Understanding R-based planning decisions and control for COVID-19 recovery

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ABSTRACT

A strategy is a high level plan to achieve one or more goals under conditions of uncertainty, it is about reaching desirable ends with available means. In this paper practical management tools to tackle the deconfinement strategy design problem are presented. But strategy is not only about design, it has much to do with implementation too. A proper control system to follow the course of action, especially in a scenario with unprecedent uncertainty, is developed. This is considered a must to launch strategy implementation.

In the paper, it is remarked the importance of R, first as a variable to monitor and control the pandemic, to ensure its decline; second as a target to score risks associated to start certain activities over, after confinement. Reducing the potential increase in the value of R, when any type of activity is re-opening, guides the strategy.

In terms of control, the paper benefits of up-to-date developments within the field of predictive maintenance (PdM). The emergence of predictive analytics and the introduction of prognosis interpretation rules can be very valuable now, when you need to take decisions based on data and predictions. A novel and innovative way to structure the data model required for such a control system is presented in the paper.

Whatever actions are taken as appropriate will impact the economy in the short-midterm, and understanding the extent of that impact by economic sector and time scale is rather interesting. This paper also provides an answer to this concern.

With this paper, SIM research group ends a trilogy related to Covid 19 pandemic management analysis. Our aim has been always to put our best skills and our experience to serve our communities when facing this unprecedent situation.

Keywords: Basic reproductive number, Effective reproductive number, Covid-19 control, Jensen-Shannon divergence, GDP recovery analysis, Covid-19 risk analysis

1. Introduction

Reaching the end of the confinement phase, it is essential to have a strategy to face the recovery phase with the best possible guarantees. Previous studies demonstrated that saturation in hospitals could be modelled based on parameter *R*. This is considered in this paper as the key parameter for designing recovery or de-escalation phase strategies. To propose an effective strategy, the parameter R will have to be known, monitored and controlled.

But uncertainty and lack of accurate knowledge are the principal handicaps of any attend of Covid 19 pandemic control. This crisis is not an IT problem or a mathematical modeling challenge. It is a catastrophe which impacts should be minimize with management reinforcement.

Sometimes the best you can do is come back, stop and step back, to look all the picture from the simplest principles that govern the challenge you are facing with. In this case control pandemic is the objective, but management is the challenge: optimize management we can do according with each moment knowledge and information we have. Simplest management principles could be summarized and related to recovery management problem as follow:

- *Risk-benefit assessment* is the principal element of any decision. For pandemic recovery management the risk is composed by the high likelihood of relapses and their consequences severity. Consequences including not only infected and casualties but also the HS saturation. R parameter is emerging day by day as best risk indicator (short, mid and long term)
- Management can always be improved, even more, should always be improved. This is the *continuous improvement principle* that is universally accepted. In this moment, Covid19 crisis management has a tremendous improvement margin, because there is not any previous experience in the world.
- So, we have to start the *basic cycle Plan-do-check-act (Deming Cycle)*. So simple, so difficult. So simple to understand but so difficult to implement in so complex context. In this work we are proposing *a tool for planning* (measure and activities) and *a tool for checking* (control parameters and method). Both things are intimately related because you cannot manage what you cannot measure (Lord Kelvin *dixit*).
- *Hierarchization*. Not all possible options have the same relevance in terms of recovery optimization.

To start the recovery phase and to return the country to its "new" normal activity, a tool to monitor and control how the pandemic is evolving is needed. Otherwise, relapses could occur without realizing it and an essential time to stop the relapse could be lost. In the present work, a control system allowing the detection, diagnosis and prognosis of pandemic abnormal behavior is proposed. Also, a tool to identify important divergencies in incoming data that will be processed in this system is presented.

Once there is a tool proposed to control the evolution of the pandemic, the work proceeds to design the post-confinement strategy. The methodology selected to design a strategy for the sequential opening of activities will minimize the risk of the potential impact of these activities on *R*. In order to do so, the number of contacts, the intensity of the contacts and the modification potential of each one of the activities will be assessed. Based on this evaluation, strategies are established for each level of risk, minimizing the possibility of contagion. Logically, those activities with a higher risk of contagion will take longer to start up than those with a minimal risk. Companies whose activity is in a high-risk area will have to take measures to reduce the probability of contagion to an acceptable level and thus re-enter into economic activity.

The current public health crisis is accompanied by a worrying economic situation and the strategy designed for deconfinement will be a critical step in minimizing the economic impact. Based on the strategy of incorporating activities according to their risk, we measure the evolution of the economy in terms of production of available GDP until economic "normality" recovers around May 2021.

The structure of the work is as follows: First, an introduction to R and its main related features is presented. Second, a model is developed to measure, monitor and control the evolution of the pandemic. To control this evolution, a tool is developed to detect bad behaviors in the evolution of the pandemic based on the Jensen-Shannon divergence. Finally, the strategy for the reincorporation of economic activities is developed according to their level of risk and the impact it has on the economy.

2. Number R

2.1. Understanding basic and effective reproductive numbers, R_0 & R

The basic reproductive number is an intuitive epidemiologic metric which describes the contagiousness of an infectious agent. Defined as the expected number of cases directly generated by one case in a population where all individuals are susceptible to infection (Fraser *et al.*, 2009). It is possible to estimate a R_0 value from three parameters that characterize the contagiousness (Dietz, 1993):

- The contact rate (R_C); and
- The likelihood of infection per contact between a susceptible person and an infectious person or vector (R_i)
- The average infection duration after a person becomes infected (T_{id}).

Although there are models that describe transmission cycles with additional parameters that make modeling more complex, in this paper we will consider the basic equation to determine R_0 value as:

$$R_0 = R_C \times R_i \times T_{id} \qquad (1)$$

R_0 is a rather complex property, which depends specifically on the model used to calculate it, on the population under study (since refers its demographic characteristics and contact modalities), the host, the pathogen, and frequently its specific strain (Ridenhour, Kowalik and Shay, 2018). Therefore, when estimating, reporting, and applying R_0 to decision-making, this must be done with great caution, because this basic metric is far from simple (Delamater *et al.*, 2019).

Once a pandemic is underway, it is necessary to measure the number of secondary cases generated by an infectious case. This is defined as the effective reproductive number, R, which will thus depend on R_0, ,. In the absence of control measures,

$$R = R_0 \times F_S \qquad (2)$$

where F_S is the proportion of the susceptible population. During an epidemic, *R* declines because of the depletion of those susceptible in the population and the implementation of specific control measures. To stop an outbreak, *R* must be maintained below 1 (Lipsitch *et al.*, 2003), as explained later.

To understand the real value of R_0 and R, it is necessary to invest in the estimation of other epidemic parameters such as transmission rates, fraction of susceptible, or latency and infectious periods, which are more relevant to the public health response to disease outbreaks and specially in COVID 19 pandemics (Ridenhour, Kowalik and Shay, 2018).

Fraction of susceptible population and diagnostic tests

This variable is a very interesting for the pandemic control and very difficult to measure. Ultimately will depend on the possibility to do testing to a representative sample of the population. But testing devices and procedures, as we explain in the following paragraphs, are not always available nor economically affordable to a certain extent. This is why, since the fraction of the population susceptible will be very high compared to the other groups of people (exposed, infected and recovered), it is assumed all individuals to be always susceptible to infection. Under this consideration $R_0=R$.

Concerning testing possibilities, the microbiological diagnosis of COVID-19 has so far been based around the world, on the detection of viral genetic material (RNA) of SARS-CoV-2 by means of PCR techniques, in respiratory samples from patients with compatible symptoms. PCR is a very sensitive and specific technique that is performed in microbiology laboratories for the diagnosis of various infectious diseases. For these reasons, PCR is currently the diagnostic technique. According to data collected in recent weeks, Spanish hospitals and health centers are performing more than 15,000 PCRs a day (*Ministerio de Sanidad, Consumo y Bienestar Social - Professionals - Enfermedad por nuevo coronavirus, COVID-19*). Analytical determinations with PCR must always be carried out by experienced personnel, using specific materials, agents and solutions, and usually take several hours to provide results.

The use of rapid antibody COVID-19 detection tests has offered the possibility of increasing the diagnostic capabilities of the National Health Systems. Results are obtained in 15 minutes and are easy to use by healthcare personnel. Studies of the dynamics of generation of antibodies against CoV-19 have shown that they begin to be produced from the 6th day of the onset of symptoms while a decrease in viral load is observed. At 7 days, almost half of the cases have total antibodies and at 15 days almost 100%, in both mild and severe cases. Based on this, the antibody techniques seek to detect the immune response of the patients which increases as the infection progresses and therefore offer the possibility of detecting active disease of several days of evolution. The presence of antibodies, on the other hand, does not exclude the possibility of continuing to transmit the virus. This test has shown a specificity of 100% (% of true negatives among actual negatives, i.e no false positives) and a sensitivity of 64% (% of true positives among actual positives) when applied in patients without considering the time of evolution of the disease, being around 80% in patients with more than 7 days of evolution (*Ministerio de Sanidad, Consumo y Bienestar Social - Professionals - Enfermedad por nuevo coronavirus, COVID-19*). In the case of serological tests, the sample can be analyzed at the same extraction point. Again, in general, diagnostic tests will only be performed in symptomatic, moderate or severe patients in the hospital setting, or mild in the out-of-hospital setting, where priority is given to using the tests in nursing homes and social and health centers in order to detect cases early and investigate possible outbreaks. In these cases, its use is indicated only in symptomatic patients if several days have elapsed since the onset of symptoms.

A conclusion to this section, an estimation of the fraction of susceptible population will not be accessible in the short-medium term in this country. At the moment this paper is written the serological study has been just released and a lead time of two months to have representative results is expected.

