Modelling COVID-19

Sharing Knowledge and Expertise

SCOR
The Art & Science of Risk

Since the early stage of the COVID-19 pandemic, SCOR's actuarial and medical workforce came together to better understand the virus and its consequences, for our customers and partners, but also for any interested party, close or not to our business.

During this period, SCOR's business-facing teams have chosen to regularly share with their customers the extent of our knowledge on the subject, for example through webinars on the pandemic and its impacts on our business.

We have also developed a modelling tool that allows to anticipate the possible developments of this tragedy in all the countries where SCOR's clients are established, based on a SEIR epidemiological model.

Modelling efforts were initially focusing on the first wave in the United States, the United Kingdom and France.

Hence, this brochure will first give a presentation of a SEIR epidemiological model, followed by a detailed example of the tool based on the country of France.

SCOR teams' in-depth knowledge of the local markets combined with the flexibility of the tool have allowed to be efficient in measuring the impacts of the disease on the mortality of a given population.

This tool is the result of a collaborative work between our data scientists, actuaries and epidemiologists. We strive to continuously update the app, especially by integrating new relevant reported data and local specificities.

Feel free to contact your usual contacts at SCOR, to exchange on all subjects related to the pandemic of COVID-19, its modeling and impacts on portfolios.

SCOR
The Art & Science of Risk

What is a SEIR model?

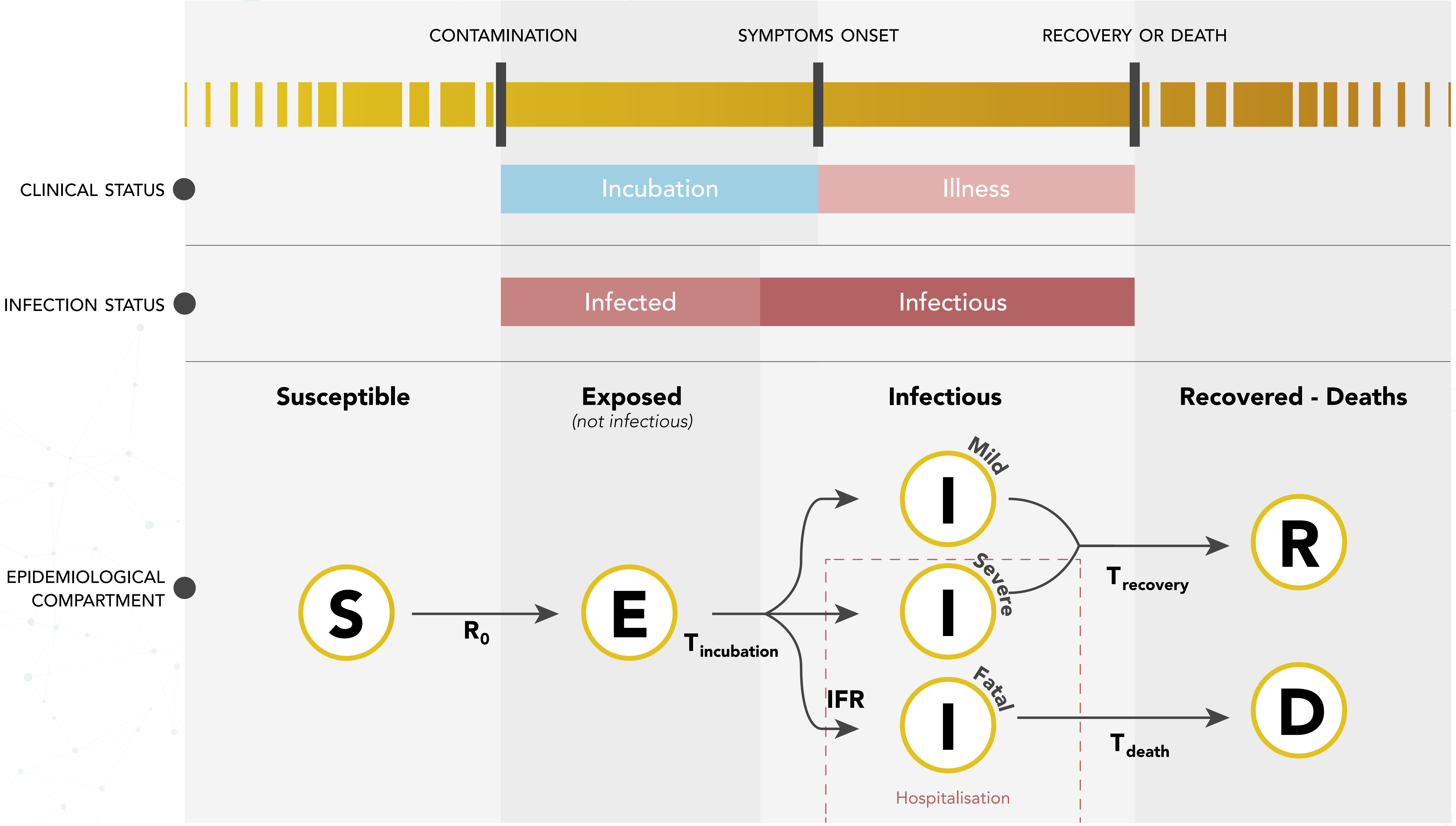
The SEIR model belongs to a family of epidemiological models (including SIR, SEIS, MSEIR) that maps the spread of an epidemic through the sequential interaction of 4 compartments. This family of models is used on the current frontline war against COVID-19.

