Long-term scenarios for the number of new hospitalisations during subsequent waves in the Belgian COVID-19 epidemic

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Summary

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Methodological background

In this report, we provide long-term predictions of the daily number of new hospitalizations based on a stochastic discrete age-structured compartmental model calibrated on hospitalization, mortality and serological survey data (see report for more details thereon). Model assumptions and limitations are listed in the report.

Stochastic realisations are generated under different scenarios in terms of changes in social contact behaviour. The first three scenarios quantify the impact of an increase in social contacts upon relaxing the stringent lockdown measures with an additional increase following the start of the holiday period (July 1, 2020). Contacts are assumed to increase in both work-related, transportation and leisure contacts. A re-adjustment of current contact behaviour which increased following deconfinement of the measures and as determined based on the current resurgence of the disease, is explored in three additional scenarios.

Findings and recommendations

1. Scenarios with a moderate to high increase in the number of contacts (relative to the contact behaviour during lockdown) are currently in line with the reported number of new hospitalizations.

2. These scenarios predict a high number of new hospitalizations if contact behaviour is not adjusted.

3. In the worst case scenario the peak in the daily number of hospitalizations is observed early October and under this scenario the ICU load will exceed the increased COVID-19 ICU capacity (peak size: 2066 - 95% prediction interval: 1890; 2270).

4. Lowering the number of leisure and work-related contacts as of July 28, 2020 could prevent the second COVID-19 wave to exceed the peak of hospitalizations during the first wave.

5. Upon reducing contacts drastically, an increase in school-related contacts after partial reopening of schools implies a delayed increase in number of hospitalizations due to an insufficient depletion of susceptibles

6. Caution should be warranted for re-emergence of the disease following the second wave with contact tracing, testing and self-isolation (quarantine) as quintessential mitigation measures.

7. In this sense, it is important that we do not allow the number of new cases to stabilize at a plateau of 85. The closer it comes to zero infections (cf. Finland, New Zealand) the easier it is to hold off the third wave.

8. A reduction in contact behaviour is of utmost importance to avoid the epidemic to get out of control.

9. Household bubbles (Willem et al., 2020), in addition to contact tracing, provide a way of reducing population-level transmission of the disease while avoiding reinstatement of stringent lockdown measures.

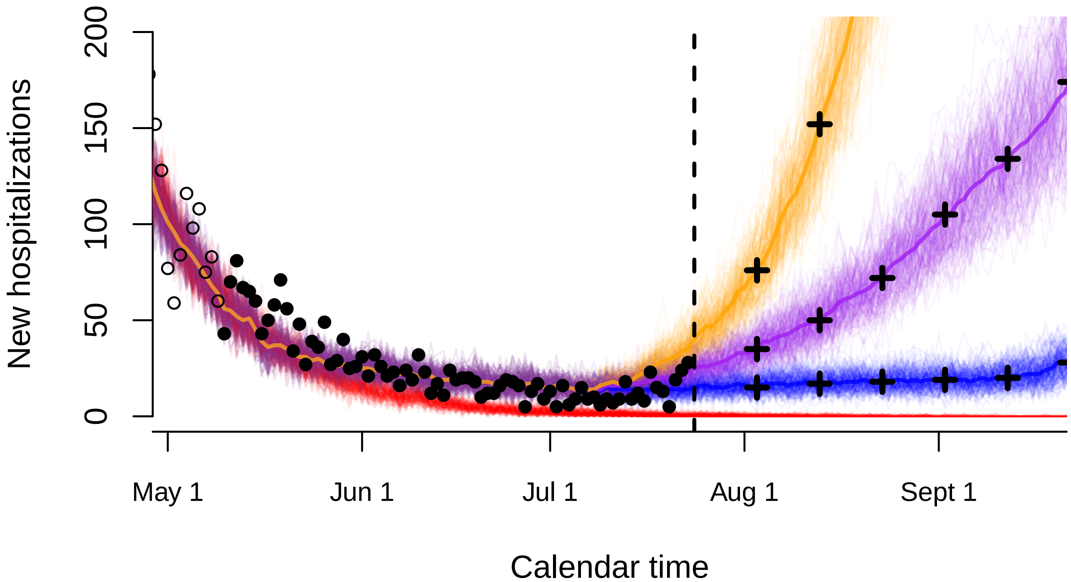

Figure 1: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools as of September 1, 2020.