The contact rate

Regardless the values of the mean duration of contagiousness (T_{id}) and the fraction of susceptible (F_S), transmission occurs primarily through prolonged, close contact with very high likelihood of infection. People with exposure to a confirmed case, household members, those who report frequent contact, and people who have traveled together or shared a meal are found to be at highest risk of infection (Rivers *et al.*, 2020). Therefore, it is important the contact rate R_C to be modeled considering two factors: the number of contacts (N_C) and the contact intensity (C_I). With

$$R_C = N_C \times C_I \quad (3)$$

The likelihood of infection

Respiratory viruses are transmitted through droplets that an infected person releases into the air when they cough or sneeze; or through contaminated objects (such as taps, handrails, doorknobs, or grab bars on buses). The probability of an actual transmission depends on the nature of the contact, as well as on environmental parameters, such as air pressure, humidity and temperature, which affect how long the droplets remain suspended in the air and how far they go (Trilla, 2020). To mitigate this likelihood of infection, people and organizations will have different options available: implementing physical distancing measures, establishing engineering or administrative controls, and/or using PPE (Rivers *et al.*, 2020).

Mean duration of contagiousness

Concerning γ, an important effort must be done for a more precise understanding of its average value. As we can see in Figure 1, infected people mostly have a high viral load (between 104 and 108 copies of the genome / ml per nasopharyngeal or saliva sample) and in patients with a mild course of infection, the peak of the viral load in nasal and oropharyngeal samples occurs during the first 5-6 days after the onset of symptoms and practically disappears on day 10.

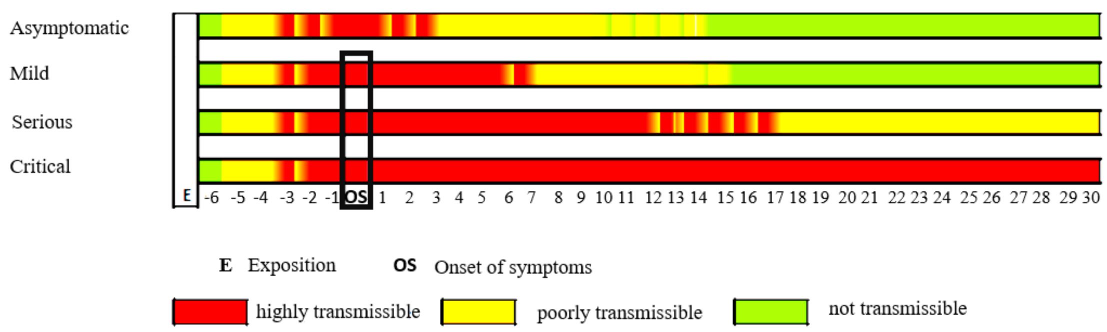

Figure 1. Viral load and time of infection duration

Although in some patients more viruses are detected beyond day 10, the viral load is of the order of 100-1,000 times lower, which would suggest a low transmission capacity these days. In people with a more severe course, the viral load can be up to 60 times higher than those with a milder course, and in addition, viral excretion may be longer. In 191 people who required hospitalization, the median duration of viral excretion was 20 days (interquartile range: 17–24) up to a maximum of 37 days in the cured and was detectable until the end in those who died.

It can be concluded that according to the existing evidence, the transmission of the infection would occur fundamentally in the first week of the presentation of the symptoms, from 1-2 days before to 5-6 days later (Liu *et al.*, 2020). In the most serious cases, this transmission would be more intense and more lasting.

2.2. Interpretation of importance of *R* for pandemic management

R is nearly always estimated retrospectively from seroepidemiologic data or by using theoretical mathematical models (Li, Blakeley and Smith, 2011). Although sometimes data-driven approaches have been used (Heffernan, Smith and Wahl, 2005), most of the contributions refer to mathematical models, mainly using ordinary differential equations (Dietz, 1993), with dependency on numerous decisions made by the modeler (Keeling and Grenfell, 2000).

One of these modeler decisions is the population structure of the model. Most popular structures are susceptible-infectious-recovered model and susceptible-exposed-infectious-recovered model, which includes compartments for persons who are exposed but not yet infectious, as well as assumptions about demographic dynamics (e.g., births, deaths, and migration over time).

Another option is the selection of a deterministic or stochastic approach (the last one including the selection of the distributions to use) to use, to describe the probable values of parameters, such as effective contact rates and duration of contagiousness. Many of suggested values are based on educated guesses, once the true values are often unknown or difficult or impossible to measure directly (Li, Blakeley and Smith, 2011).

In this work, a SEIR model as the one solved in (Crespo *et al.*, 2020a)is proposed for a post-confinement pandemic modeling. Model equations are as follows,

$$dS/_{dt} = -\beta \times {}^{(S \times I)}/_{P} \tag{4}$$

$$dE/_{dt} = \beta \times {}^{(S \times I)}/_{P} - a \times E \tag{5}$$

$$dI/_{dt} = a \times E - \gamma \times I \tag{6}$$

$$dR/_{dt} = \gamma \times I \tag{7}$$

where *S, E, I* and *R* are for *Susceptible, Exposed, Infectious* and *Recovered* populations, respectively. *P* is the complete population of the region under study (e.g., the population of a province), β is the force of infection or the disease transmission rate, *a* is the inverse of the latent infection period ($a = 1/T_{ii}$) and γ is the inverse of the infection duration time ($\gamma = 1/T_{id}$) . For this model Ro, the disease basic reproduction number, is defined as $R0 = \beta/\gamma$, and then

$$dS/_{dt} = -\beta \times F_S \times I = -(R_0 \times \gamma) \times F_S \times I = -(R \times \gamma \times I) \tag{8}$$

According to differential equations above, under conditions of disease decline, we may expect

$$\gamma \times I \ > (R \times \gamma \times I) \tag{9}$$

Where $\gamma \times I$ is the rate of infected people finishing their infectious period, and then it is demonstrated that to stop the outbreak it is necessary that

$$R < 1 \text{ and } R_0 < {}^{1}/_{F_S} \tag{10}$$

Therefore, R parameter is the key element to pay attention to. As concluded in the previous section, to control the pandemic rate of infection, $R < 1$, that means

$$R = {}^{N_C}/_{(\gamma \times I)} < 1 \tag{11}$$

Where N_C is the number of new cases that are diagnosed every day. Therefore, to monitor the number R, the three variables: N_C, γ and I, must be monitored. N_C and I would be taken from the information provided by the corresponding NHS and the estimation of γ must be improved as much as possible over time, incorporating not only accurate data for more infected cases, but also the evolution of knowledge from medical research about time duration and propagation potential of infected people, which is being improving significantly by week. Short-time R rising (days) will become mid-term (months) health system high strain scenarios.

In order to implement a plan for a post-confinement de-escalation phase, tools for monitoring the status of the pandemic must be in place, and models for predicting its future potential evolution and consequences for the health system must be ready too. Beside the fact that the number R represents the pandemic status and its potential evolution at a given indenture level (Flahault *et al.*, 2006) (Crespo *et al.*, 2020a), a very important point is that all re-opening measures can be evaluated in terms of their "R contribution" (Rivers *et al.*, 2020). Also, any measure non-compliance and/or measure malfunction will increase the expected value of R. In summary, it is possible to employ R to monitor pandemic and to design, and control, measures that will be included in different recovery phase scenarios.

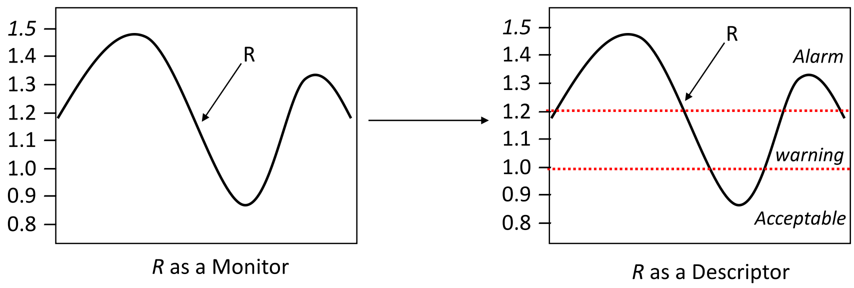

Figure 2. R as a monitor (value) and as a descriptor (value, interpretation) of the problem

When R increases over one (principal warning threshold), this can be a clear symptom of a possible pandemic relapse. Most accurate alarm thresholds are supposed to be established in relation to HS capacity, as suggested in previous papers (Crespo *et al.*, 2020b). For instance, assuming a 1.5 R would generate a serious strain on the HS in less that 3 months, establishing an alarm threshold of 1.2 R could result in a reasonable conservative level for the threshold. Therefore, R is not only a good monitor but also what is defined a good descriptor of the post-confinement plan situation (See Figure 2).

3. Checking tool: A Monitoring & Control System proposal, based on *R*

3.1. Control system structure and methodology

Consequently, there must be a Control System focused on *R*, and on the implementation of mechanisms for monitoring and integrating variables about the activities and resources that contributes to it. This Control System has the responsibility as a unique repository of information and governance coordination.

This paper adapts a pre-existing methodology that is being applied successfully to monitor and control complex engineering assets (Guillén *et al.*, 2016, Ferrero *et al.*, 2019). The fundamentals of this proposal are:

- Providing a clear data/information structure for monitoring related to detection, diagnosis and prognosis issues*;*
- Offering a clear methodology for the accurate definition of the descriptors and interpretation rules, which are linked with different decisions and temporal horizons, formalizing expert knowledge within the monitoring process;

In order to describe, practical implementation of this Control System for *R* monitoring, Figure 3 is a UML proposal about how structure data and integrate information flows. For this purpose, five different blocks are proposed (see Table 1) according to International standards.