Dimensions to be considered to model an outbreak:

- The spread of the virus represented by the reproduction number or R_0. It is critical to track this number precisely.
- The clinical evolution of the disease:

> At the start of the epidemic, except for the first infected people, everyone is healthy, i.e. neither infected by the virus, nor contagious.

> Once a person is contaminated by the virus, we know that:
- There is an incubation phase when the infected person does not show any symptom of the disease.
- Then the person gets sick with various degrees of illness :
  - Asymptomatic,
  - The person shows symptoms but does not require hospitalisation,
  - The person shows symptoms and requires hospitalisation or ICU (Intensive Care Unit) admission,
  - Ultimately, this person may recover or die.



There are many dimensions that need to be considered to correctly model the COVID-19 outbreak. The considered population is split into 4 compartments corresponding to the stages of the disease:

S E I R

*The **S**usceptible population: people who may be infected. Usually, for a new virus like COVID-19, it can be the entire population of a country or a state.*

*The **E**xposed: people who got into contact with infectious people. They are infected and at the incubation stage. They don't show symptoms yet.*

*The **I**nfectious: all the people who are ill and are infectious, either with no symptoms, mild, severe or critical symptoms.*

The Removed compartment is composed of:
*- the fully recovered **R** and*
*- the dead **D***

Given an initial population, a forecast period, a set of parameters that control the rate at which individuals jump from one stage to another and a mortality rate, one can simulate the size of these groups across the forecast horizon.

The population where the virus is circulating is assumed to be a closed population, meaning its size, N, is the sum of the 4 mentioned compartments:

$$N = S+E+I+R.$$

The model depends on clinical, epidemiological and other parameters. But the calibration is only focusing on the epidemiological and the other parameters:

- number of deaths,

- initial number of infected people (sometimes called the "patients zero"),

- the reproduction number of the virus R_0 (the number of secondary cases infected by a primary case). If R_0 is less than 1, the infection will eventually die out. The higher the value of R_0 is, the more likely the virus is spreading leading to an epidemic, without control measure. So obviously the aim is to maintain the R_0 below 1.

- the infection fatality ratios IFR, which is the proportion of dead people among the infected cases.

PARAMETERS

Clinical	Epidemiological	Other parameters
Duration of incubation period	Population size	Number of deaths
Duration while patient is infectious	Initial number of infected people	ICU beds occupancy
% of infections that are severe	Reproduction number R_0	Mobility data
Recovery time for mild cases	Infection fatality rate	
Recovery time for hospitalized cases		
Recovery time for severe cases		
Average time between symptoms onset to death for critical cases		

We also want to be able to calibrate the model with the real-world data.