References

Willem et al. (2020). *The impact of contact tracing and household bubbles on deconfinement strategies for COVID-19: an individual-based modelling study*. medRxiv.

Full report

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Key messages

- The intervention measures taken by the Belgian government were effective in lowering the spread of SARS-CoV-2 in the population
- Behavioural change will determine the sustainability of the exit strategies and will drive future waves of COVID-19 infections in Belgium
- Since (long-term) predictions are driven by assumptions with regard to social contact behaviour of individuals during the course of the epidemic, and no clear picture about the impact of the different phases in the exit strategy is available to date, several scenarios are explored
- No probabilistic statements about the likelihood of the aforementioned scenarios can be obtained and these merely present potential evolutions of the future course of the epidemic
- Monitoring the further evolution of the epidemic is essential, hence, bi-weekly updates of the modeling will be provided thereby relying on new data on hospitalisations and deaths that have become available
- During the course of the epidemic and depending on the status of hospitalisations and deaths, it is likely that governmental measures are either relaxed further or more stringent measures are required. As these interventions will be quintessential for the prediction of new hospitalisations, adequate refinements will be incorporated in the model to update predictions as time progresses

Assumptions and limitations

We use a stochastic discrete age-structured compartmental model calibrated on high-level hospitalisation data (Sciensano), serial serological survey data (Herzog et al., 2020) and Belgian mortality data (Sciensano). More specifically, the stochastic model predicts (stochastic realisations of) the daily number of new hospitalisations per age group (i.e., 10 year age groups). The modeling approach depends on assumptions with regard to the transmission process which inevitably implies an underestimation of the level of uncertainty. As the model-based long-term predictions rely on changes in social contact behaviour following the exit strategy initiated May 4, 2020, we present such predictions under various scenarios which aim at giving some insights in the future course of the epidemic without being able to assign a probability to each scenario related to the likelihood of a given scenario to become reality. We do account for the current resurgence of COVID-19 in the selection and presentation of plausible scenarios. As more data will become available in the next weeks, further model validation and updated prediction results are needed. Model results should be interpreted with great caution.

Some limitations of the model are listed below:

- The different scenarios are expressed in terms of changes in social contact behaviour, rather than changes in transmissibility as a result of social distancing and hygienic measures taken at different locations, e.g., at work and school

- In the stochastic model we are not explicitly accounting for re-importation of the pathogen in the population
- All scenarios are hypothetical and currently we are not able to discern more plausible scenarios
- We did not include seasonality in the model
- Contact tracing, testing and self-isolation are not incorporated in the exit strategies outlined in this report
- Although a gradual re-opening of society and relaxing of the lockdown measures is done in different phases, we assume a specified change in social contact behaviour from May 4 onwards