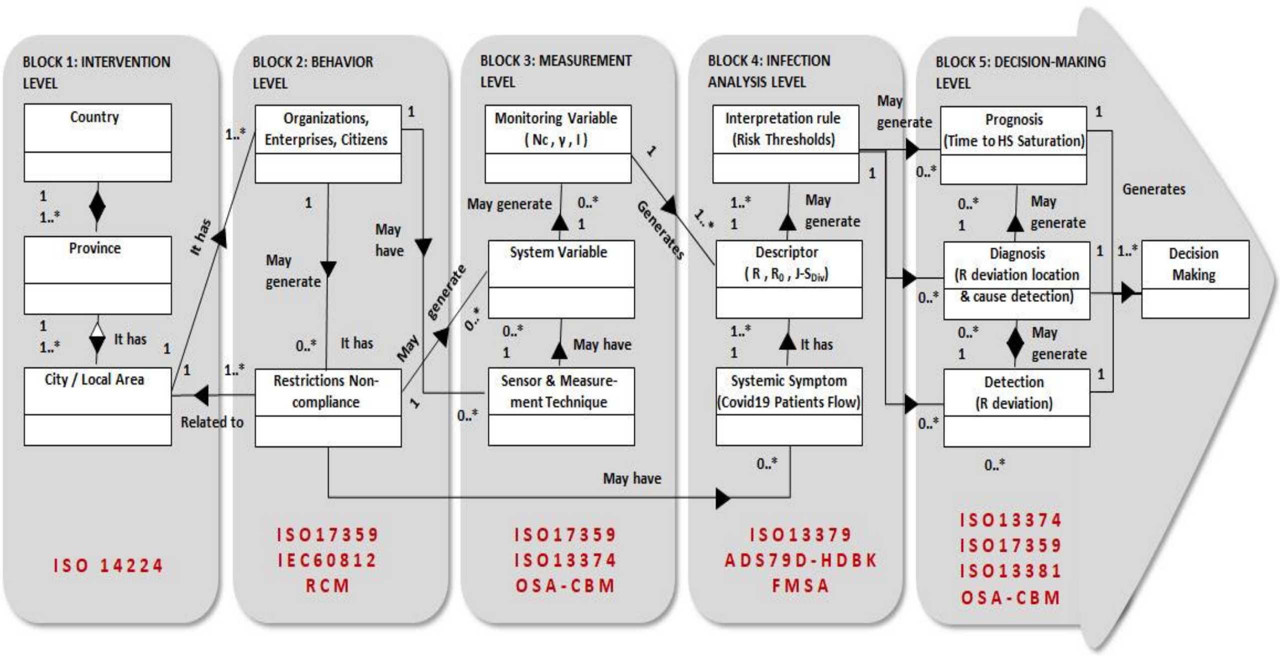

Figure 3. UML simple diagram of the monitoring and control system proposed

Each one of the five blocks is considered a level of information, first two are sources of resources and activities variables, which are processed into monitors in block 3, block 4 is centered on R and other predictors definitions, and the last one is oriented to standardize analysis and guide the decision making, see an example in next Table.

Block	Main elements	Block results for pandemic control	Use case
Block 1: **Indenture Level**	- Country - Province - City/Local area	- Definition of the element level where measures and management are applied. - Monitoring results, R calculation and R gathering will be done to this level.	- Provinces of Spain
Block 2: **Behavior description level**	- Citizens - Organizations - Measures - Measure failures	- Citizens & Organizations are located in a specific city/area of a province. - Citizens and organizations must fulfill the measures. - Citizens are items where test are applied - Citizens and organization are items where non-compliance can be located. - Measure failure is a state of the system, related to fulfillment levels or measure performance. Related to specific measures and citizen groups or organizations.	- Opening measure elicitation is done by activities by organizations/companies of each sector. - Measures impose limit to citizen behavior. - Measures impose limit to organizations behavior. - Status of measure failures can be monitored by R interpretation.
		-	

Block 4:
Infection Analysis
	- Systemic Symptom
	- Descriptor
	- Interpretation rule
		- Systemic Symptom
		- Descriptor
		- Interpretation rule
			- Systemic Symptom R deviations
			- Descriptors & Interpretation Rules
			  - R<1, ● ; 1<R<1,2; ●; R>1,2 ●
			  - JS-R,
			  - UCI occupation projection,
			  - UCI TTS:

Block 5: **Decision Making**	- Detection - Diagnostics - Prognostics - Decision making	- Detection - Diagnostics - Prognostics - Decision making	-Detection: moment that R present a bad behavior globally or compare between province. -Diagnostics: this solution does not determine where and how (causes) of the deviation. Diagnosis requires additional variables -Prognostics: Time to UCI saturation; prediction of UCI occupation level over time. -Decision making: (i) Phase promotion or Back to previous phase; (ii) Do diagnosis (iii), UCI capacity and logistics management.

Table 1. Monitoring and Control system description and use case

Obviously, data quality is crucial for an adequate control, and control mechanisms have to evaluate continuously this issue, as it is explained in the next section.

3.2. Benchmarking of different disease behavior in specific areas

Pandemic control system will rely on incoming data, and data is obtained for different areas with different population, by different organizations following a similar protocol. Under these circumstances, data analysis is a must to observe potential data divergence over time, as a symptom of a different disease behavior in specific areas over time, or simply to react to a possible observed deviation to the protocol. In this work we suggest to use the Jensen-Shannon (J-S) divergence to quantify the similarity between data.

For two distribution functions P and Q that one wants to compare, the J-S divergence is a symmetric measure, a distance, based on relative entropy (or Kullback-Leibler divergence) and that has the following expression (Lin, 1991):

$$D_{JS}(P,Q) = \sqrt{\frac{D(P|M)+D(Q|M)}{2}} \quad (1)$$

where M is the point-wise average of both distributions:

$$M = {}^{(P+Q)}/_{2} \quad (2)$$

$D(P|M)$ is the relative entropy defined as:

$$D(P|M) = \sum_k P_k \times Log_n(\frac{P_k}{M_k}) \quad (3)$$

If used with a base 2 logarithm, the Jensen-Shannon divergence is normalized between 0 and 1, where 0 indicates two identical distributions and 1 indicates two distributions with no overlap. Note that for identical distributions $M_k = P_k$ thus the logarithm is always 0 (Salvador Palau *et al.*, 2020). Using this method, a list of values of the Jensen-Shannon divergence is produced and may be used as an unsupervised learning process for pattern recognition.

The proposed application of this tool for the monitoring of data distributions follows the following steps:

1) Raw data acquisition from official sources (Z_i)
2) Transformation to dimensionless data (Y_i)
3) Choice of a baseline origin for the dimensionless data (X_i)
4) Calculation of a weighted ΔX_i per day ($P_{k,i}$)
5) Calculation of Point-Wise Average ($M_{k,i,j}$) and Relative Entropy for each distributions pair ($P_{k,i}$ and $P_{k,j}$)

As an example, the case analyzed here refers to the daily accumulated data of infected people (Z_i) in the eight Andalusian provinces, together with the total amount for Spain. Since the accumulated data are referred to different amounts of population, they have more significance if they are referred as (Y_i) a proportion of the number on inhabitants. In addition to this, the beginning of the infectious process has taken place in different moments for each province. Therefore, it has been decided to consider the starting point for each distribution when they refer to a similar proportion of infected people. In particular, the origin ($k=1$) considered in the dimensionless data are those ones higher than 0,00025. With this, the data treatment results in values referring to an accumulated amount of infected people, proportional to the number of inhabitants in the corresponding area (X_i). The divergences to analyze will be those related to the distribution functions that correspond to the proportional value in the increment of X_i for each k (where i = 1, … 10, and refers to the areas under study: Spain, Andalucía, Almería, etc.; and k = 1, …, 24, and refers to the different discrete points where the distribution functions are evaluated).

Once the ten distribution functions (eight provinces, plus Andalucía and Spain) are obtained, $P_{k,i}$ (i = 1, … 10; k = 1, …, 24), the Point-Wise Average ($M_{k,i,j}$) and the Relative Entropy for each distributions pair is calculated. With these values, the relative entropy

D(P|M) for each pair of distributions is calculated according to (3) and, subsequently, the related value for $D_{JS}(P,Q)$, according to expression (1).

Since the Jensen-Shannon Divergence is a symmetric measure, with value 0 when functions are identically distributed, the result will be a symmetric matrix with 0-values in its diagonal. This exercise can be performed in different time horizons, as for example for *k=13* and for *k=24*, observing the evolution in the divergence between distribution pairs (Tables 2 and 3).

