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

Report version 2.1

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Disclaimer

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 (Wouters 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. 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

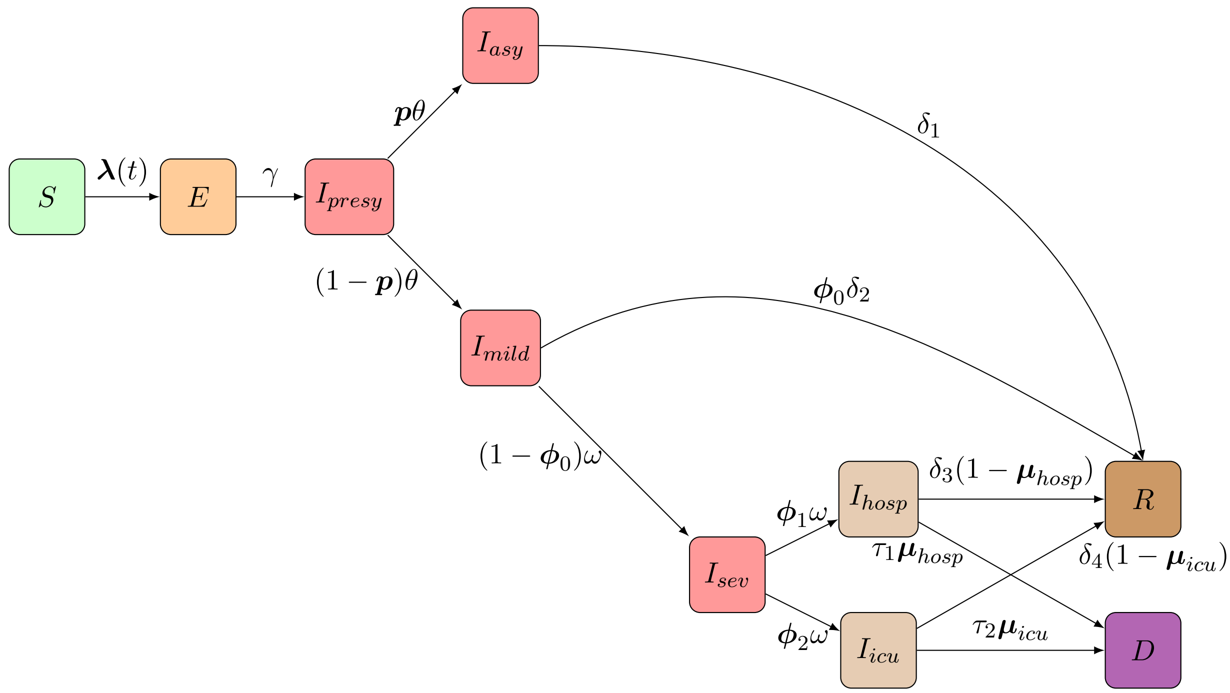

Figure 1: Schematic overview of the flows of individuals in the compartmental model.

Long-term predictions under different scenarios

Impact of partial re-opening of schools on September 1, 2020

In Figure 2, we present stochastic realisations of the model to predict the number of new hospitalisations 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. From May 4 onwards, we presume that work-related contacts will increase to 40% 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 40% and 30% of their pre-pandemic values. 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% (S1 - blue lines), 40% (S2 - purple lines) or 60% (S3 - orange lines) 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 reduction of all school-related contacts to 0%. Furthermore, we assume 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. Note that the baseline scenario (in red) represents a continuation of lockdown measures throughout the year. Clearly, no large second waves are present in all of these scenarios whereas a third wave occurs later on of which the extent depends on the depletion of the number of susceptibles prior to September 1, 2020.