Schematic diagram of the stochastic model

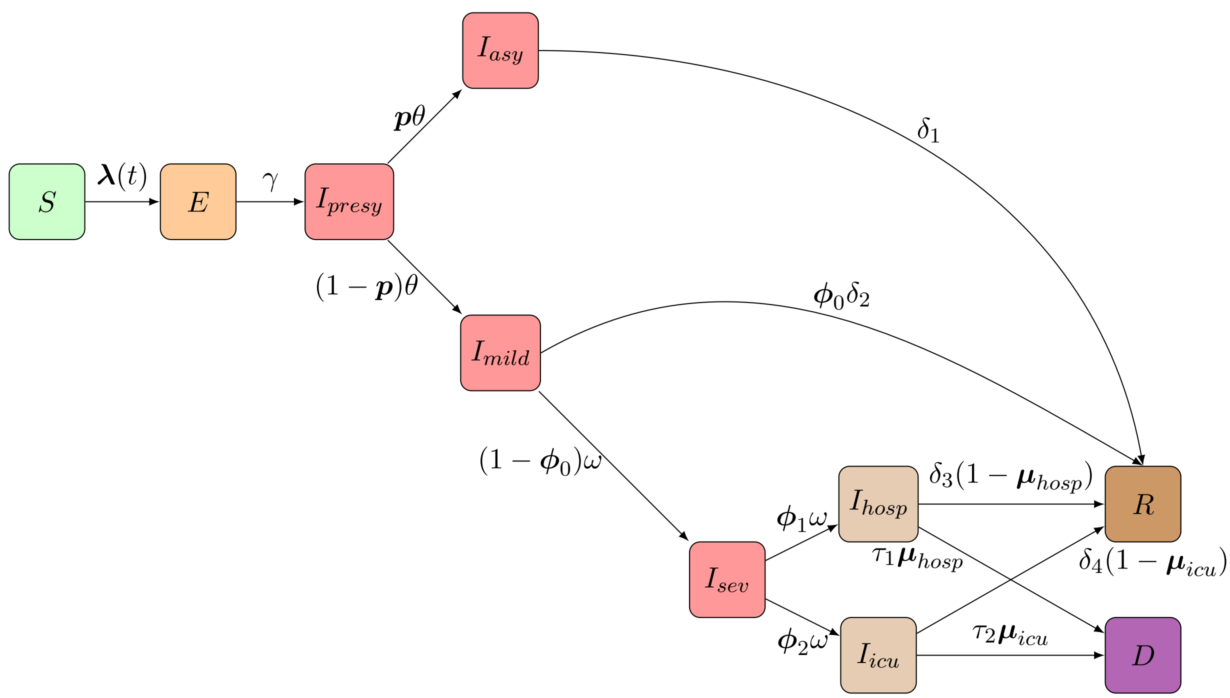

Figure 2: Schematic overview of the flows of individuals in the compartmental model.

Long-term predictions under different scenarios

Impact of an increase in contacts from July 1, 2020 onwards on the second wave

In Figure 3, we present stochastic realisations of the model to predict the number of new hospitalizations under different scenarios upon relaxing the lockdown measures taken in the Belgian population as of May 4, 2020 (S1-S3). More specifically, the scenarios assume that the relaxing of the stringent intervention measures leads to an increase of the (age-specific) number of contacts made by individuals at different locations. In the baseline scenario (under lockdown), individuals reduced their work and transportation contacts by 80%, children were not attending school (0% of pre-pandemic contacts) and only 10% of normal leisure contacts or contacts at other locations were retained. From May 4 onwards, we presume that work-related contacts will increase to 30% of the pre-pandemic number of contacts at work (or transmissibility is reduced to an extent equivalent with the assumed reduction in work-related contacts), and that the number of transport contacts and contacts during leisure and other activities will increase respectively to 30% and 20% of their pre-pandemic values. These reductions in social contacts are in line with the observed number of hospitalizations from May 4, 2020 onwards (black solid dots). We presume a gradual compliance to these measures with full compliance after one week. Furthermore, the number of school-related contacts is assumed to be 20% of these contacts prior to the epidemic between May 11 and July 1, 2020. The start of the summer holiday, at July 1, 2020, implies a complete reduction of all school-related contacts to 0%. In addition, from July 1, 2020 onwards, we assume that work-related and transport contacts increase to 40% (S1 - blue lines), 50% (S2 - purple lines) or 60% (S3 - orange lines) with leisure contacts equal to 30% (S1 - blue lines), 40% (S2 - purple lines) or 50% (S3 - orange lines) of pre-pandemic values. Finally, we assume in all scenarios that contact behaviour at schools following re-opening at September 1, 2020 is equivalent to 60% of the pre-pandemic social contacts made at school. Due to the re-opening of schools, leisure contacts are presumed to be reduced in all three scenarios (explaining the bending points in the curves). Note that the baseline scenario (in red) represents a continuation of lockdown measures throughout the entire year.

From Figure 3 it is clear that scenario S1 assumes a very long period comprising a stable number of new hospitalizations which is not in line with the current evolution of the daily number of new hospitalizations. On the other hand, scenarios S2 and S3 are the most plausible ones in view of the current epidemiological situation with S3 having a more pronounced increase in the number of new hospitalizations (and a faster depletion of the number of susceptible individuals in the population).

In order to show the complete extent of the number of hospitalisations in the second COVID-19 wave, we present the cumulative number of hospitalisations for the three scenarios mentioned previously and accommodating a partial re-opening of schools after September 1, 2020 (see Figure 4). In this figure, we depict the cumulative number of hospitalisations over time starting from May 4, 2020. The cumulative number of hospitalisations by the end of the year are very different across the different scenarios due to the difference in rate of increase of the number of daily hospitalizations.