Therefore, the SCOR SEIR app integrates milestone events that affect the transmission speed of the virus. These events range from the emergence of clusters (e.g. because of social gatherings) to the various non-medical measures implemented to contain the virus such as school closures or general lockdowns. How strictly people comply with containment measures (physical distancing, wearing masks, etc.) also impacts R_0.

What are the benefits of the SEIR app?

It helps **understand** the spread of the disease and how individuals flow from one compartment to the other.

We can **predict** multiple scenarios over time, simulate subsequent waves and assess the number of deaths, as well as the potential overload of hospitals which can generate excess mortality.

The model is used to **influence** our analysis and actions on how to respond both now and in the future as the situation develops (See our Call to Action letter).

The fact that we have developed this app from scratch enables us to have **full control** over the tool, adapt it as needed and react quickly. It allows for **complete fitting** of model to different countries and geographies. The architecture of our model allows us to include much granular data, when we acquire new knowledge. In this respect, our epidemiologists are a precious resource to **ilter** the current research literature on COVID-19 that is overwhelming and largely not peer-reviewed.

Understanding a population's mortality is a pre-requisite to assess an insurer's mortality book of business (see in appendix how portfolio impact assessment can be done leveraging the SEIR model outputs with the caveats related to the uncertainties listed below).

Showing how the SEIR model works through the app help us **engage a fully transparent discussion** about the rationale behind our underwriting position, including change in pricing.

HOW CAUTIOUS SHOULD WE BE ON PROJECTIONS?

Despite this extensive modelling and close monitoring of the latest developments, some elements make this type of modelling particularly challenging. It is currently difficult to provide definitive estimates of the impact on a given population or a given book. However, we can list some biases and "known unknowns":

- *Maturity of the pandemic*
  The infection is very dynamic and rapidly changing, affecting regions at different stages.
- *Spread of the Virus (R_0)*
  Driven by a complex web of factors including human behaviour and government measures, the R_0 is particularly sensitive to the respect of social distancing measures and the use of face masks.
- *Data challenges linked to deaths reporting*
  Different reporting approaches between countries can result in under-reporting or other biases.
- *Several medical unknowns*
  Immunity, impact of warm weather, development of potential medical treatments, impact of combination with seasonal flu, potential future waves: all contribute to an additional uncertainty.

FLEXIBILITY AND AGILITY OF OUR APPROACH

The architecture of the SCOR SEIR model enables the integration of new findings on topics listed above. For instance, if research shows that immunity is lost after recovery, the model can take into account a re-infection probability of Recovered people. The same goes for the use of face mask: if research materially confirms its impact on R_0, we would be able to integrate such findings.

HOW TO CALIBRATE THE SEIR MODEL?

SCOR's Knowledge Community is a network of experts including doctors, epidemiologists, actuaries and data scientists. This community created the SEIR model and built the app to embed the model. This community likewise ensures that the calibration of the model is done using the relevant data. Since the calibration step is a prerequisite for the estimation of probable mortality outcomes, integrating local specificities is crucial.

Why and how integrate local specificities ?

Though the model requires the same inputs (e.g. death count data, IFR), local differences must be considered to enable a good fit of the calibration: death counts (only in hospitals or including nurs-ing homes), testing policy (only those admitted to hospital with severe symptoms or almost every-one) are very different across countries. Such dis-parities are appreciated only by local teams who are the best managers of the necessary adjust-ments.

In the following section, we chose the French example to illustrate some of these specificities, detailing how the calibration of the parameters is done for the French population.

Illustrative example with France

The outcomes of the calibration for France presented below illustrate the handover from Global Knowledge Team to a local team: France (WELA macro market).