	Spain	Andalucía	Almería	Cádiz	Córdoba	Granada	Huelva	Jaén	Málaga	Sevilla
Spain	0,000	0,137	0,354	0,254	0,185	0,098	0,354	0,150	0,204	0,170
Andalucía	0,137	0,000	0,286	0,199	0,188	0,177	0,270	0,159	0,238	0,132
Almería	0,354	0,286	0,000	0,268	0,341	0,372	0,244	0,375	0,385	0,272
Cádiz	0,254	0,199	0,268	0,000	0,314	0,306	0,260	0,260	0,287	0,142
Córdoba	0,185	0,188	0,341	0,314	0,000	0,189	0,354	0,277	0,255	0,276
Granada	0,098	0,177	0,372	0,306	0,189	0,000	0,384	0,178	0,208	0,212
Huelva	0,354	0,270	0,244	0,260	0,354	0,384	0,000	0,373	0,382	0,297
Jaén	0,150	0,159	0,375	0,260	0,277	0,178	0,373	0,000	0,275	0,151
Málaga	0,204	0,238	0,385	0,287	0,255	0,208	0,382	0,275	0,000	0,261
Sevilla	0,170	0,132	0,272	0,142	0,276	0,212	0,297	0,151	0,261	0,000

Table 2. Jensen-Shannon Divergence in the Infection Distribution till April 10th

	Spain	Andalucía	Almería	Cádiz	Córdoba	Granada	Huelva	Jaén	Málaga	Sevilla
Spain	0,000	0,174	0,393	0,281	0,237	0,131	0,360	0,159	0,210	0,188
Andalucía	0,174	0,000	0,314	0,209	0,200	0,201	0,283	0,186	0,260	0,155
Almería	0,393	0,314	0,000	0,282	0,362	0,407	0,275	0,394	0,431	0,311
Cádiz	0,281	0,209	0,282	0,000	0,319	0,314	0,266	0,269	0,310	0,198
Córdoba	0,237	0,200	0,362	0,319	0,000	0,259	0,358	0,294	0,273	0,280
Granada	0,131	0,201	0,407	0,314	0,259	0,000	0,390	0,194	0,229	0,216
Huelva	0,360	0,283	0,275	0,266	0,358	0,390	0,000	0,354	0,396	0,304
Jaén	0,159	0,186	0,394	0,269	0,294	0,194	0,354	0,000	0,270	0,193
Málaga	0,210	0,260	0,431	0,310	0,273	0,229	0,396	0,270	0,000	0,293
Sevilla	0,188	0,155	0,311	0,198	0,280	0,216	0,304	0,193	0,293	0,000

Table 3. Jensen-Shannon Divergence in the Infection Distribution till April 21st

According to the results obtained, one can observed that the highest divergences appear between the distributions of Málaga and Almería. In fact, it is possible to remark that Almería time series behaves more divergently regarding Spain and Andalucía time series. In contrast, Sevilla time series shows the most similarity with Spain and Andalucía time series. With these values, other exercises can be performed, as for example the calculation of the divergence standard deviation and average for each province. These results can be displayed in radial graphic (Figure 4), where the diverging behavior is much more easily observed. According to these values, it is possible also to infer that the distributions tend to diverge conforming more data are available. This increment in the divergence values are not drastically high, but the trend is remarkable. The information provided by this tool allows to increase the knowledge on the behavior of such time series, which facilitates their control and related decision-making process. Such control and decision-making process improve when the proposed monitoring tool is used with other possible surveillance methods.

Figure 4. Standard deviation and average for the divergence of the different time series distributions

As mentioned, J-S divergence has been applied here for the infected distribution, but it can be used also for other monitoring variables or even for the descriptor R or for every dynamic available data, obtaining for each interest variable a kind of similarity index. New possible research lines may consider a reference distribution function. Such a reference function can be provided analyzing the data from a highly controlled province. Hence, the divergence value will be a good estimator of the better or worse approach from the distribution under study to the reference one, being considered this estimator as a possible control over such divergence.

4. Planning tool: A plan for de-escalation of confinement based on *R*

Once understood the important of the effective reproductive number *R*, and established in advance a surveillance, monitor and control system for *R*, a plan for the de-escalation of confinement will now be elaborated with the intention to reduce the risk of sudden *R* increase.

At this point, and before proceeding with any possible escalation of activities, the following advice should be a golden rule (*National coronavirus response: A road map to reopening | American Enterprise Institute - AEI*): (i) to keep physical distancing measures, and to ask people to remain at home; (ii) To increase access to diagnostic testing (focusing testing and resources on individuals with disease who may be infectious and their close contacts); (iii) Sectors to start reopening when the following 4 criteria are met: (1) two weeks decline in the number of new cases; (2) rapid diagnostic testing capacity sufficient to test people with symptoms, close contacts and those in essential roles; (3) the HS has appropriate PPE for healthcare workers; and (4) there is sufficient public health capacity to conduct contact tracing for all new cases and their close contacts.

Considering that all previous paragraphs requirements are fulfilled, this Section provides a strategy, a manner to proceed with a staggered reopening of activities, that is based on modelling their risk, and the expected time to the establishment of effective risk mitigation measures preventing the spread of the virus. The list of activities is the one included in the CNAE (National Classification of Economic Activities), which defines the different entities and businesses according to the economic activity under which they have been registered (*Códigos CNAE*).

Two features of an activity, with a direct impact on R, will drive this course of action (Rivers *et al.*, 2020): The activity contact rate (R_C) and the likelihood of infection per contact (R_i) —between a susceptible person and an infectious person or vector— during the time the activity takes place. In addition, the contact rate will be characterized by: the contact intensity (C_I) and the expected number of contacts (N_C) that the infected is supposed to have during that activity. The activity contact intensity (C_I) is now rated as either low, medium, or high. It depends on the contact type (close-to-distant) and its duration (brief-to-prolonged). Low contact intensity activities are brief and fairly distant interactions while high contact intensity activities involve prolonged close contact (like sharing a dormitory). Sharing a meal in seats separated by several feet can be considered a medium contact intensity activity. The number of contacts (N_C) will also be rated as either low, medium, or high. Defined as the approximate number of people in the setting at the same time, on average. A higher N_C is presumed to be riskier.

Finally, each activity will have a *modification potential* (the degree to which mitigation measures can reduce those risks, R_i). For instance, businesses that can effectively incorporate physical distancing and engineering controls are considered to have a higher modification potential than those relying on administrative controls or personal protective equipment, to reduce risk. A hierarchy of COVID-19 mitigation measures can look like:

- Physical Distancing: wherever possible having people work or access the business from home; including restructuring efforts to minimize physical presence.
- Engineering controls: creating physical barriers between people.
- Administrative controls: restructuring responsibilities to reduce contacts and using technology to easy communication.
- PPE: having people wear gloves and masks.

Qualitative assessment of these factors, based on expert judgement, is first presented in Table 5. Then, in Table 4, a value for the different levels is allocated. Values are then used to populate a risk matrix resulting from the analysis.

Contact Intensity (C_I)		
Criteria	**Nivel**	**Value**
Long contact time and distance less than 2 m	High	5
Long contact time and distance greater than or equal to 2 m	Medium	3
There is no contact time and distance is greater than or equal to 2 m.	Low	1
Number of Contacts (N_C)		
Criteria	**Nivel**	**Value**
Extensive working group (> 10 people)	High	5
Reduced working group (< 10 people)	Medium	3
No need for contact	Low	1
Modification Potential (R_i)		
Criteria	**Nivel**	**Value**
Measures to reduce contagion: - Eng. Controls. – Phys. distance	High	1
Measures to reduce contagion: - Administrative controls	Medium	3
Measures to reduce contagion: - Use of PPEs	Low	5

Table 4. Control variables' evaluation criteria.

The risk matrix ranks activities by its contagion ratio and modification potential. Lowering the risk when reopening activities is the key to success. The x-axis of the matrix represents the modification potential (R_i), and the y-axis the contact rate (R_C), as the the contact intensity (C_I) times the number of contacts (N_C).

	C_I	N_C	R_i
A Agriculture, livestock, forestry and fisheries			
01 Agriculture, livestock, hunting and related services	L	M	M
02 Forestry and forestry	L	L	M
03 Fisheries and aquaculture	M	M	L
B Extractive industries			
05 Extraction of anthracite, coal and lignite	L	M	M
06 Oil and natural gas crude extraction	L	M	M
07 Extraction of metallic minerals	L	M	M
08 Other extractive industries	L	M	M
09 Activities to support extractive industries	L	M	M
C Manufacturing industry			
10 Food industry	M	M	M
11 Beverage manufacturing	L	M	M
12 Tobacco industry	L	M	M
13 Textile industry	M	M	M
14 Making garments	L	M	M
15 Leather and footwear industry	L	M	M
16 Wood and cork industry, except furniture; basketry and spartan	L	M	M
17 Paper industry	L	M	M
18 Graphic arts and reprod. of recorded media	L	M	M
19 Cokes and oil refining	L	M	M
20 Chemical industry	L	M	M
21 Pharmaceutical manufacturing	L	M	M
22 Manufacture of rubber and plastic prod.	L	M	M
23 Manufacture other non-metallic mineral pr	L	M	M
24 Metallurgy; manufacture of iron, steel and ferroalloy products	L	M	M
25 Manufacture of metal products, except machinery and equipment	L	M	M
26 Manufacture of computer, electronic and optical products	L	M	M
27 Manufacture of electrical equip. and mat.	L	M	M
28 Manufacture of machinery and equipment	L	M	M
29 Manufacture of motor vehicles & trailers	M	M	M
30 Manufacture of other transport material	L	M	M
31 Furniture manufacturing	M	M	M
32 Other manufacturing industries	L	M	M
33 Repair and installation of machinery & eq.	M	M	M
D Supply of electricity, gas, steam and air conditioning			
35 Supply of electricity, gas, steam and air c.	L	L	H
E Water supply, sanitation activities, waste management …			
36 Water capture, purification and distribution	L	L	M
37 Wastewater collection and treatment	L	L	M
38 Waste collection, treatment and disposal;	L	L	M
39 Decontamination and other waste mgmt.	L	L	M
F Construction			
41 Building construction	M	M	L
42 Civil engineering	M	M	L
43 Specialized construction activities	M	M	L
G Trade sector			
45 Sale and repair of motor vehicles and motorcycles	M	M	L
46 Wholesale trade and trade intermediaries, except motor vehicles and motorcycles	M	M	M
47 Retail trade, except motor vehicles and motorcycles	M	M	M
H Transport and storage			
49 Land and pipeline transport	H	H	M
50 Maritime and inland waterway transport	M	M	M
51 Air transport	H	H	M
52 Storage and activities attached to transport	L	M	M
53 Postal and postal activities	M	M	M