Assuming a Weibull distribution for the time spent in the hospital (scale = 10.46, shape = 1.34), implying an average duration of hospitalisation of about 9.6 days, the hospital load is graphically depicted in Figure 5. Furthermore, the ICU load is displayed therein as well relying on 25% of the hospitalisations becoming Intensive Care Unit (ICU) admissions. Limits on the number of available ICU beds for COVID-19 patients are indicated with red dashed lines. In general, scenarios S1 and S2 do not exceed the upper limit on COVID-19 beds (i.e., 2000 ICU beds), whereas scenario S3 does.

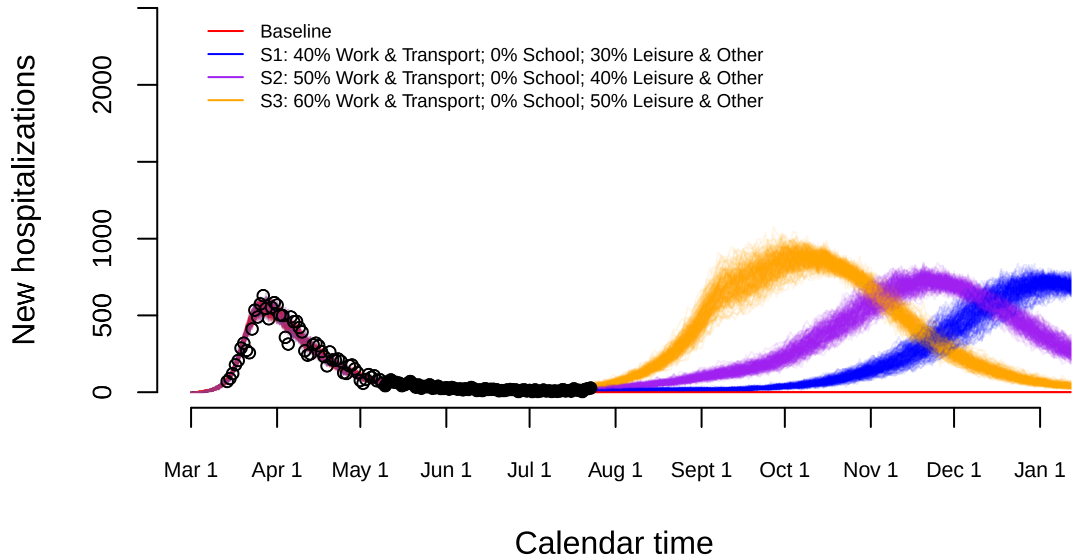

Figure 3: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools as of September 1, 2020.

Re-adjusting contacts from July 28, 2020 onwards

In this section, we explore re-adjustment of leisure contacts from July 28, 2020 onwards starting from the most extreme scenario (S3) as defined hereabove. More specifically, in scenarios S4-S6 work-related contacts and leisure contacts are reduced in order to flatten the (second) epidemic curve and to prevent the healthcare system from collapsing. In Figure 6, scenarios S4-S6 are graphically depicted. Work-related contacts are assumed to decrease from 60% to 30% (S1 - blue lines), 40% (S2 - purple lines) or 50% (S3 - brown lines). In addition, leisure contacts are decreased from 50% to 20% (S1 - blue lines), 30% (S2 - purple lines) or 40% (S3 - brown lines). Scenario S3 is presented for comparison. A reduction in the aforementioned contacts has a clear impact on the epidemic curves and the number of daily hospitalizations. In Figures 7 and 8, we present the cumulative number of hospitalisations and the hospital load for the scenarios S4-S6. Varying the leisure (and work-related) contacts implies that the second waves are smaller in size, keeping the number of school contacts prior to the summer vacation and after September 1 constant across the three scenarios. Leisure contacts play an important role in the sense that an increase in those contacts to a similar level across all scenarios after September 1, 2020 increases the number of hospitalisations drastically (not shown here).

