19
Knowledge, information Focus	Established “Business as usual”	Vague Warning, alert	Vague or missing High, global alert
Control effectiveness	High	Low	Very low, inexistent
Signals, indications, occurrences	Good and numerous	Weak and seldom	Weak and ambiguous
Maturity of risk management	High	Low, vague	Low, missing
Regulatory/legal framework	Exists	Vague or missing	Missing, inconsistent

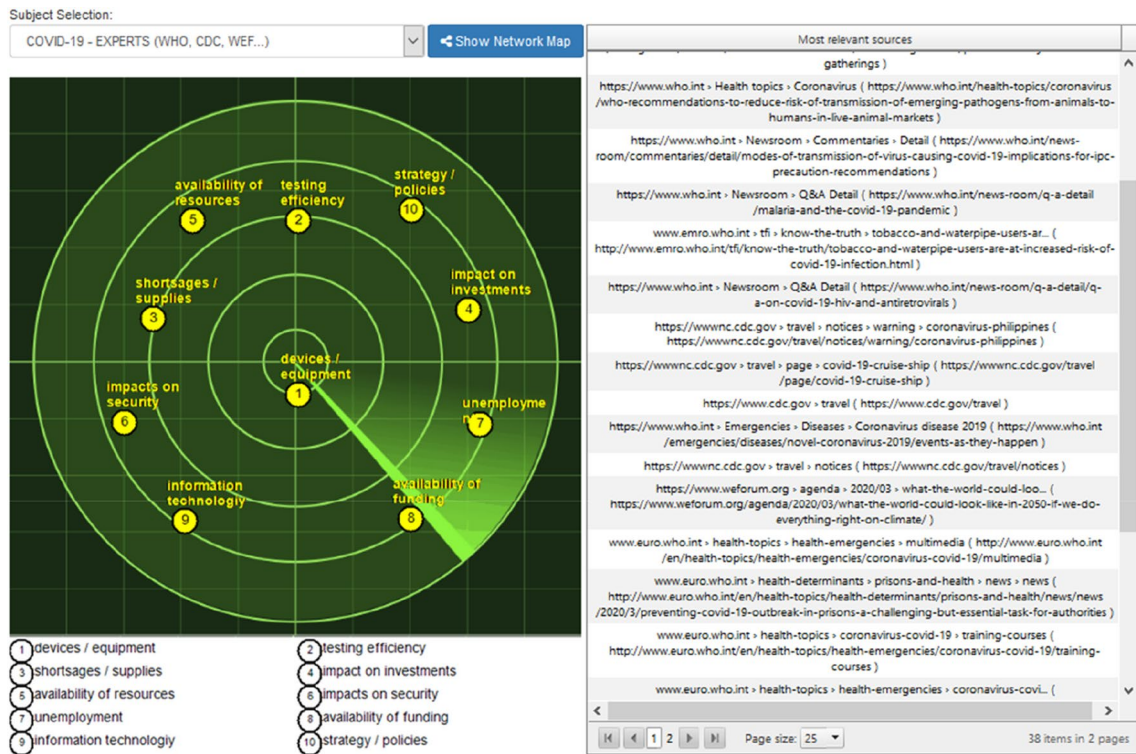


Fig. 20 Risk Radar tool applied to the Corona/COVID-19 issue: Web-semantic based analysis identifying the issues of interest and potential new risks, including main sources (on the right); the num-

bers indicate risks; the vicinity to the centre of the radar (Steinbeis 2020) corresponds to their importance; here the risks resulting from analysis of expert opinions extracted from the course on the risk

8 International risk and resilience standards relevant for COVID-19 risk and crisis management

The main calling of the relevant ISO standards (ISO 31,000 series and 223xx series, Fig. 26) is to provide universal, yet meaningful guidance on developing new competencies and business models to create relevant and realistic recommendations in an ever-changing uncertain world. Risk enters every decision in life, but clearly some decisions need a structured approach and the more complex and uncertain the issues, the more an adaptive and comprehensive policy, framework and processes are required. Dealing with risk is part of governance and leadership. These considerations are

at the heart of ISO 31,000, *Risk management—Guidelines*, which delivers a clearer, shorter and more concise guide that will help organizations use risk management principles to improve planning and make better decisions.

In the standard, risk is defined as the “effect of uncertainty on objectives”, which focuses on the effect of incomplete knowledge of events or circumstances on an organization’s decision-making. This requires a change in the traditional understanding of risk, forcing organizations to tailor risk management to their needs and objectives—a key benefit of the standard. The framework supports all activities, including decision-making across all levels of the organization. The ISO 31000 framework and its processes should be integrated with governance, strategy and management systems to ensure consistency and the effectiveness



Fig. 21 Risk Radar tool applied to the Corona/COVID-19 issue: comparison between press and media (left) and public www sources (right)