	C_I	N_C	R_i
I Hospitality			
55 Accommodation services	M	M	M
56 Food and beverage services	M	H	M
J Information and communications			
58 Edition	M	H	H
59 Film, video and TV programs, sound recording and music ed.	M	H	H
60 Radio and television programming and broadcasting activities	M	H	H
61 Telecommunications	M	H	H
62 Programming, consulting and other IT-related activities	M	H	H
63 Information services	M	H	H
K Financial and insurance activities			
64 Fin. services except insurance and pension funds	M	H	H
65 Insurance, reinsurance and pension funds, except social security	M	H	H
66 Ancillary activities to financial services / insurance	M	H	H
L Real estate activities			
68 Real Estate Activities	M	M	M
M Professional, scientific and technical activities			
69 Legal and accounting activities	M	M	H
70 Activities of headquarters; business management consulting activities	M	H	H
71 Technical services of architecture and engineering; testing, etc.	M	H	H
72 Research and development	M	M	H
73 Advertising and market research	M	M	H
74 Other professional, scientific and technical activities	M	M	H
75 Veterinary activities	M	M	M
N Administrative activities and ancillary services			
77 Rental activities	M	M	M
78 Employment-related activities	M	M	H
79 Activities of travel agencies, tour operators, booking services and related activities	M	M	H
80 Safety and Research Activities	M	M	M
81 Building services and gardening activities	L	M	L
82 Office admin activities and other business activities	M	H	H
O Public administration and defense, mandatory social security			
84 Public administration and defense, compulsory social security	M	H	H
P Education			
85 Education	H	H	M
Q Health activities and social services			
86 Health activities	H	H	L
87 Assistance in residential areas	H	H	L
88 Social services activities without accommodation	H	H	L
R Artistic, recreational and entertainment activities			
90 Creation activities, arts and shows	H	H	L
91 Activities of libraries, archives, museums and other	H	H	L
92 Gambling and Betting Activities	H	H	L
93 Sports, recreational and entertainment activities	H	H	L
S Other services			
94 Associative activities	M	H	H
95 Repair of computers, personal effects and household items	M	L	M
96 Other personal services	M	M	M
T.- Household activities as employers of domestic staff; household activities as producers of goods and services for their own use			
97 Household activities as employers of domestic staff	M	M	L
98 Household activities as producers of goods and services for their own use	M	M	L
U.- Activities of offshore organizations and agencies			
99 Activities of offshore organizations and bodies	M	M	M

** L: Low; M: Medium; H: High.*

Table 5. Control variables' definition.

Depending on the location in the matrix, the risk of the activity changes and so changes the likelihood of that risk to be mitigated in the near term (Figure 5). Thus, the rules for the reopening strategy can be formulated.

R_C			
25	**Last to go !! with possible measures.** High risk of contact and high potential for modification.	**Cannot go !!.** High risk of contact and with potential means of modification.	**Cannot go !!** Very high risk of contact and low potential for modification.
15	**Could go with high safety measures.** High risk of contact and high potential for modification.	**Last to go !! with all safety measures.** High risk of contact and potential means of modification.	**Cannot go !!** High risk of contact and low potential for modification.
9	**Can go with protective measures.** Medium-high contact risk and high modification potential.	**Could go with high safety measures.** Medium-high contact risk and high modification potential.	**Last go!!** Medium-high contact risk and low modification potential.
5	**Can go with caution.** Activities with average contact risk and high modification potential.	**Can go with protective measures.** Medium risk of contact and with potential means of modification.	**To avoid as much as possible.** Medium risk of contact and low potential for modification.
3	**First to go.** Low-medium contact risk and with high modification potential.	**Can go with caution.** Low-medium contact risk and with potential means of modification.	**Can go with extreme caution.** Low-medium contact risk and potential means of modification.
1	**First to go.** Low contact risk and high modification potential.	**First to go.** Low contact risk and potential means of modification.	**Can go with caution.** Low contact risk and low modification potential.
	1	**3**	**5**	R_i

Figure 5. Risk matrix definition and action plan for the activities.

In each box of the matrix, activities that have the corresponding risk level can be located and numbered. This is a way to quantify the activities on which the strategy of gradual reopening will have an effect (see Figure 6). See in detail the risk level measured for each sectorial activity in Annex I. The result obtained shows four risk levels, where 17,84%, 52,35%, 13,39% and 16,42% correspond to the % of activities in each risk level. The lower the activity risk level the shorter time to full recovery.

R_C	Number of Activities			
25	1	3	7	
15	14	1	0	
9	6	15	7	
5	0	0	0	
3	0	27	1	
1	1	5	0	
	1	**3**	**5**	R_i

Figure 6. Number of activities per risk matrix position.

Notice that some of the activities did never ceased completely —such as health activities or some social services—, they encompass large economic sectors that never worked at their full potential.

The reactivation strategy, with the lowest possible and gradual impact on R, will now be presented for all economic sectors. The more contacts the activity involves (R_C) and/or the more difficult it is to implement measures to prevent infection (R_i), the slower and progressive recovery of the activity will be. A proposal for the staggered recovery of the activities according to their location in the risk matrix is shown in Figure 7, starting from the day that the confinement measures will be removed (T_{DC}).

R_C \ R_i	1	3	5
25	At T_{DC} = 50% At T_{DC} + 1 m. = 80% At T_{DC} + 2 m. = 100%	At T_{DC} = 0% At T_{DC} + 3 m. = 30% At T_{DC} + 6 m. = 60% At T_{DC} + 9 m. = 100%	At T_{DC} = 0% At T_{DC} + 6 m. = 20% At T_{DC} + 8 m. = 50% At T_{DC} + 10 m. = 80% At T_{DC} + 12 m. = 100%
15	At T_{DC} = 50% At T_{DC} + 1 m. = 80% At T_{DC} + 2 m. = 100%	At T_{DC} = 10% At T_{DC} + 3 m. = 40% At T_{DC} + 6 m. = 100%	At T_{DC} = 0% At T_{DC} + 3 m. = 20% At T_{DC} + 6 m. = 50% At T_{DC} + 9 m. = 80% At T_{DC} + 12 m. = 100%
9	At T_{DC} = 80% At T_{DC} + 1 m. = 80%	At T_{DC} = 50% At T_{DC} + 3 m. = 80% At T_{DC} + 5 m. = 100%	At T_{DC} = 10% At T_{DC} + 2 m. = 30% At T_{DC} + 4 m. = 50% At T_{DC} + 6 m. = 70% At T_{DC} + 8 m. = 100%
5	At T_{DC} = 100%	At T_{DC} = 70% At T_{DC}+1 m. = 90% At T_{DC} + 2 m. = 100%	At T_{DC} = 20% At T_{DC} + 2 m. = 40% At T_{DC} + 4 m. = 60% At T_{DC} + 6 m. = 100%
3	At T_{DC} = 100%	At T_{DC} = 80% At T_{DC} + 1 m.= 100%	At T_{DC} = 30% At T_{DC} + 2 m. = 60% At T_{DC} + 4 m. = 100%
1	At T_{DC} = 100%	At T_{DC} = 100%	At T_{DC} = 60% At T_{DC} + 1 m. = 100%

Figure 7. Risk-based de-escalation strategy (% of activity recovery over time, m=month).

In the least critical scenario, virus transmission is very low, the contact intensity is low and there are lots of possible measures that can prevent contagion (physical distancing, engineering and administrative controls, PPE, etc.), when *R<1* and deconfinement begins (T_{DC}), the activities of these sectors can be fully reactivated (100%). However, in the most critical scenario, where the transmission could be very high, because the contact intensity is high and the only one measure to prevent contagion is the use of PPE, the proposed gradual openness is as follows:

- At T_{DC}, regardless *R*<1, the activity is not recovered.
- After 6 months since T_{DC}, a gradual opening of 20% can be reactivated, as long as *R* does not reach the *alarm* level.
- After 8 months, with the same considerations, 50% of the activity is recovered,
- 80% after 10 months and, 100% of normal activity when one year is turned since the opening of confinement.

5. Recovery strategy results on GPD potential evolution in Spain

The current public health crisis is accompanied by a worrying economic situation and the strategy designed for deconfinement will be a critical step in minimizing the economic impact. This impact depends, among other factors, on the intervention level at which the gradual reopening plan is implemented (Crespo *et al.*, 2020b). The losses in GDP are greater if the confinement de-escalation measures are carried out at the national level than if it were done at the regional level and, even higher, at the provincial level, since infection focusses and force of infection differ along the geographical map. This paper's approach allows a plan to de-escalate by the lowest indenture level (provinces or even lower), with a strategy easily replicable, according to the speed that, each type of activity in the matrix, demonstrate that the mitigation measures are put into effect, at a lowest possible level of geographical intervention.

The GPD% provided by each of the defined economic activities, belonging to each level of the matrix, is now calculated. This offers a cost-risk-benefit analysis of this confinement de-escalation strategy, and how it impacts the country economics (Figure 8).

R_C	Activities	%GPD	Activities	%GPD	Activities	%GPD
25	0	0,00%	3	7,79%	7	8,63%
15	14	17,55%	1	3,80%	0	0,00%
9	6	3,20%	16	31,61%	7	8,75%
5	0	0,00%	0	0,00%	0	0,00%
3	0	0,00%	27	14,30%	1	0,83%
1	1	2,32%	5	1,22%	0	0,00%
	1		**3**		**5**	R_i

Figure 8. GPD contribution of each risk level.

The *state of alarm* decreed is Spain reduced the economic activity significantly, to the extent of allowing those activities considered essential only. To simulate the evolution of the GPD over the de-escalation period, it is necessary to estimate the % of the economic activity that remained operative. As an example of the analysis accomplished, Table 6 shows, for the manufacturing industry, the approximation done according to the Bank of Spain and Ernst & Young reports (*Banco de España - Publicaciones - Boletines y revistas - Artículos Analíticos - Coyuntura económica*, no date), *Informe sector moda en España*, no date). See all reports considered for all activities under analysis during confinement in Annex II.