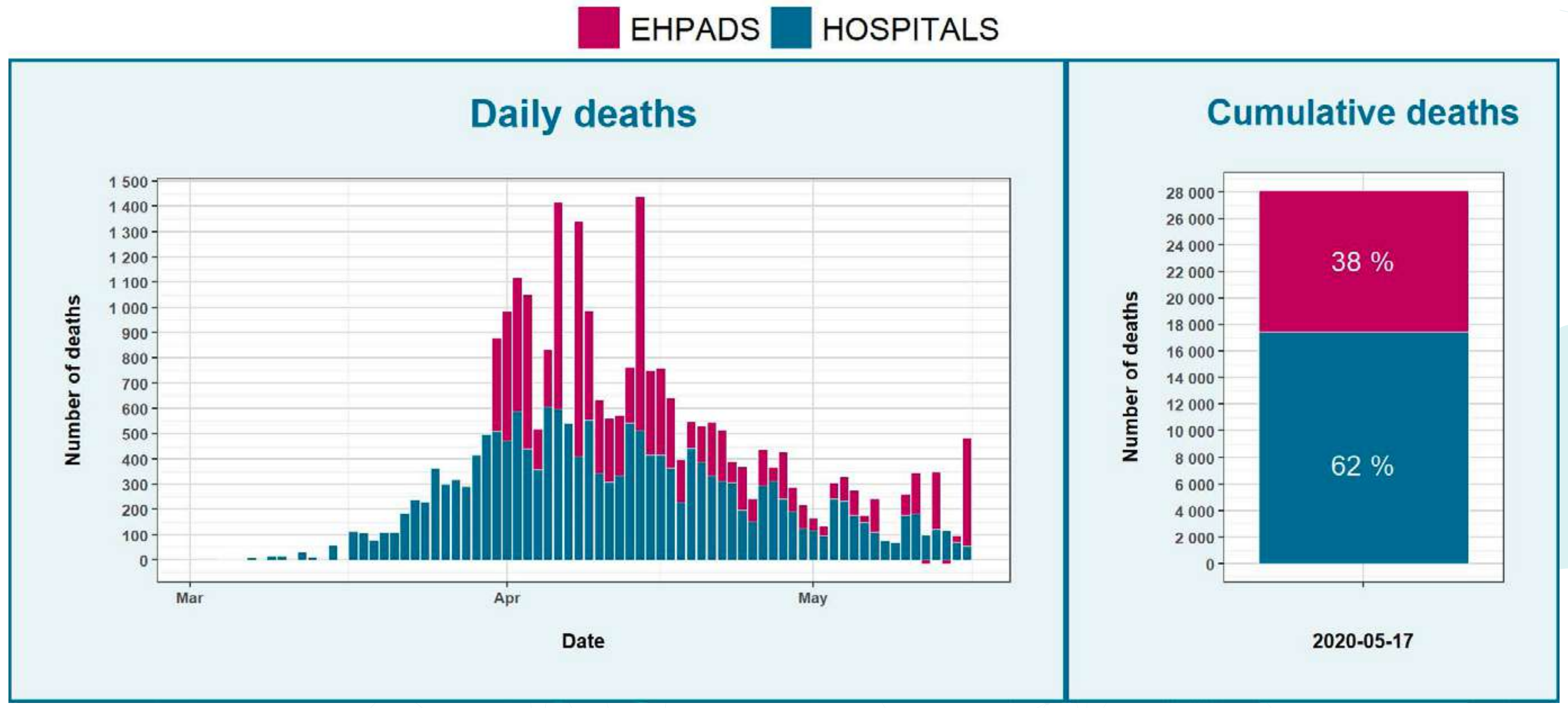
In France, the batch reporting of nursing homes (EHPAD) deaths makes the aggregation with the daily reporting of hospital deaths challenging. Therefore, the calibration has only been performed with the hospital death count, which is regularly reported. Equally important is the ICU-bed critical occupancy which has to be consistent with the government's objectives for lockdown easing.