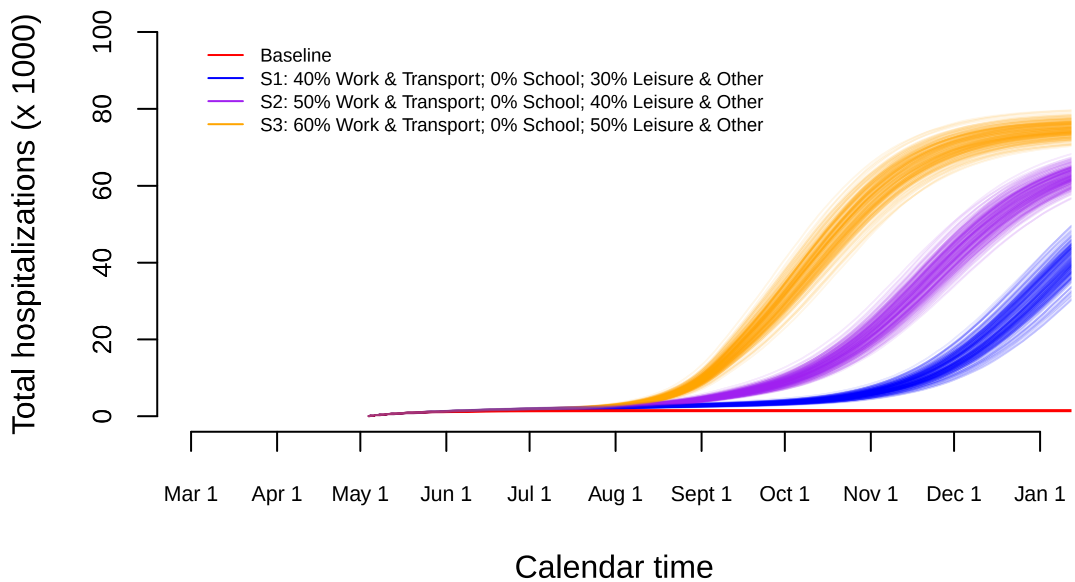

Figure 4: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020.

It is important to stress that the increase in daily number of hospitalizations in scenario S4 (blue lines) is the result of an increase in school-related contacts after partial re-opening of schools from September 1, 2020 onwards. This is the result of an insufficient depletion of susceptibles in the second wave. It should be mentioned that such an increase (third wave) will only occur if other measures such as contact tracing and self-isolation upon having symptoms are ineffective in a later stage of the epidemic. Needless to say, in this scenario (S2) we clearly buy time and prevent the current epidemiological situation and the second wave of the epidemic to become out of control at this moment in time.