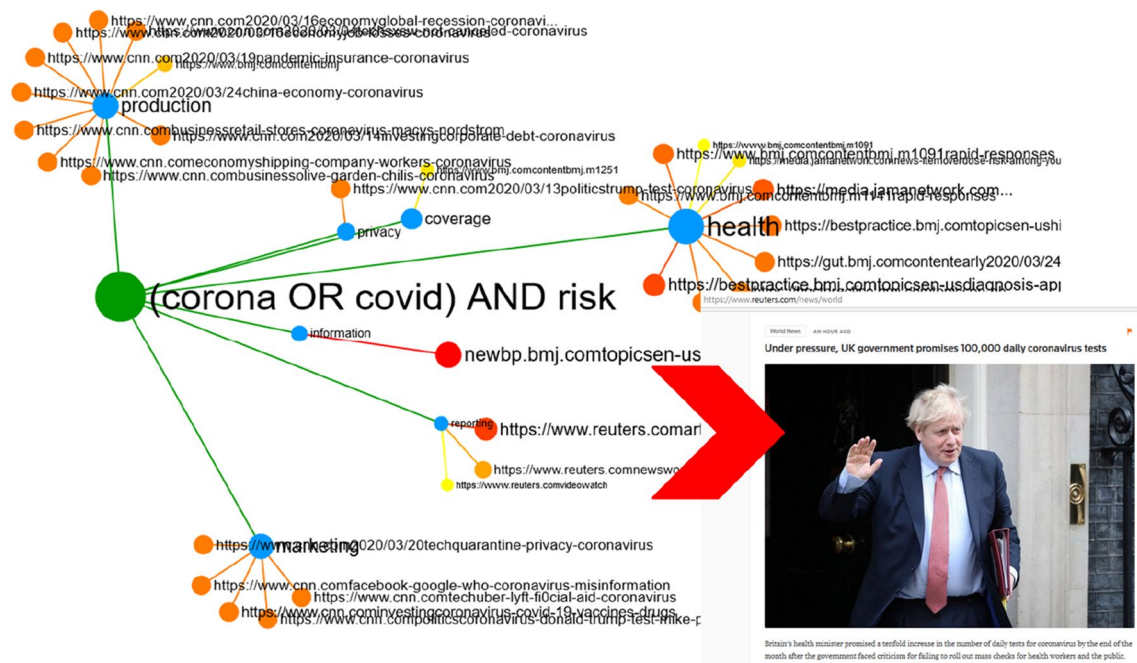


Fig. 22 Risk Radar tool applied to the Corona/COVID-19 issue: Web-semantic based analysis identifying the issues of interest and potential new risks, including their sources in www-snapshot made 7 days before Boris Johnson was hospitalized (Steinbeis 2020)

of management control across all areas of the organization. This includes strategy and planning, organizational

resilience, IT, corporate governance, human resources, compliance, quality, health and safety, business continuity,