C Manufacturing industry			
Activity	**Occupancy**	**Activity**	**Occupancy**
10 Food industry	80%	22 Manufacture of rubber and plastic prod.	85%
11 Beverage manufacturing	80%	23 Manufacture other non-metallic mineral product	85%
12 Tobacco industry	100%	24 Metallurgy; manufacture of iron, steel and ferroalloy products	85%
13 Textile industry	60%	25 Manufacture of metal products, except machinery and equipment	85%
14 Making garments	60%	26 Manufacture of computer, electronic and optical products	85%
15 Leather and footwear industry	60%	27 Manufacture of electrical equip. and mat.	85%
16 Wood and cork industry, except furniture; basketry and spartan	100%	28 Manufacture of machinery and equipment	85%
17 Paper industry	100%	29 Manufacture of motor vehicles, trailers	85%
18 Graphic arts and media reprod.	85%	30 Manufacture of other transport material	85%
19 Cokes and oil refining	85%	31 Furniture manufacturing	85%
20 Chemical industry	100%	32 Other manufacturing industries	85%
21 Pharmaceutical manufacturing	100%	33 Repair and installation of machinery & eq.	85%

Table 6. Manufacturing industry occupancy during confinement.

Of course, the de-escalation of activities must be applied to their non-operative portion only, thus allowing to recover the "normal" sectors’ conditions. Figure 7 shows the recovery of six relevant national economic sectors over a one-year horizon. Note that sectors such as agriculture and industry will be the first to achieve full recovery, while the entertainment sector will not return to full normality until May 2021 (where we may expect a vaccine could be released). It is very important the fact that, although the sector reaches100% of activity, that does not mean the production will be at the same level since demand may drop. For example, in the case of hostelry, it could be working 100% after the end of 2020, but transportation activities would not reach 100% until February 2021, which would cause a drop in hostelry sector's revenues.

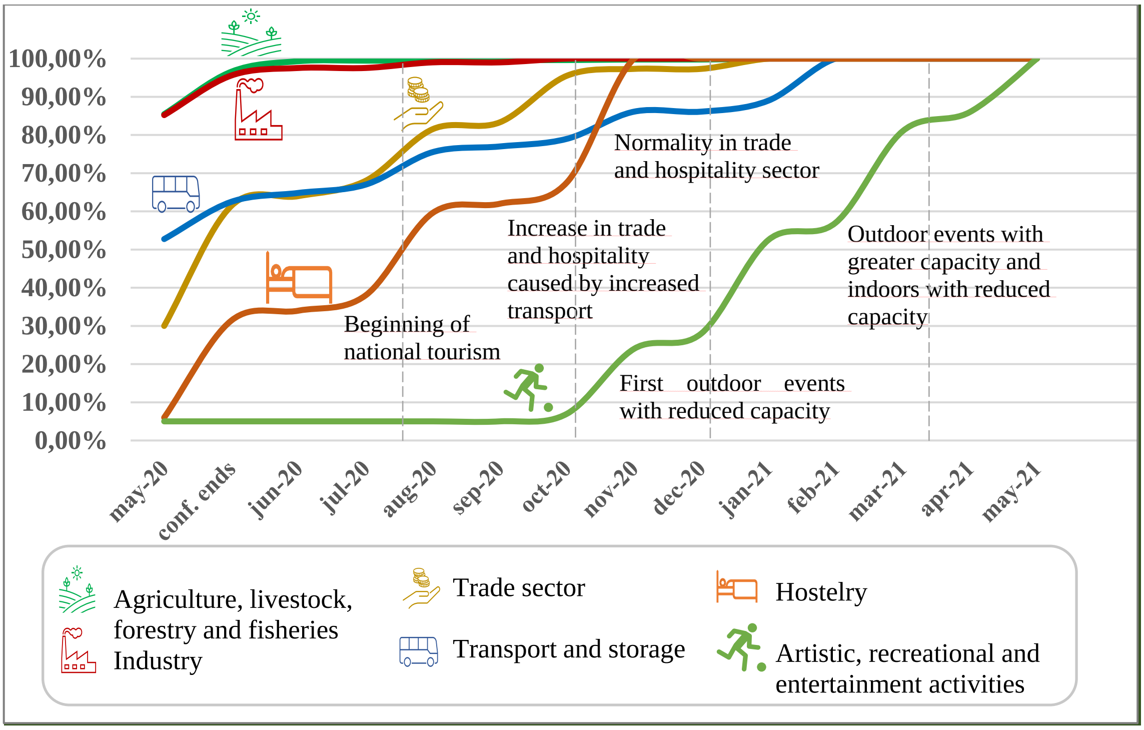

Figure 9. Recovery by sector (in%)

Considering the proposed risk-based de-escalation strategy, Figure 10 shows the evolution of the national GDP from confinement release to full recovery. Three risk areas are distinguished throughout the recovery period. As activities involving greater risk are incorporated, there must be greater vigilance in terms of compliance with prevention measures and greater control of a possible upsurge in contagion, with the aim of carrying out case-based interventions. Note that the first major rise in GDP is due to the entry of the industry after the confinement. The second peak is due to the incorporation of low-risk activities, so it occurs quickly and finally, the third peak is reached in a more gradual and extended manner over time since they correspond to medium and high-risk activities. As previously mentioned, reaching 100% of the evolution of the GDP indicates that the country is ready to return to normal situation. Given a demand similar to that which existed before the pandemic, it would reach a similar level of GDP. In general, in the face of a decrease in demand, the pre-pandemic GDP value will not be reached, although all sectors may function 100% of their capacity.

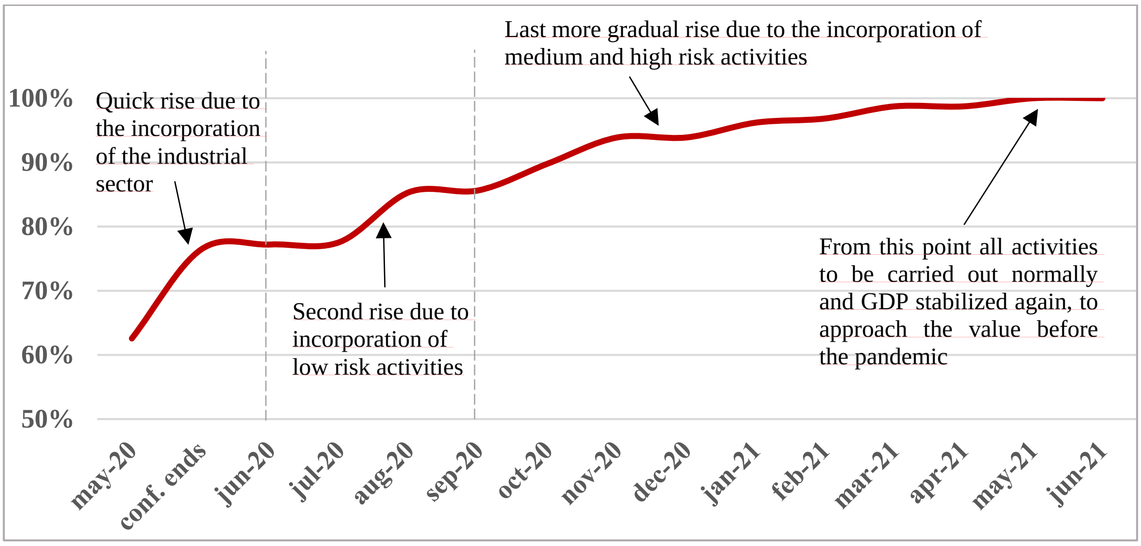

Figure 10. Evolution of national potential GDP

6. Conclusions

With this paper, SIM research group ends a trilogy COVID19 pandemic management analysis. Our aim always has been to put our best skills and our experience serving the society facing this unprecedent situation.

The first impression that we had when in mid-march we started reading very serious papers on COVID 19 emergency was that the generation of practical management tools to tackle the crisis was being forgotten. We found great volume of data, mathematical models, etc., but, how could government, companies and citizen take advantage of these results to reduce the pandemic impact?

Since the very beginning we have highlighted great similarities and analogy points between pandemic recovery management and maintenance management of a complex engineering asset. Our research discipline provides specific verified tools and powerful analysis methodologies that we really think can be used as reference for this brand-new scenario management, especially when there is no similar previous experience. In particular, predictive maintenance (PdM) has improve its tools and skills over last years and all this experience is very valuable when, as COVID 19 management demands, you need to take decisions based on data and predictions. At this point, as a conclusion of the entire series, we would like to highlight our main contributions:

- Paper 1 (Crespo *et al.*, 2020a), in this paper we introduce the importance of correct determination of the indenture level to manage the COVID recovery. This level was linked with geographical areas where management should focus on. We proposed and justify for Spain to use at least the province level as a reference, from local different quarantine time estimation according with real local pandemic behaviour and GDP province expect impact. Three weeks after paper 1 publication date, Spain Government has followed a similar strategy, either also countries as Germany. Thus confirms, at least by the current knowledge, the goodness of this approach.
- Paper 2 (Crespo *et al.*, 2020b), proposes a tool based on a ICUs and plants capacity model. Principal outputs: (i) ICUs and plants saturation estimation data (according to incoming rate of patients), (ii) with this results new local and temporal confinement measure can be planned and also a dynamic analysis can be done to

estimate maximum Ro saturation scenarios, and finally (iii) provide citizen with clear and accurate data allow them adapting their behaviour to authorities' previous recommendations. Just releasing this research to be published we could see Chancellor Angela Merkel presenting a similar approach in Germany.