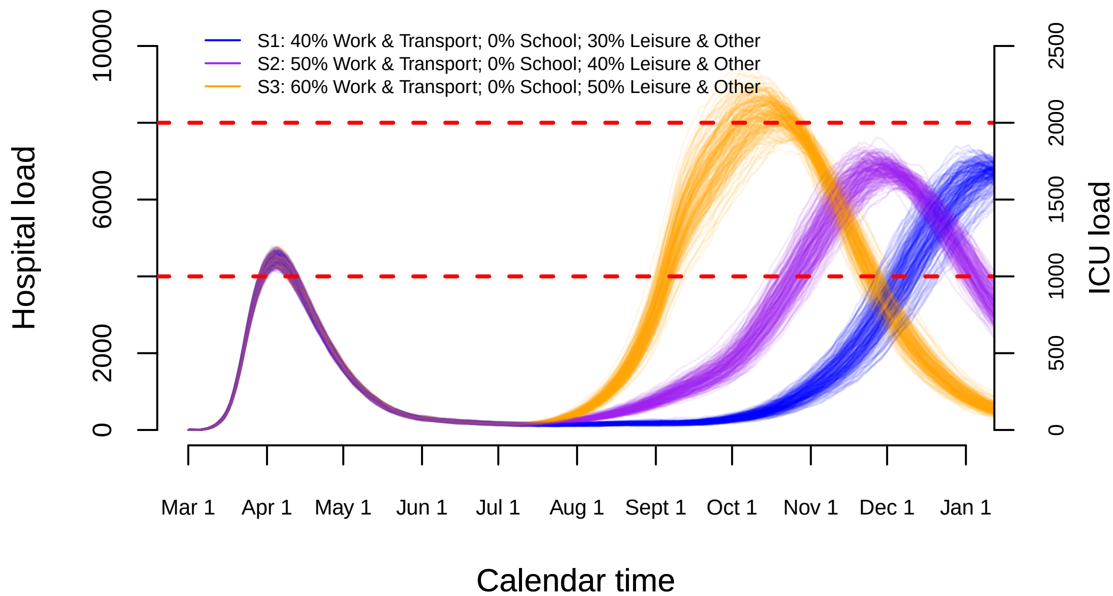

Figure 5: The time-dependent number of hospitalisations and ICU admissions in the three scenarios under the assumption of a Weibull distribution for the length of stay in the hospital (scale = 10.46, shape = 1.34). Red dashed lines indicate limits on the number of available ICU beds for COVID-19 patients (1000: normal COVID ICU capacity, and 2000 ICU beds: increased COVID ICU capacity).

Conclusions

We generated predictions for scenarios S1 to S6 to provide an insight into the evolution of the resurgence of COVID-19 in Belgium and the number of daily hospitalizations to be expected in this second wave. From the presented scenarios, scenario S1 is unrealistic. Scenarios S2 and S3 show a high number of new hospitalizations in the second COVID-19 wave in Belgium, with scenario S3 implying an ICU load that exceeds current hospital capacity in Belgium. In order to avoid that the healthcare system is not able to cope with the number of COVID-19 related hospitalizations, scenarios S4-S6 quantify the impact of lowering the number of contacts made during leisure and other activities and at work (and transport). The scenario analyses presented in this document are performed under the limitations and assumptions highlighted above, and are used to inform policy thereabout.

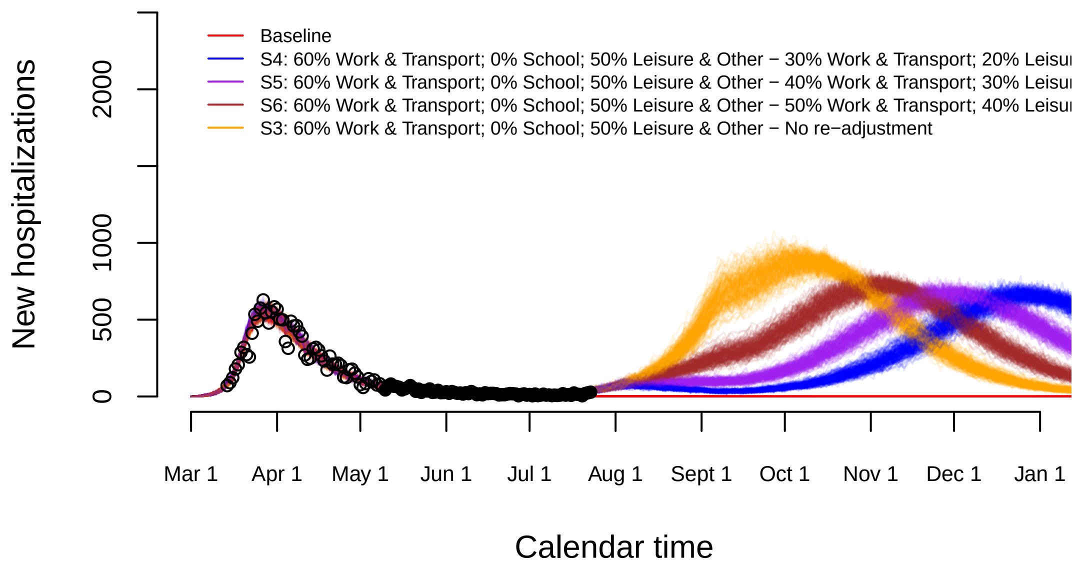

Figure 6: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools as of September 1, 2020.