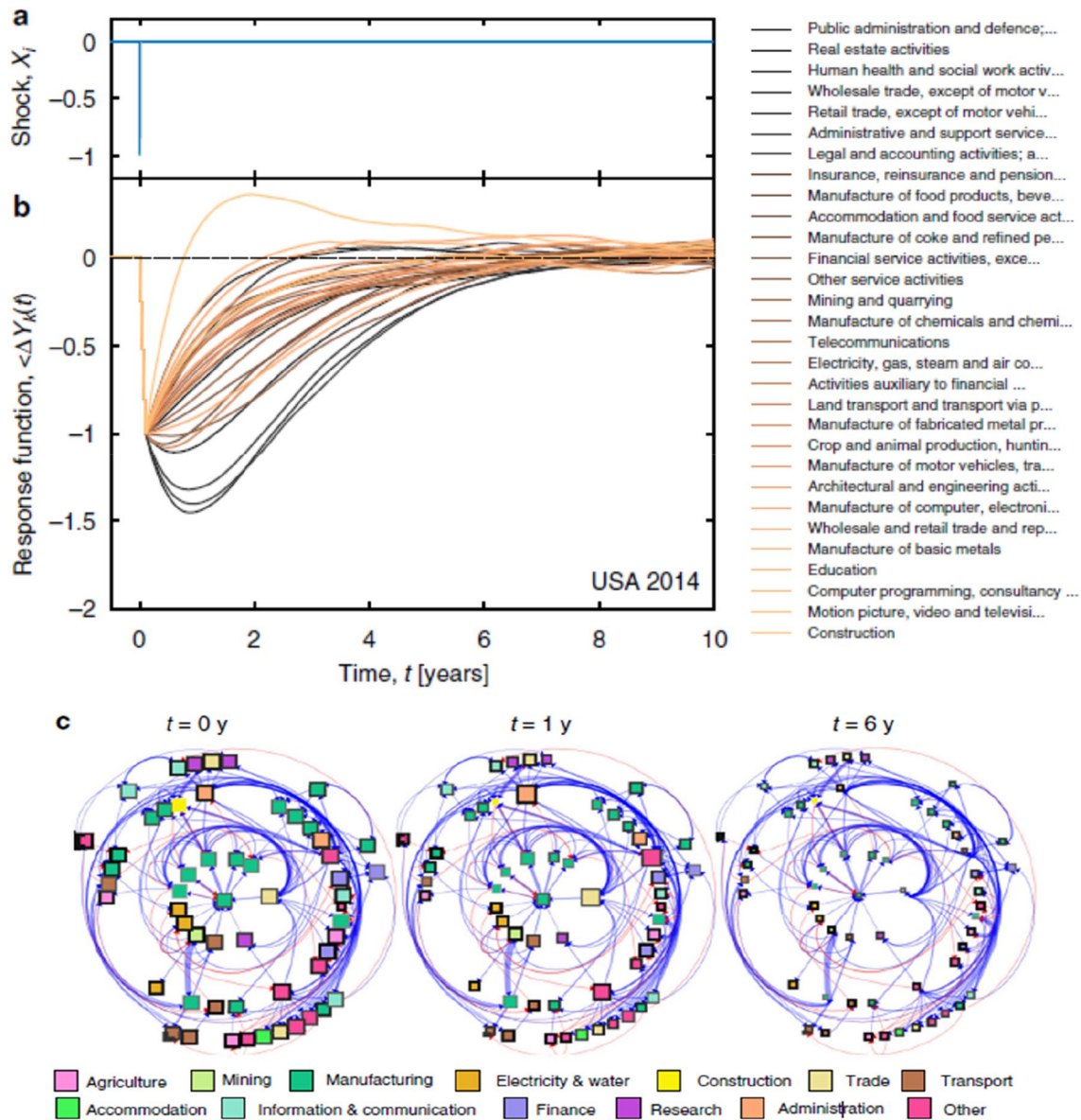


Fig. 23 Visualization of response curves. a An impulse shock of unit size is applied in year $t=2014$ to every sector, i , in the USA. In response, the output of each sector is driven from its equilibrium value. b Every line corresponds to one of the 30 largest sectors, ordered according to their susceptibility to the shock (i.e. the area between the response curve and the dotted line that represents

the equilibrium value). The sectors with the largest impact are public administration, real estate activities, human health, and wholesale trade. On the other end of the scale one finds the construction sector, that after the initial shock profits from the disruptive event. Depending on the sector, full economic recovery might take up to 6–10 years (Klimek et al. 2019)

crisis management and security. All of which are relevant to responding to a pandemic. Resilience is built on understanding current and emerging risk and building the adaptive and responsive elements of the organization to deal with the risk one knows and anticipate, through a resilience strategy to address both the known and unknown “Knowns” and the known and unknown “Unknown”. The application is supported by the methodologies available in IEC/ISO 31010 Risk Management—Risk assessment techniques, providing

guidance on the selection and application of techniques for assessing risk in a wide range of situations.

With the new ISO 31050, currently under development, the decision makers will be better equipped to manage both known (ISO 31000) and emerging risks (ISO 31050). To this aim, ISO 31050 will deliver structured context (e.g. definitions, drivers, metrics, etc.), emerging risk management framework, the procedure, the guidance for common format(s) for interoperability and indicators. It will also deliver emerging risk application examples in the

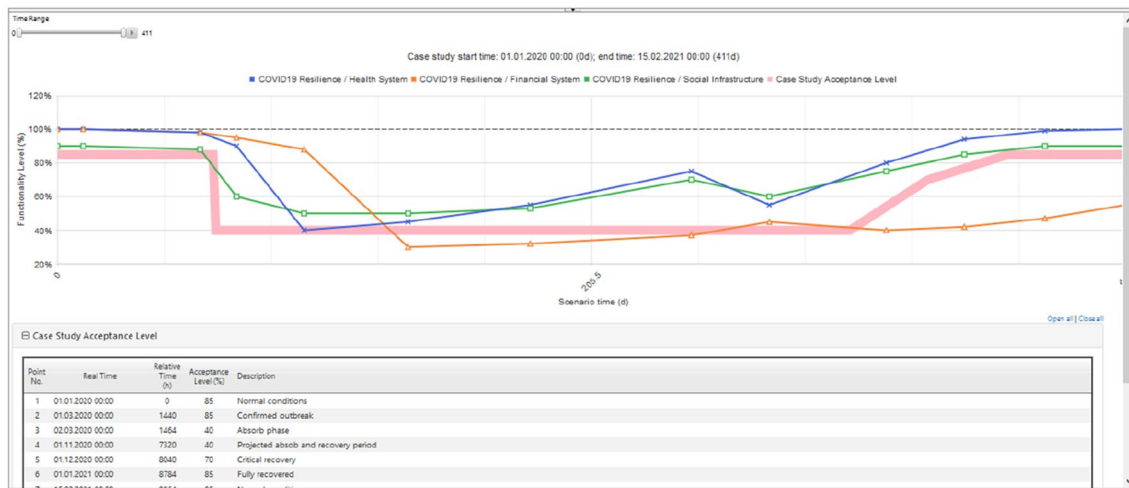
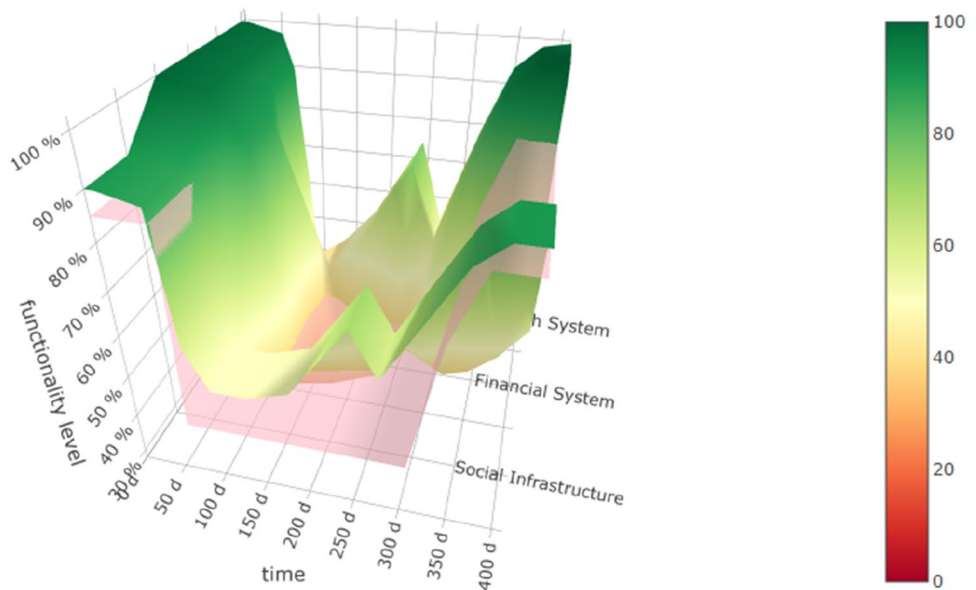