- Paper 3, Is the most complete and may be most complex, of this trilogy. Now we face how to take decisions and how to control the performance of proposed measures and their impact. A complete process (end-to-end) is now proposed, describing with great detail the challenges of these solutions and the proposed tool. Three fundamental pillars are considered:
  - Definition of activities and their hierarchy in terms of risk in *R* contribution.
  - Consideration of uncertainty of data and *R* model calculation.
  - Monitoring and Control system proposal.

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Annex 1. Qualitative assessment and risk level of the sectoral activities.

	Contact intensity (C_I)	Number of contacts (N_C)	Modification potential (R_i)	%GDP	Risk activity level
A Agriculture, livestock, forestry and fisheries				3,0909%	
01 Agriculture, livestock, hunting and related services	Low	Medium	Medium	2,8414%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
02 Forestry and forestry	Low	Low	Medium	0,0945%	**First to go.** Low contact risk and potential means of modification.
03 Fisheries and aquaculture	Medium	Medium	Low	0,1551%	**Last go!!** Medium-high contact risk and low modification potential
B Extractive industries				0,1946%	
05 Extraction of anthracite, coal and lignite	Low	Medium	Medium	0,0097%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
06 Oil and natural gas crude extraction	Low	Medium	Medium	0,0973%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
07 Extraction of metallic minerals	Low	Medium	Medium	0,0486%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
08 Other extractive industries	Low	Medium	Medium	0,0195%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
09 Activities to support extractive industries	Low	Medium	Medium	0,0195%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
C Manufacturing industry				12,6017%	
10 Food industry	Medium	Medium	Medium	0,9972%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
11 Beverage manufacturing	Low	Medium	Medium	0,9972%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
12 Tobacco industry	Low	Medium	Medium	0,4986%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
13 Textile industry	Medium	Medium	Medium	0,3512%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
14 Making garments	Low	Medium	Medium	0,3512%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
15 Leather and footwear industry	Low	Medium	Medium	0,1756%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
16 Wood and cork industry, except furniture; basketry and spartan	Low	Medium	Medium	0,1815%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
17 Paper industry	Low	Medium	Medium	0,3582%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
18 Graphic arts and reprod. of recorded media	Low	Medium	Medium	0,2092%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
19 Cokes and oil refining	Low	Medium	Medium	0,3329%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
20 Chemical industry	Low	Medium	Medium	0,8760%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
21 Pharmaceutical manufacturing	Low	Medium	Medium	0,6527%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
22 Manufacture of rubber and plastic prod.	Low	Medium	Medium	0,5841%	**Can go with caution.** Low-medium contact risk and with potential means of modification.

	Contact intensity (C_I)	Number of contacts (N_C)	Modification potential (R_i)	%GDP	Risk activity level
23 Manufacture other non-metallic mineral pr	Low	Medium	Medium	0,5332%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
24 Metallurgy; manufacture of iron, steel and ferroalloy products	Low	Medium	Medium	0,6528%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
25 Manufacture of metal products, except machinery and equipment	Low	Medium	Medium	1,0812%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
26 Manufacture of computer, electronic and optical products	Low	Medium	Medium	0,1554%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
27 Manufacture of electrical equip. and mat.	Low	Medium	Medium	0,4166%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
28 Manufacture of machinery and equipment	Low	Medium	Medium	0,6576%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
29 Manufacture of motor vehicles & trailers	Medium	Medium	Medium	1,1191%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
30 Manufacture of other transport material	Low	Medium	Medium	0,3892%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
31 Furniture manufacturing	Medium	Medium	Medium	0,1656%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
32 Other manufacturing industries	Low	Medium	Medium	0,2484%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
33 Repair and installation of machinery & eq.	Medium	Medium	Medium	0,6170%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
D Supply of electricity, gas, steam and air conditioning				2,3179%	
35 Supply of electricity, gas, steam and air c.	Low	Low	High	2,3179%	**First to go.** Low contact risk and high modification potential.
E Water supply, sanitation activities, waste management …				1,1224%	
36 Water capture, purification and distribution	Low	Low	Medium	0,4518%	**First to go.** Low contact risk and potential means of modification.
37 Wastewater collection and treatment	Low	Low	Medium	0,2237%	**First to go.** Low contact risk and potential means of modification.
38 Waste collection, treatment and disposal;	Low	Low	Medium	0,2237%	**First to go.** Low contact risk and potential means of modification.
39 Decontamination and other waste mgmt.	Low	Low	Medium	0,2237%	**First to go.** Low contact risk and potential means of modification.
F Construction				5,9996%	
41 Building construction	Medium	Medium	Low	2,0000%	**Last go!!** Medium-high contact risk and low modification potential
42 Civil engineering	Medium	Medium	Low	2,0000%	**Last go!!** Medium-high contact risk and low modification potential
43 Specialized construction activities	Medium	Medium	Low	2,0000%	**Last go!!** Medium-high contact risk and low modification potential
G Trade sector				12,9909%	
45 Sale and repair of motor vehicles and motorcycles	Medium	Medium	Low	1,6594%	**Last go!!** Medium-high contact risk and low modification potential
46 Wholesale trade and trade intermediaries, except motor vehicles and motorcycles	Medium	Medium	Medium	6,0839%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
47 Retail trade, except motor vehicles and motorcycles	Medium	Medium	Medium	5,2476%	**Could go with high safety measures.** Medium-high contact risk and high modification potential

	Contact intensity (C_I)	Number of contacts (N_C)	Modification potential (R_i)	%GDP	Risk activity level
H Transport and storage				4,6428%	
49 Land and pipeline transport	High	High	Medium	2,2941%	**Cannot go!!** High risk of contact and with potential means of modification.
50 Maritime and inland waterway transport	Medium	Medium	Medium	0,0715%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
51 Air transport	High	High	Medium	0,2608%	**Cannot go!!** High risk of contact and with potential means of modification.
52 Storage and activities attached to transport	Low	Medium	Medium	1,7990%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
53 Postal and postal activities	Medium	Medium	Medium	0,2174%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
I Hospitality				6,3266%	
55 Accommodation services	Medium	Medium	Medium	2,5306%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
56 Food and beverage services	Medium	High	Medium	3,7959%	**Last to go !! with all safety measures.** High risk of contact and potential means of modification.
J Information and communications				3,6995%	
58 Edition	Medium	High	High	0,2447%	**Could go with high safety measures.** High risk of contact and high potential for modification.
59 Film, video and TV programs, sound recording and music ed.	Medium	High	High	0,2525%	**Could go with high safety measures.** High risk of contact and high potential for modification.
60 Radio and television programming and broadcasting activities	Medium	High	High	0,2525%	**Could go with high safety measures.** High risk of contact and high potential for modification.
61 Telecommunications	Medium	High	High	1,3960%	**Could go with high safety measures.** High risk of contact and high potential for modification.
62 Programming, consulting and other IT-related activities	Medium	High	High	0,7770%	**Could go with high safety measures.** High risk of contact and high potential for modification.
63 Information services	Medium	High	High	0,7770%	**Could go with high safety measures.** High risk of contact and high potential for modification.
K Financial and insurance activities				3,8058%	
64 Fin. services except insurance and pension funds	Medium	High	High	2,7162%	**Could go with high safety measures.** High risk of contact and high potential for modification.
65 Insurance, reinsurance and pension funds, except social security	Medium	High	High	0,6649%	**Could go with high safety measures.** High risk of contact and high potential for modification.
66 Ancillary activities to financial services / insurance	Medium	High	High	0,4246%	**Could go with high safety measures.** High risk of contact and high potential for modification.
L Real estate activities				11,5481%	
68 Real Estate Activities	Medium	Medium	Medium	11,5481%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
M Professional, scientific and technical activities				4,6039%	
69 Legal and accounting activities	Medium	Medium	High	1,0075%	**Can go with protective measures.** Medium-high contact risk and high modification potential
70 Activities of headquarters; business management consulting activities	Medium	High	High	1,0075%	**Could go with high safety measures.** High risk of contact and high potential for modification.
71 Technical services of architecture and engineering; testing, etc.	Medium	High	High	1,0662%	**Could go with high safety measures.** High risk of contact and high potential for modification.
72 Research and development	Medium	Medium	High	0,4965%	**Can go with protective measures.** Medium-high contact risk and high modification potential