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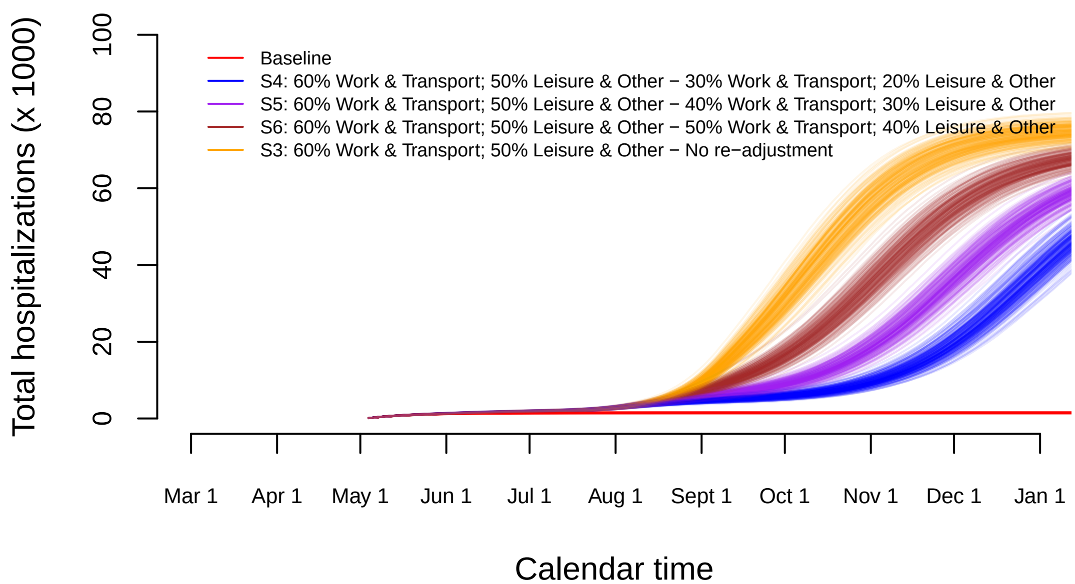

Figure 7: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020; partial re-opening of schools as of September 1, 2020 and with varying number of contacts during work, transportation and leisure and other activities from July 28, 2020 onwards.

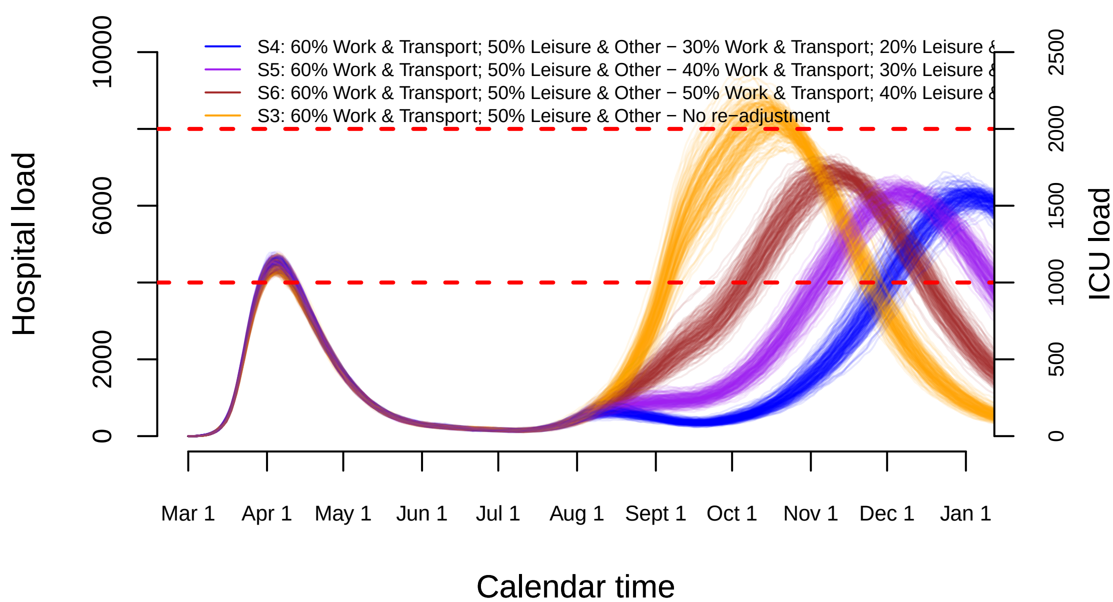

Figure 8: The time-dependent number of hospitalisations in the three scenarios under the assumption of a Weibull distribution for the time spent in the hospital (scale = 10.46, shape = 1.34); partial re-opening of schools as of September 1, 2020 and with varying number of contacts during leisure and other activities. Red dashed lines indicate limits on the number of available ICU beds for COVID-19 patients (1000: normal COVID ICU capacity, and 2000 ICU beds: increased COVID ICU capacity).