Fig. 24 Functionality graphs for three representative aspects of Societal Resilience: Healthcare sector, Financial sector and Society-as-an-Infrastructure. The scenario estimates a time horizon of just over a year, similar to previous outbreaks in 2002 and 2009, and projects one reemergence of COVID-19, as a worst case, given the lack of current data on possible treatments. The GDP-data forecast is from German sources (Der Spiegel 15/2020). The Acceptance level indi-

icates the estimated loss of functionality which is still considered tolerable by society, as defined by the state. Each functionality curve represents its segment as a whole, i.e. Financial systems, including stability indicators as well as debt, recovery programs, etc. Special note is given to Social Infrastructure as it relies often on perceptions and expectations that are not necessarily founded on facts

Fig. 25 The “Resilience landscape” corresponding to the scenario in Fig. 24



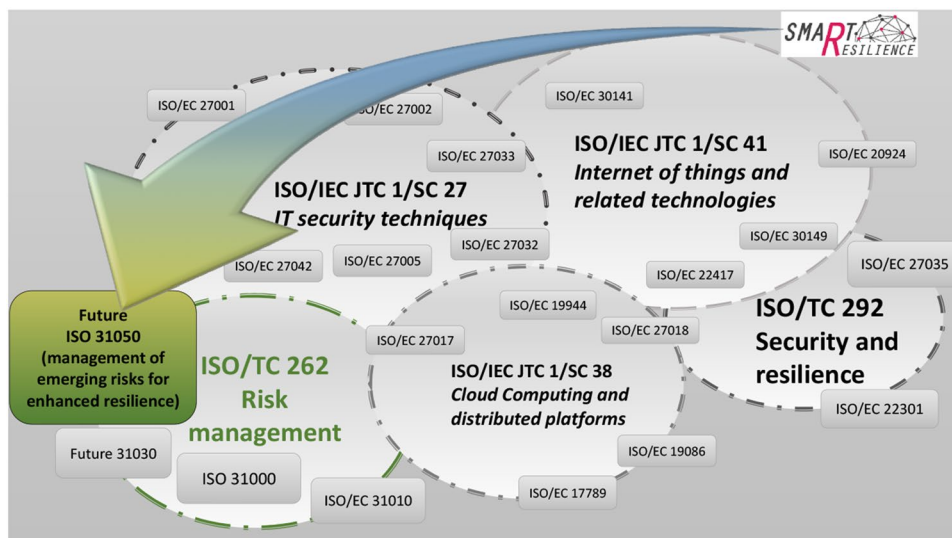
informative annexes of the standard. The recommendations of the standard should facilitate best practices, enhance resilience, promote agility, assist transformation, deliver insight, insure foresight, establish value and integrate resources—also for enhancing resilience of critical infrastructures. The standard is monitored by the ISO Technical Committees TC262 and TC292.

9 Conclusions—preparing for “COVID-2.0”

9.1 Will the “how” become more important than “what”?

As in the preceding cases of pandemics-like events and other disasters and shocks, also in the case COVID-19 crisis, the recommendations, related to future cases (“COVID-2.0”) for the future actions and measures start appearing in parallel to

Fig. 26 Managing risk and resilience under the umbrella of ISO



the crisis. But before looking for the new ones, for the “lessons learned” and “new agendas”, it might be useful to look at the inheritance from the past. Especially the organizations like UN (1994), WEF (2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020), OECD, IRGC (2010, 2011) or WHO have provided a number of seminal documents of the kind, focused around the idea that the new threat of breakdown of essential systems. What needs to be done? Improve effective monitoring and communication of virus activities, coordination of response and mitigation by different countries, research and development for new vaccines, building capacity for vaccine production, improve supply chain readiness and cooperation, improve emergency communication, transport and treatment infrastructure and adjusting the coordination of public and private resources to mitigate a pandemic. A simple check shows that the most of the recommendation made in the reports above, some of them almost two decades old, still fully apply (e.g. OECD 2003), as for instance, in the case of COVID-19:

1. Adopt a broader view on risk
 - a. Enhance multidisciplinary in risk assessment and management
 - b. Consider communication needs of different target groups as an integral part of risk management and provide a convincing rationale for justifying levels of acceptance
 - c. Detect changes in the risk landscape early
2. Examine the consistency of policy across risk areas... etc.

... but are not fully implemented, not only at the global, but also at the regional and national levels. Similarly, the

results of the analysis covering over 25 years of experience in the area of pandemics (provided in OECD 2011b) are still far from being implemented. Hence, when talking about COVID-2.0 one should consider finding the reasons for non-implementation and look that known “whats” are accompanied by the respective realistic and implementable “hows”. The main “hows” proposed by this paper are.

1. to focus more onto the extreme phases of the resilience cycle, namely onto
 - a. the phase of emerging risks and
 - b. the phase of adaptation and transformation
2. to use more the resilience indicators as a part of
 - a. international benchmarking and
 - b. improved communication for facilitating consensus on acceptance levels and intervention points
3. better align and standardize best practices globally, primarily
 - a. the approaches, principles and methods (e.g. by means of international standards) and
 - b. the tools and ways for dealing practically with practically with crises like COVID-19

9.2 Challenges

The list of challenges which preparation for the next round and implementation of the numerous lessons learned (the flood of which is certainly to be expected after COVID-19 crisis) will necessarily need to look at the issues such as.