	Contact intensity (C_I)	Number of contacts (N_C)	Modification potential (R_i)	%GDP	Risk activity level
73 Advertising and market research	Medium	Medium	High	0,5279%	**Can go with protective measures.** Medium-high contact risk and high modification potential
74 Other professional, scientific and technical activities	Medium	Medium	High	0,2988%	**Can go with protective measures.** Medium-high contact risk and high modification potential
75 Veterinary activities	Medium	Medium	Medium	0,1992%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
N Administrative activities and ancillary services				4,1468%	
77 Rental activities	Medium	Medium	Medium	0,7979%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
78 Employment-related activities	Medium	Medium	High	0,5412%	**Can go with protective measures.** Medium-high contact risk and high modification potential
79 Activities of travel agencies, tour operators, booking services and related activities	Medium	Medium	High	0,3284%	**Can go with protective measures.** Medium-high contact risk and high modification potential
80 Safety and Research Activities	Medium	Medium	Medium	0,8255%	**Could go with high safety measures.** Medium-high contact risk and high modification potential
81 Building services and gardening activities	Low	Medium	Low	0,8255%	**Can go with extreme caution.** Low-medium contact risk and potential means of modification.
82 Office admin activities and other business activities	Medium	High	High	0,8255%	**Could go with high safety measures.** High risk of contact and high potential for modification.
O Public administration and defense, mandatory social security				6,1943%	
84 Public administration and defense, compulsory social security	Medium	High	High	6,1943%	**Could go with high safety measures.** High risk of contact and high potential for modification.
P Education				5,2359%	
85 Education	High	High	Medium	5,2359%	**Cannot go!!** High risk of contact and with potential means of modification.
Q Health activities and social services				6,5618%	
86 Health activities	High	High	Low	5,1204%	**Cannot go!!** Very high risk of contact and low potential for modification.
87 Assistance in residential areas	High	High	Low	0,7205%	**Cannot go!!** Very high risk of contact and low potential for modification.
88 Social services activities without accommodation	High	High	Low	0,7205%	**Cannot go!!** Very high risk of contact and low potential for modification.
R Artistic, recreational and entertainment activities				2,0681%	
90 Creation activities, arts and shows	High	High	Low	0,3453%	**Cannot go!!** Very high risk of contact and low potential for modification.
91 Activities of libraries, archives, museums and other	High	High	Low	0,3453%	**Cannot go!!** Very high risk of contact and low potential for modification.
92 Gambling and Betting Activities	High	High	Low	0,3453%	**Cannot go!!** Very high risk of contact and low potential for modification.
93 Sports, recreational and entertainment activities	High	High	Low	1,0312%	**Cannot go!!** Very high risk of contact and low potential for modification.
S Other services				1,9096%	
94 Associative activities	Medium	High	High	0,9506%	**Could go with high safety measures.** High risk of contact and high potential for modification.
95 Repair of computers, personal effects and household items	Medium	Low	Medium	0,1182%	**Can go with caution.** Low-medium contact risk and with potential means of modification.
96 Other personal services	Medium	Medium	Medium	0,8408%	**Could go with high safety measures.** Medium-high contact risk and high modification potential

	Contact intensity (C_I)	Number of contacts (N_C)	Modification potential (R_i)	%GDP	Risk activity level
T.- Household activities as employers of domestic staff; household activities as producers of goods and services for their own use				0,9388%	
97 Household activities as employers of domestic staff	Medium	Medium	Low	0,4695%	**Last go!!** Medium-high contact risk and low modification potential
98 Household activities as producers of goods and services for their own use	Medium	Medium	Low	0,4695%	**Last go!!** Medium-high contact risk and low modification potential
U.- Activities of offshore organizations and agencies				0,0000%	
99 Activities of offshore organizations and bodies	Medium	Medium	Medium	0,0000%	**Could go with high safety measures.** Medium-high contact risk and high modification potential

Annex II. Sectoral activities. Current activity ratio approximation

	Occupancy (%)	References&Comments
A Agriculture, livestock, forestry and fishing		
01 Agriculture, livestock, hunting and related services	85%	Only domestic consumption and no restoration in operation
02 Forestry	100%	BOE-A-2020-3692
03 Fishing and aquaculture	85%	Only domestic consumption and no restoration in operation
B Extractive industries		
05 Extraction of anthracite, coal and lignite	65%	According to COMINROC report 18/04/2020
06 Extraction of crude oil and natural gas	65%	According to COMINROC report 18/04/2020
07 Extraction of metallic minerals	65%	According to COMINROC report 18/04/2020
08 Other extractive industries	65%	According to COMINROC report 18/04/2020
09 Activities to support extractive industries	65%	According to COMINROC report 18/04/2020
C Manufacturing industry		
10 Food industry	80%	Only domestic consumption and no restoration in operation
11 Beverage manufacturing	80%	Only domestic consumption and no restoration in operation
12 Tobacco industry	100%	BOE-A-2020-3692
13 Textile industry	60%	The other 40% will be recovered based on demand. Fashion Sector Report in Spain Ernst&Young 2020
14 Making garments	60%	The other 40% will be recovered based on demand. Fashion Sector Report in Spain Ernst&Young 2020
15 Leather and footwear industry	60%	The other 40% will be recovered based on demand. Fashion Sector Report in Spain Ernst&Young 2020
16 Wood and cork industry, except furniture; basketry and spartan	100%	BOE-A-2020-3692
17 Paper industry	100%	BOE-A-2020-3692
18 Graphic arts and reproduction of recorded media	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
19 Cokes and oil refining	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
20 Chemical industry	100%	BOE-A-2020-3692
21 Pharmaceutical manufacturing	100%	BOE-A-2020-3692
22 Manufacture of rubber and plastic products	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
23 Manufacture of other non-metallic mineral products	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
24 Metallurgy; manufacture of iron, steel and ferroalloy products	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
25 Manufacture of metal products, except machinery and equipment	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
26 Manufacture of computer, electronic and optical products	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
27 Manufacture of electrical equipment and material	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
28 Manufacture of machinery and equipment n.e.c.	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
29 Manufacture of motor vehicles, trailers and semi-trailers	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
30 Manufacture of other transport material	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
31 Furniture manufacturing	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
32 Other manufacturing industries	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
33 Repair and installation of machinery and equipment	85%	Collapse from decreased demand, supply difficulties. Banco España Report 20/04/2020
D Electricity, gas, steam and air conditioning supply		
35 Electricity, gas, steam and air conditioning supply	100%	BOE-A-2020-3692
E Water supply, sanitation activities, waste management and decontamination		
36 Collection, purification and distribution of water	100%	BOE-A-2020-3692
37 Collection and treatment of wastewater	100%	BOE-A-2020-3692

	Occupancy (%)	References&Comments
38 Collection, treatment and disposal of waste; valorization	100%	BOE-A-2020-3692
39 Decontamination activities and other waste management services	100%	BOE-A-2020-3692
F Construction		
41 Construction of buildings	100%	BOE-A-2020-3692
42 Civil engineering	100%	BOE-A-2020-3692
43 Specialized construction activities	90%	BOE-A-2020-4424 Not activated works in inhabited areas
G Trade sector		
45 Sale and repair of motor vehicles and motorcycles	30%	Banco España Report 04/20/2020
46 Wholesale trade and trade intermediaries, except of motor vehicles and motorcycles	30%	Banco España Report 04/20/2020
47 Retail trade, except of motor vehicles and motorcycles	30%	Banco España Report 04/20/2020
H Transport and storage		
49 Ground and pipeline transportation	40%	BOE-A-2020-3692
50 Sea and inland waterway transport	40%	BOE-A-2020-3692
51 Air transport	10%	Banco España Report 04/20/2020
52 Storage and transport-related activities	70%	
53 Postal and courier activities	100%	BOE-A-2020-3692
I Hospitality		
55 Accommodation services	0%	BOE-A-2020-3892
56 Food and beverage services	10%	Only home delivered meals
J Information and communications		
58 Edition	100%	BOE-A-2020-3692
59 Film, video and television program activities, sound recording and music publishing	20%	BOE-A-2020-3692
60 Radio and television programming and broadcasting activities	100%	BOE-A-2020-3692
61 Telecommunications	100%	BOE-A-2020-3692
62 Programming, consulting and other computer related activities	100%	BOE-A-2020-3692
63 Information services	100%	BOE-A-2020-3692
K Financial and insurance activities		
64 Financial services except insurance and pension funds	100%	BOE-A-2020-3692
65 Insurance, reinsurance and pension funds, except compulsory social security	100%	BOE-A-2020-3692
66 Activities auxiliary to financial services and insurance	100%	BOE-A-2020-3692
L Real estate activities		
68 Real estate activities	20%	Interview with FAI of Spain 03/25/2020
M Professional, scientific and technical activities		
69 Legal and accounting activities	100%	BOE-A-2020-3692
70 Headquarters activities; business management consulting activities	100%	BOE-A-2020-3692
71 Technical architectural and engineering services; technical testing and analysis	100%	BOE-A-2020-3692
72 Research and development	90%	Telecommuting
73 Advertising and market research	90%	Telecommuting
74 Other professional, scientific and technical activities	90%	Telecommuting
75 Veterinary activities	20%	Only emergencies
N Administrative activities and auxiliary services		
77 Rental activities	80%	Only regular housing rentals remain
78 Employment-related activities	100%	BOE-A-2020-3692

	Occupancy (%)	References&Comments
79 Activities of travel agencies, tour operators, reservation services and related activities	0%	BOE-A-2020-3692
80 Security and investigation activities	100%	BOE-A-2020-3692
81 Services to buildings and gardening activities	100%	BOE-A-2020-3692
82 Office administrative activities and other activities auxiliary to companies	100%	BOE-A-2020-3692
O Public administration and defense, compulsory social security		
84 Public administration and defense, compulsory social security	100%	BOE-A-2020-3692
P Education		
85 Education	100%	BOE-A-2020-3692. 100% virtual education
Q Health activities and social services		
86 Health activities	15%	Private healthcare with activity not counting Covid. ELPaís 04/25/2020
87 Assistance in residential installations	100%	BOE-A-2020-3692
88 Social service activities without accommodation	100%	BOE-A-2020-3692
R Artistic, recreational and entertainment activities		
90 Creative, artistic and entertainment activities	0%	BOE-A-2020-3692
91 Activities of libraries, archives, museums and other cultural activities	0%	BOE-A-2020-3692
92 Gambling and betting activities	30%	Estimate for online game
93 Sports, recreation and entertainment activities	0%	BOE-A-2020-3692
S Other services		
94 Associative activities	0%	BOE-A-2020-3692
95 Repair of computers, personal effects and household items	100%	BOE-A-2020-3692
T Household activities as employers of domestic personnel; household activities as producers of goods and services for their own use		
97 Activities of households as employers of domestic personnel	100%	BOE-A-2020-3692
98 Household activities as producers of goods and services for own use	100%	Interview with FAI of Spain 03/25/2020
U Activities of extraterritorial organizations and agencies		
99 Activities of extraterritorial organizations and agencies	100%	BOE-A-2020-3692