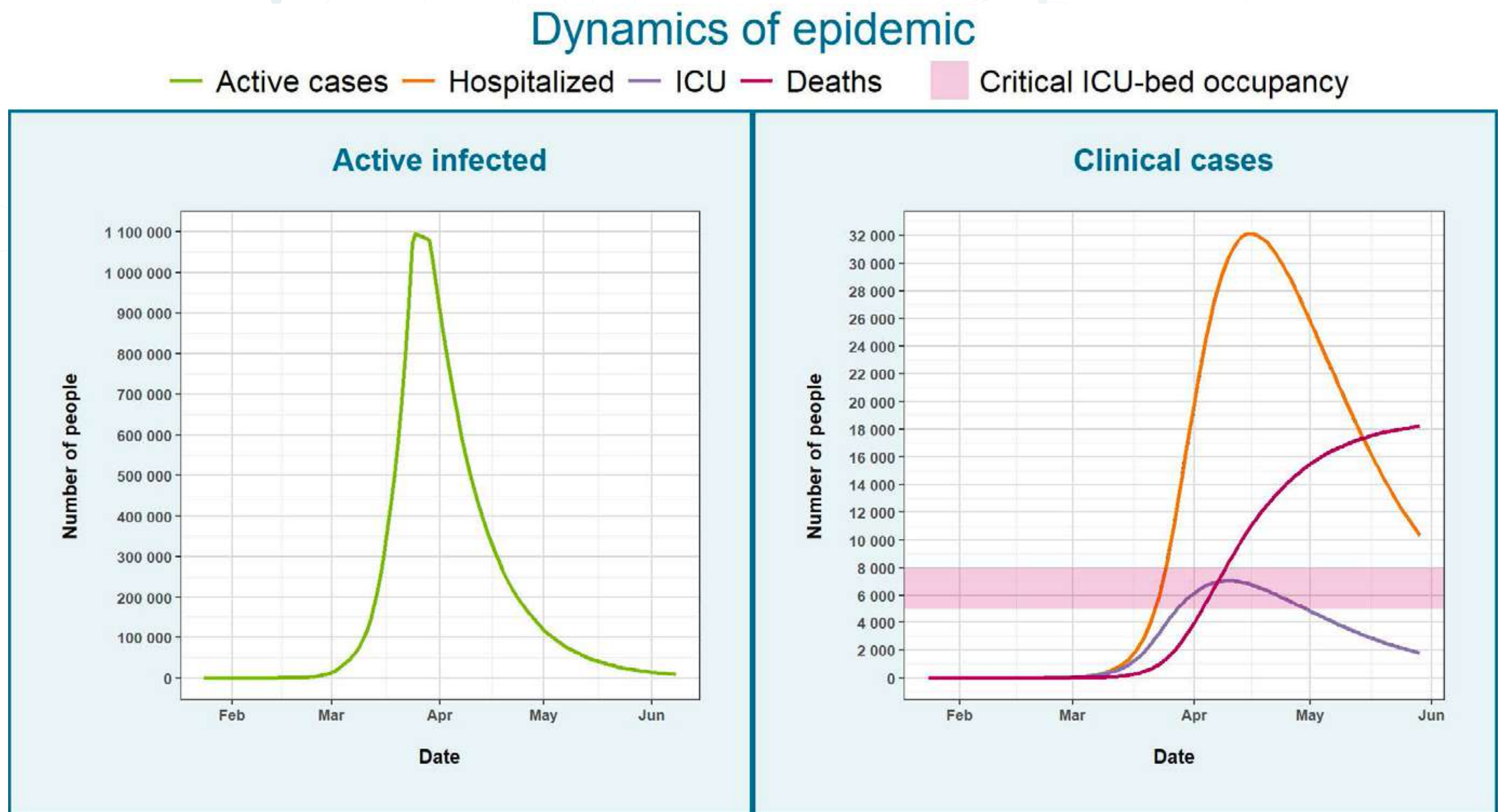
The dynamics of the epidemic as projected by the model from 24 January to 10 May 2020 are aligned with the data observed over this period. The same goes for the evolution of bed occupancies in ICU units.

Local knowledge enables good model fitting as well as consistent 1st wave dynamics

Once the model is fitted, adjustments are made to get to the total cumulative deaths (hospitals and non-hospitals). Then, the overall dynamics of the epidemic is projected to visualise the evolution of some compartments of the SEIR model: such as "Infectious", and "Deaths" compartments. The "Infectious" compartment is split into "Active Infected cases" and "Hospitalized" in the chart. Not being explicitly modelled, ICU bed occupancy is derived from the "Clinical cases". And research is needed to get the information since the data is not widely circulated.