- Global management of resources

- Global managing of the dynamic of pandemic (and other global shocks)—because the strategies based on time (e.g. postponing or flattening of curves) can be the only, albeit, almost “medieval” available strategy in face of completely new threats or new combinations of known threats (e.g. the 2020 combination of drought and COVID-19 in Chile)
 - New ethics of disaster management—questioning the principles embedded in traditional approaches
 - New understanding of established social categories likeun
 - Privacy vs. need for surveillance,⁸ data protection, and related issues
 - Work and employment
 - Return on Safety Investment
(What is the value of ICU and excess ventilators in times of no epidemic/pandemic spreads?)
 - Appropriate narratives for communication targeted towards different cultures, societies and value groups (global “emoticons” in crisis communication, such as black swans, grey rhinos, tigers & flies, etc., familiar in some parts of the world were hardly used or misunderstood elsewhere; the society relying always more on condensed information, might be needing more of these in the future)
 - Need to quantify and stress the unknown future (and be caught by surprise, Sechrist 2019)
 - Focus on functionality, not assets or infrastructures (CISA 2019)
 - Fight misinformation and misuse of disaster related information for political or similar purposes
 - Actively work on the agility of the society as a whole—especially on hyper-long and extremely complex supply chains, global infrastructures (infrastructures-of-infrastructures) exposed to complex systemic risks
- a. The 57 indicators used in the sample analysis were, were hardly giving a *complete picture* of COVID-19 related the complex situation in the respective countries;
 - b. The *definitions of these indicators* in different countries were by large not the same (e.g. the definition of an “intensive care unit bed”—e.g. including the ventilation capacity or not);
 - c. *The acquired values of indicators* (cf. Figure 5 and Fig. 7) were acquired in different ways (e.g. the number of deaths—including the care home deaths or not—leading to large differences in the UK⁹) and are, generally, more difficult to obtain for the indicators being most interesting;
 - d. The values of indicators in a check list, no matter the effort, are practically always *referring to different points* in time and are often different in character (e.g. interval vs. cumulative)
 - e. *The (perceptual, cognitive and contextual) salience of indicators*, their efficiency, as well as their independence of each other and capacity to discriminate differences (e.g. among countries in COVID-19 crisis), remain to be explored in future research.

The above issues are, obviously, not COVID-19 specific. But, in this analysis, it came as a surprise to see how readily these issues were forgotten in comments and discussions taking place during the COVID-19 crisis: the (generally few) available ones were readily used.

9.4 COVID-2.0 as a case of both risk and resilience consideration

COVID-19 was foreseen: WEF published various articles about pandemic risk estimating the impact, always in the range of more than one million deaths and a likelihood of occurrence between 1 and 10% (see reports in the last decade). Uncertainty about the nature of a potential outbreak persisted.

In the Global Risk Report 2010 the situation remained similar, indicating lack of preparedness for pandemics on international and on state and corporate levels. In the 2013 Global Risks Report, the focus was put on the danger of on human hubris on health. Despite the big successes in the management of new diseases and the containment of recent pandemic (SARS, Avian Flu, Swine Flu) we still face rising rates of chronic illnesses killing millions of people each year and we are “never far from the edge of a catastrophe, as new biological mutations will eventually overcome a prior human innovation”. In the subsequent year, Global Risks Report was reporting that pandemic spreads could lead to decreased

9.3 Use of indicators

The analysis in the paper is largely based on indicators and the paper shows how such an approach can be used in a case like COVID-19. But when using this approach, one should be always aware of the limitations linked to the indicators and approaches based on them. This should be a part of the subsequent analysis, but already so far, the above analysis has faced a number of non-trivial issues, the main (“top 5”) of which should be mentioned here:

⁸ <https://www.pepp-pt.org/>

⁹ <https://www.bbc.com/news/health-52103808>

social stability and dysfunctional cities. Considering the fact that over 3 billion people are living in the world major cities, communicable disease may spread faster and our healthcare systems might be heavily overloaded. Interestingly the most recent reports WEF mentions the risk that global supply chains might be too lean and that they are vulnerable to systemic risks e.g. to a pandemic.

Similarly, in 2015 The Swiss Government issued the report “National Risk Analysis of Disasters and Emergencies in Switzerland” (Swiss Federal Office for Civil Protection, Brem 2015). The Risk Report provide a Risk Analysis, methodology and hazard catalogue with hazard files. As one of the top risks, actually the 2nd highest, “Pandemic” was identified. But these and other numerous warnings have led to few practical actions, both globally and locally and globally—COVID-19, when it came, has been generally perceived as surprise.

The above blurs the hope that there will be to many “lessons learned” from COVID-19 for “future COVID’s”. On the contrary, many side-phenomena, such as flood of fake news, wide spread of conspiracy theories, and/or use of the crisis for “politicking”, are probably here to stay. The same applies the lasting consequences of some of the solutions applied during the crisis. The quarantine enforcement will certainly stop once the crisis is over, but people’s contact tracing, flow modelling, social-graph making and other and tools applied in the crisis will probably not. These are likely to have deep and lasting impact on civil liberties on all scales, especially when combined creeping changes in change in ethics, caused by the enforced choosing among the patients to be treated (or not) in the peaks of the crisis.

The research performed here, although based on very scattered and largely preliminary unverified (manly online) data, has as the main goal to show the validity of the approach applied, the approach based on.

- improved management emerging risks
- broad use of resilience indicators
- new way of analysis of interdependencies and
- relying on international standards

will help to prepare better for future crises (“COVID-2.0”). The research was looking primarily at the health infrastructure, but is has.

- partly tackled also the economy/financial infrastructure and
- (in the area of indicators used) the societal/political one.

These are areas where future research is certainly needed and, when made, will bring new insights clearly needed. Nevertheless, research has, however, indicated some of surprising sides of the COVID-19 crises: at least as of April 2020, the world has shown a surprising level of resilience—serious difficulties, yes, but no collapses of the health infrastructure. Some political disturbances were recorded, but no social unrest (possibly looming for the time of the economic ripple effect of the health crisis). The rather optimistic self-assessments of own performance were rather the rule then exception (see [Annexes](#)) and the expectations that the world will overcome the COVID-19 crises were high. But for overcoming COVID-2.0 of tomorrow, one will probably need more: the threats are going to become more sophisticated and the complexity of the society and its vulnerability increase.

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The standardization related results presented are related and refer to the work taking place in the JWG1 of the ISO technical committees TC262 and TC 292.

The work owns a lot to the great collaboration with partners in several EU and other international projects (such as iNTeg-Risk, Smart-Resilience, ResiStand, InfraStress and others), as well as the support of the Steinbeis R-Tech and EU-VRi current and ex-colleagues.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Annexes

Annex 1: Second level reports of the countries analysed

Resilience Level Overview		Resilience level (RL) matrix						Comment
Country	Phase / Dimension	Resilience level (RL) matrix						
		I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform	RL per dimension	
AUSTRIA	a. System / physical	-	3.33	3	-	-	3.16	
	b. Information / smartness	3.5	-	2.67	-	-	3.08	
	c. Organization / business	3.33	3.5	3.07	-	-	3.3	
	d. Societal / political	3	3.5	3.36	-	-	3.29	
	e. Cognitive / decision making	3	3.5	3.56	-	-	3.35	
	RL per PHASE	3.21	3.46	3.13	-	-	3.33	
	<p><i>Weaknesses:</i></p> <ul style="list-style-type: none"> - Preparedness level not sufficient related to medical equipment/intensive care equipment <p><i>Strength:</i></p> <ul style="list-style-type: none"> - Good monitoring of situation - Fast implementation of measures - Good coverage of medical equipment 							
CHINA	a. System / physical	-	3	4.13	-	-	3.56	
	b. Information / smartness	3.5	-	4	-	-	3.75	
	c. Organization / business	3.67	3.14	4.09	-	-	3.63	
	d. Societal / political	4	3	4	-	-	3.67	
	e. Cognitive / decision making	4	3.5	4	-	-	3.83	
	RL per PHASE	3.79	3.16	4.04	-	-	3.55	
	<p><i>Weaknesses:</i></p> <ul style="list-style-type: none"> - Initial medical equipment and intensive care beds not sufficient <p><i>Strength:</i></p> <ul style="list-style-type: none"> - Very efficient building of additional first response centers/hospitals - Efficient measures implemented in short time - Good plan for reintegration of the isolated workforce into the production processes 							
FRANCE	a. System / physical	-	3	3.18	-	-	3.09	
	b. Information / smartness	3.75	-	3	-	-	3.38	
	c. Organization / business	3.17	3.29	3.2	-	-	3.22	
	d. Societal / political	2	3.5	3.09	-	-	2.86	
	e. Cognitive / decision making	2	3.5	3.18	-	-	2.89	
	RL per PHASE	2.73	3.32	3.13	-	-	3.08	
	<p><i>Weaknesses:</i></p> <ul style="list-style-type: none"> - available medical equipment quantities don't meet the excess workload - available intensive care beds not sufficient - triage and transportation of patients to other countries required <p><i>Strength:</i></p> <ul style="list-style-type: none"> - very effective isolation/quarantine rules as well as other societal measures <p>See also: Annex 2</p>							
GERMANY	a. System / physical	-	4	3.83	-	-	3.92	
	b. Information / smartness	3.5	-	3.17	-	-	3.34	
	c. Organization / business	2.67	4.14	3.71	-	-	3.51	
	d. Societal / political	1	4	3.77	-	-	2.92	
	e. Cognitive / decision making	1	4	4.1	-	-	3.03	
	RL per PHASE	2.04	4.04	3.72	-	-	3.43	
	<p><i>Weaknesses:</i></p> <ul style="list-style-type: none"> - Lack of understanding the risk on Societal dimension - Although specific studies and pandemic plans are available, decision making was slow <p><i>Strength:</i></p> <ul style="list-style-type: none"> - the medical system and available intensive care equipment are on a high level - testing capacities are on high and will be extended during the absorb phase 							
<p>Sources for the indicators values (Germany):</p> <ol style="list-style-type: none"> https://dipbt.bundestag.de/dip21/btd/17/120/1712051.pdf https://www.who.int/influenza/preparedness/pandemic/influenza_risk_management_update2017/en/ https://www.rki.de/EN/Content/infections/infectious_diseases_node.html https://apps.who.int/iris/bitstream/handle/10665/259884/9789241513623-eng.pdf;jsessionid=37593730881AD4385F0994489BD7B1D3?sequence=1 "§ 23 Zivilschutz- und Katastrophenhilfegesetz (ZSKG) Biostoffverordnung (BioStoffV) https://www.rki.de/DE/Content/Infekt/Preparedness_Response/Rahmenkonzept_Epidemische_bedeutsame_Lagen.pdf? blob=publicationFile https://www.auswaertiges-amt.de/de/ReiseUndSicherheit/10.2.8Reisewarnungen https://www.ecdc.europa.eu/en/threats-and-outbreaks/reports-and-data/risk-assessments https://www.gesetze-im-internet.de/ifsg/ https://www.gesetze-im-internet.de/ifsg/_5.html 								