Local knowledge combined with the flexibility of the model gives our French market team confidence in using the SEIR model to project potential mortality impacts.





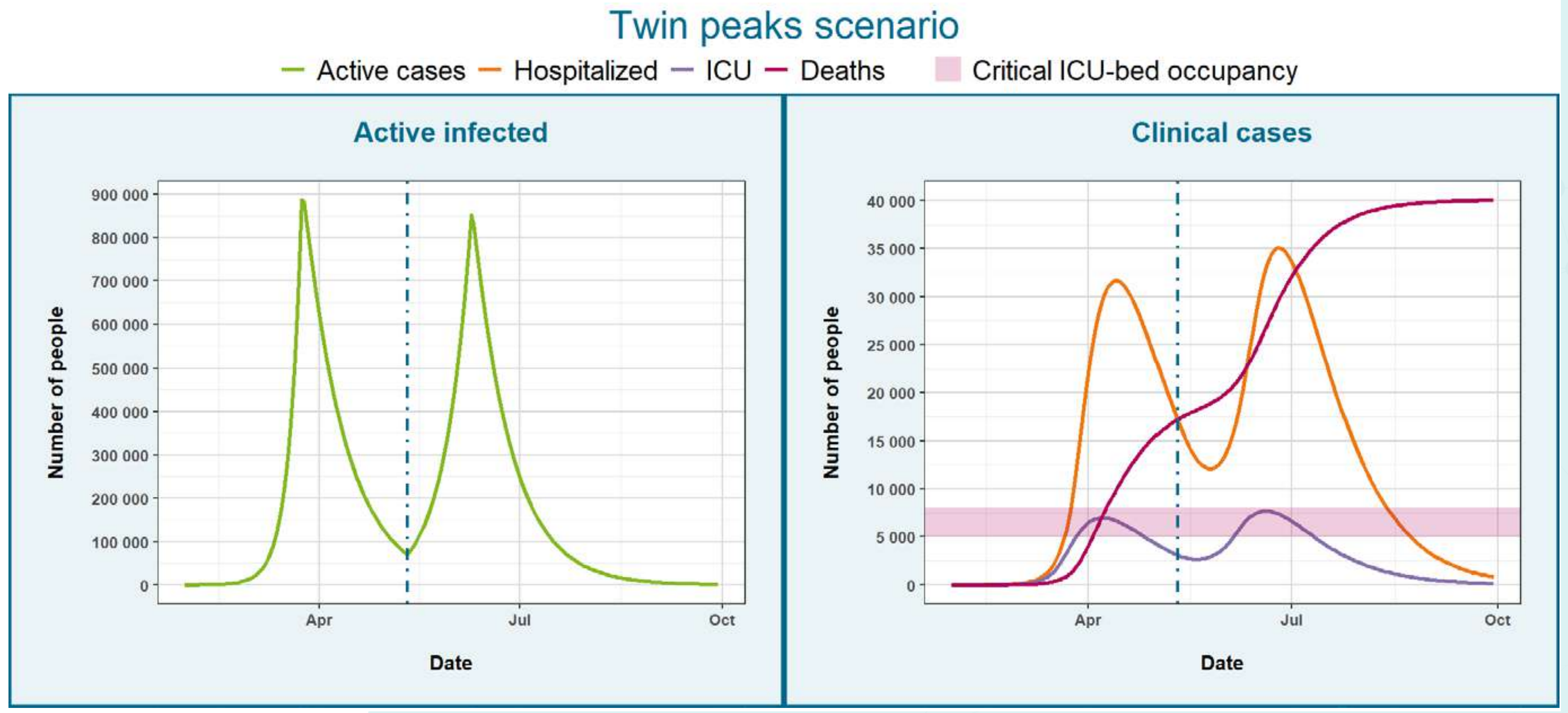
Designing proper scenarios after lockdown easing requires good knowledge of benchmark research

As a prerequisite, the model should give a fair and accurate representation of the evolution of the outbreak until now. Being able to define "what if" scenarios is the major added value of the app.