Resilience Level Overview		Comment																																																	
<p>11. Gesetz zur Verhütung und Bekämpfung von Infektionskrankheiten beim Menschen (Infektionsschutzgesetz - IfSG) "https://www.gesetze-im-internet.de/ifsg/BJNR104510000.html#BJNR104510000BJNG000201116"</p> <p>12. https://www.bmi.bund.de/DE/themen/bevoelkerungsschutz/coronavirus/coronavirus-node.html</p> <p>13. https://www.tagesspiegel.de/wirtschaft/bahn-setzt-weniger-fernzuwege-ein-ice-1-flotte-steht-bis-mindestens-ende-april/25697966.html</p> <p>14. https://www.handelsblatt.com/technik/it-internet/virus-auswirkungen-corona-wird-fuer-homeoffice-anbieter-zum-haertetest/25653070.html?ticket=ST-1125554-tlefyozdMJabdhjC9d1-ap5</p> <p>15. https://www.zeit.de/arbeit/2020-03/homeoffice-arbeitgeber-angestellte-coronavirus-freistellung</p> <p>16. https://www.tagesspiegel.de/politik/wie-die-coronakrise-auf-den-politikbetrieb-wirkt-die-bundesregierung-setzt-auf-homeoffice/25650090.html</p> <p>17. https://background.tagesspiegel.de/mobilitaet-transport/industrie-vs-virus-kann-die-autoindustrie-medizintechnik</p> <p>18. https://www.n-tv.de/auto/Die-Autoindustrie-im-Kampf-gegen-Corona-article21684802.html</p> <p>19. https://www.welt.de/wirtschaft/plus206422893/Coronavirus-offenbart-riesige-Defizite-an-Deutschlands-Schulen.html</p> <p>20. https://www.bundesregierung.de/breg-de/aktuelles/pressekonferenz-von-bundeskanzlerin-merkel-zu-massnahmen-der-bundesregierung-im-zusammenhang-mit-dem-coronavirus-1731022</p> <p>21. https://www.aerztekammer-bw.de/news/2020/2020-03/corona-studierende/index.html</p> <p>22. https://www.n-tv.de/politik/Spahn-will-Aerzte-im-Ruhestand-reaktivieren-article21640571.html</p> <p>23. https://www.tagesschau.de/inland/medizinstudenten-101.html</p> <p>24. https://www.aerzteblatt.de/nachrichten/111125/Bund-und-Laender-beschliessen-Krankenhaus-Notfallplan</p> <p>25. https://www.rki.de/DE/Content/Infekt/EpidBull/Archiv/2020/Ausgaben/15_20.pdf? blob=publicationFile</p> <p>26. https://www.businessinsider.de/wissenschaft/gesundheit/mit-diesem-verfahren-entscheiden-aerzte-im-corona-notfall-welche-patienten-behandelt-werden-und-welche-nicht/</p> <p>27. https://www.telekom.com/en/company/details/corona-prediction-telekom-supports-rki-597114</p> <p>28. https://www.bundesregierung.de/breg-de/themen/coronavirus/corona-massnahmen-1734724</p> <p>29. https://www.auswaertiges-amt.de/de/ReiseUndSicherheit/covid-19/2296762</p> <p>30. https://www.bundesregierung.de/breg-de/themen/coronavirus/corona-massnahmen-1734724</p> <p>31. https://www.bundesgesundheitsministerium.de/weitere-beschluesse-krisenstab-bmi-bmg.html</p> <p>32. https://www.bundesgesundheitsministerium.de/weitere-beschluesse-krisenstab-bmi-bmg.html</p> <p>https://www.welt.de/politik/deutschland/article206762429/Corona-Sechs-Millionen-Schutzmasken-fuer-Deutschland-verschwunden.html</p>																																																			
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	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform	RL per dimension																																												
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PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform	RL per dimension																																													
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Resilience Level Overview							Comment	
NORWAY	Resilience level (RL) matrix						<p>Weaknesses:</p> <ul style="list-style-type: none"> - Not sufficient testing done - No apps available - Only average social distancing measures taken <p>Strength:</p> <ul style="list-style-type: none"> - Song in upscaling of intensive care/medical equipment - Good economic measures in place - Good on-boarding of additional medical support personnel 	
	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform		RL per dimension
	a. System / physical	-	3.33	3.36	-	-		3.34
	b. Information / smartness	3.5	-	2.25	-	-		2.88
	c. Organization / business	3.33	3.71	3.14	-	-		3.39
	d. Societal / political	3	4	3.33	-	-		3.44
	e. Cognitive / decision making	3	3	3.5	-	-		3.17
RL per PHASE	3.21	3.51	3.12	-	-	3.52		
SOUTH AFRICA	Resilience level (RL) matrix						<p>Weaknesses:</p> <ul style="list-style-type: none"> - Health care system lacks sufficient medical and intensive care equipment - Not sufficient economic help programs available <p>Strength:</p> <ul style="list-style-type: none"> - Fast and timely reaction and implementation of measures/regulation - Efficient closing of borders 	
	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform		RL per dimension
	a. System / physical	-	2	2.56	-	-		2.28
	b. Information / smartness	2	-	2	-	-		2
	c. Organization / business	2.33	2.6	2.57	-	-		2.5
	d. Societal / political	3	3	2.6	-	-		2.87
	e. Cognitive / decision making	3	3	2.89	-	-		2.96
RL per PHASE	2.58	2.65	2.52	-	-	2.59		
SOUTH KOREA	Resilience level (RL) matrix						<p>Weaknesses:</p> <ul style="list-style-type: none"> - Initial delays for closing borders/implementation of measures <p>Strength:</p> <ul style="list-style-type: none"> - Mass testing implemented rapidly - Previous experience resulted in very good and quick implementation of measures to stop the spread - Society is very disciplined about the societal measures taken 	
	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform		RL per dimension
	a. System / physical	-	3.67	4.18	-	-		3.92
	b. Information / smartness	3.5	-	3.75	-	-		3.62
	c. Organization / business	3.67	4	3.93	-	-		3.87
	d. Societal / political	4	4	4	-	-		4
	e. Cognitive / decision making	4	3.5	4	-	-		3.83
RL per PHASE	3.79	3.79	3.97	-	-	3.92		
SWITZERLAND	Resilience level (RL) matrix						<p>Weaknesses:</p> <ul style="list-style-type: none"> - No previous experience with similar events - Amount of medical equipment not on the level that would be required for such an event <p>Strength:</p> <ul style="list-style-type: none"> - Strength monitoring of the situation - Effective closing of borders/airports - Effective implementation of societal measures 	
	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform		RL per dimension
	a. System / physical	-	4	3.2	-	-		3.6
	b. Information / smartness	3.5	-	2.75	-	-		3.12
	c. Organization / business	3.33	4.14	3.27	-	-		3.58
	d. Societal / political	3	4	3.73	-	-		3.58
	e. Cognitive / decision making	3	4	3.6	-	-		3.53
RL per PHASE	3.21	4.04	3.31	-	-	3.62		
USA	Resilience level (RL) matrix						<p>Weaknesses:</p> <ul style="list-style-type: none"> - Understanding the risk and the potential damage - Communication - Implementation of required measures were implemented with delay and to lesser extend compared to other countries <p>Strength:</p> <ul style="list-style-type: none"> - Travel recommendations and closing of borders was implemented timely and efficiently 	
	PHASE / Dimension	I. Understand Risk	II. Anticipate / prepare	III. Absorb / withstand	IV. Respond / recover	V. Adapt / transform		RL per dimension
	a. System / physical	-	2.75	2.88	-	-		2.82
	b. Information / smartness	3.5	-	2.5	-	-		3
	c. Organization / business	3.33	3.38	2.88	-	-		3.2
	d. Societal / political	3	4	2.88	-	-		3.29
	e. Cognitive / decision making	3	3.5	2.5	-	-		3
RL per PHASE	3.21	3.41	2.73	-	-	3.12		

Annex 2: Prevention and control measures for COVID-19 epidemic: main apps and functions of epidemic prevention and control in China

In order to prevent the spread of the epidemic and better monitor the health information of the floating personnel, many Apps used for health information collection and trip query have been introduced throughout China. 1 Health code Apps Health code is used to monitor the individual health status.

The first version of health code was born at 5 a.m. on Feb 5th, then began to optimize every half hour. On Feb 7th the health code H5 was released, and On Feb. 9th it officially landed on Alipay. Yuhang district, located in Hangzhou became the first pilot area, and it was then popularized in Hangzhou. After the Alipay health code was launched in Hangzhou, it was landed in more than 100 cities within a week.

In addition to Alipay, Tencent has also joined the ranks of health codes. The health code is mainly divided into 2 categories: national level and province level. Health code, is a one for one, and dynamic code. If the applicant has ever taken a train with a confirmed or suspected case, or came from a key epidemic area, or had physical discomfort, the color of the health code will be possibly affected.

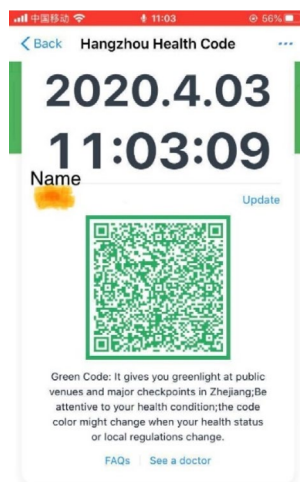
The health code is divided into three colors:

- green,
- yellow and
- red.

The person with green code can be passed directly. The person with yellow code has to be isolated centrally or at home for 7 days. After continuously applying for health card for more than 7 days and keeping well health for each day, the yellow code will be turned into green code.

The person with red code has to be isolated centrally or at home for 14 days. Similarly, after continuously applying for health card for more than 14 days and keeping well health for each day, the red code will be turned into green one. The health code is applicable to many places, such as the entry of office building, communities, shopping malls, restaurants, public transportation and other public places.

Communication big data trip card App



The sharing and mutual recognition of data across provinces (regions and cities) can be carried out

The communication big data trip card is a free query service provided by China Academy of Information and Communications Technology, allied with China Telecom, China Mobile and China Unicom for 1.6 billion mobile phone users nationwide by using the communication big data. Through the service, mobile phone users can query all the country and city information they have visited in the previous 14 days.

The communication big data trip card is based on the big data of telecom. The three operators provide the unified interface. It only needs to fill in the mobile phone number and verification code. It is easier and safer to operate and fully protects the privacy of the users. The total number of queries has exceeded 450 million until March 25, 2020.

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