Acording to a published report from the scientific council advising the French government in May 2020, a possible scenario was a relaxed lockdown followed by a renewed, strict lockdown. Based on this research, the corresponding scenario was :

Date	R_0	IFR	Comments
2020-05-11	1.89	0.7 %	Severe impact
2020-06-09	0.63	0.7 %	New lockdown

The charts show that easing the measures too much after the 1st wave results in exceeding the critical ICU-bed occupancy threshold a few months later. That triggers a new lockdown.



Conclusion

With our market-dedicated teams now trained to use and understand the SCOR SEIR Model, clients can now benefit from this global expertise. As shown by the French example, the markets are now fully equipped to assess the impact of COVID-19 on their portfolio, and spark interesting discussions with their clients.

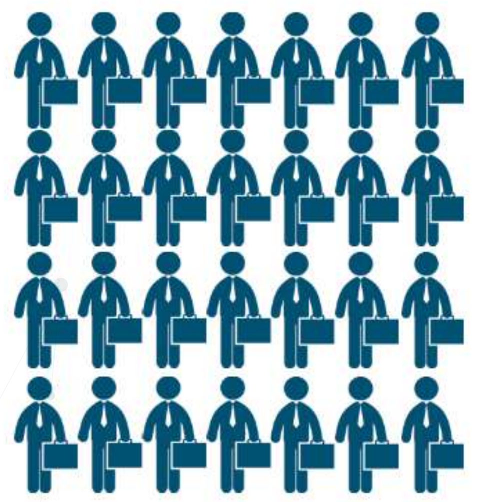
More generally, our clients benefit from the full range of SCOR expertise:

- **Our epidemiologists** provide the most updated clinical parameters like the incubation period, the latency period, the duration of stay in ICU.
- **Our data scientists** use such inputs to build not only a consistent model but also a flexible app that can adapt to local markets' specificities.
- **Actuaries** are an important resource when it comes to calibrating the model to a specific market with curated and consistent data sources, e.g. we just leverage their knowledge of local health system (like ICU beds number, consistency of cases/deaths reporting etc).

Appendix Assessing portfolio impact

Assessing insurer's portfolio impact requires a translation from general population mortality to insurer's portfolio mortality into 3 steps, each currently carrying a very high level of uncertainties

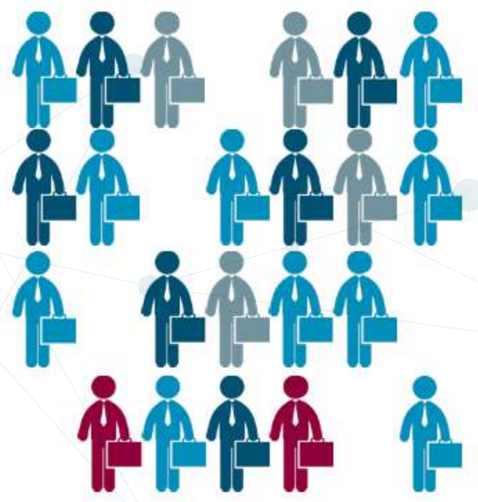
1 General Population (Number of deaths)



Sources of uncertainty:

- Challenge in defining correct reproduction number
- Data quality issues
- Dependence on government measures
- Dependence on citizen actions
- Potential for on-going new outbreaks
- Impact on other mortality causes
- Medical breakthroughs

2 Infection Fatality Rate by Age Band & Gender



Sources of uncertainty:

- Unknown number of infected people
- Uncertain breakdown by age and gender
- Unknown actual numbers of death due to COVID-19
- Differs by location
- Evolves over time

3 General Population to Insured Population Adjustment by Age & Gender

Sources of uncertainty:

- Uncertainty on how to measure the lower prevalence of certain co-morbidity as a result of underwriting,
- Uncertainty on how to assess the socio-economic effects (access to health care, adherence to social distancing, etc)
- No reliable past proxy (some indicative experience from historical flu)

4 Insurer Portfolio Exposure x insured death rate = Insurer Portfolio Impact