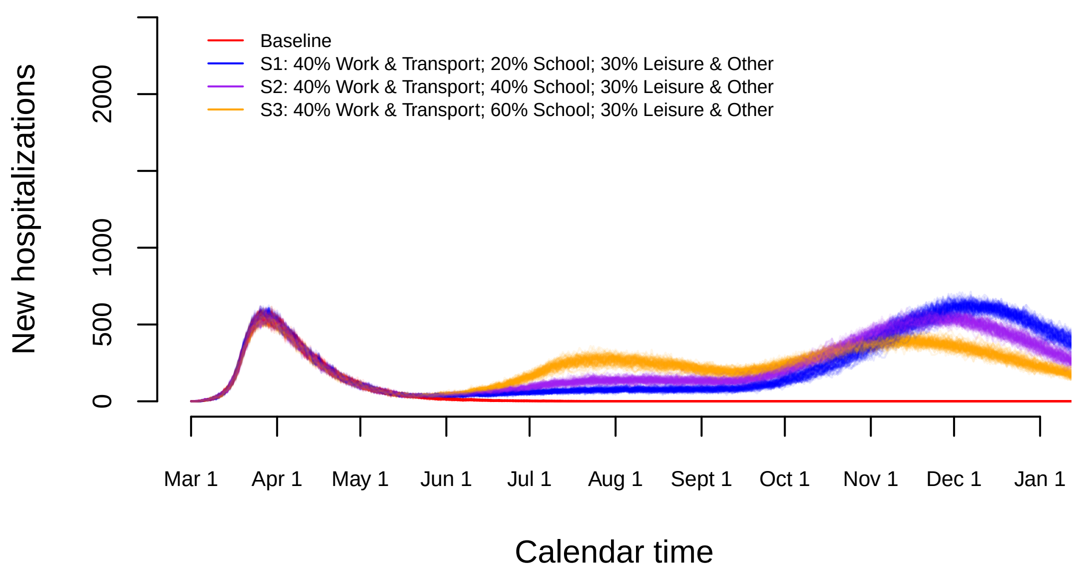

Figure 2: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools as of September 1, 2020.

In order to show the complete extent of the number of hospitalisations in future COVID-19 waves, we present the cumulative number of hospitalisations for the three scenarios mentioned previously and accommodating a partial re-opening of schools (see Figure 3). 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 is quite comparable across the different scenarios, albeit that the trajectories over time are very much different.

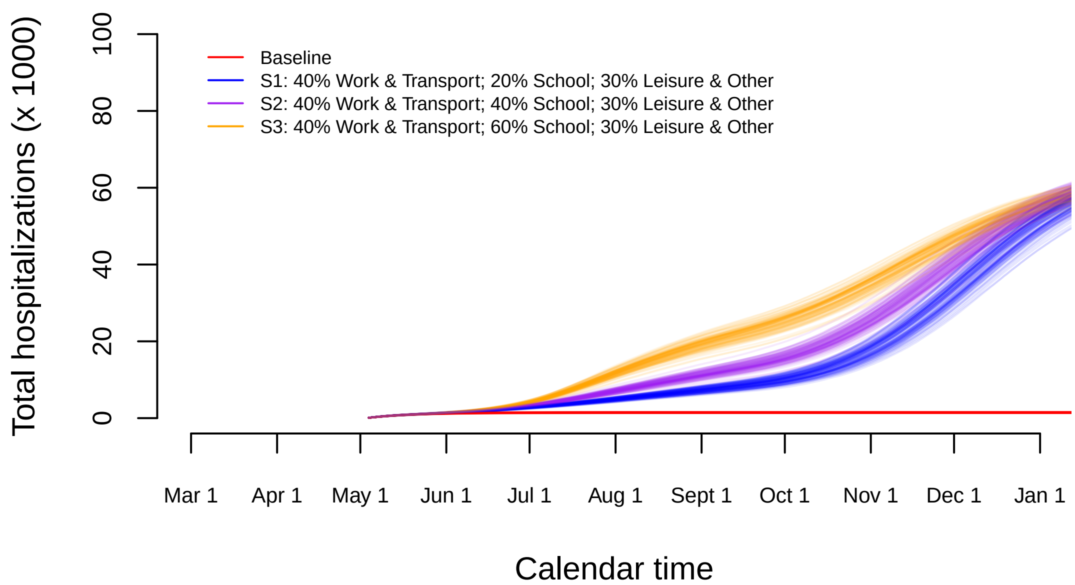

Figure 3: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020.

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 4. 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, all three scenarios do not exceed the upper limit on COVID-19 beds (i.e., 2000 ICU beds).

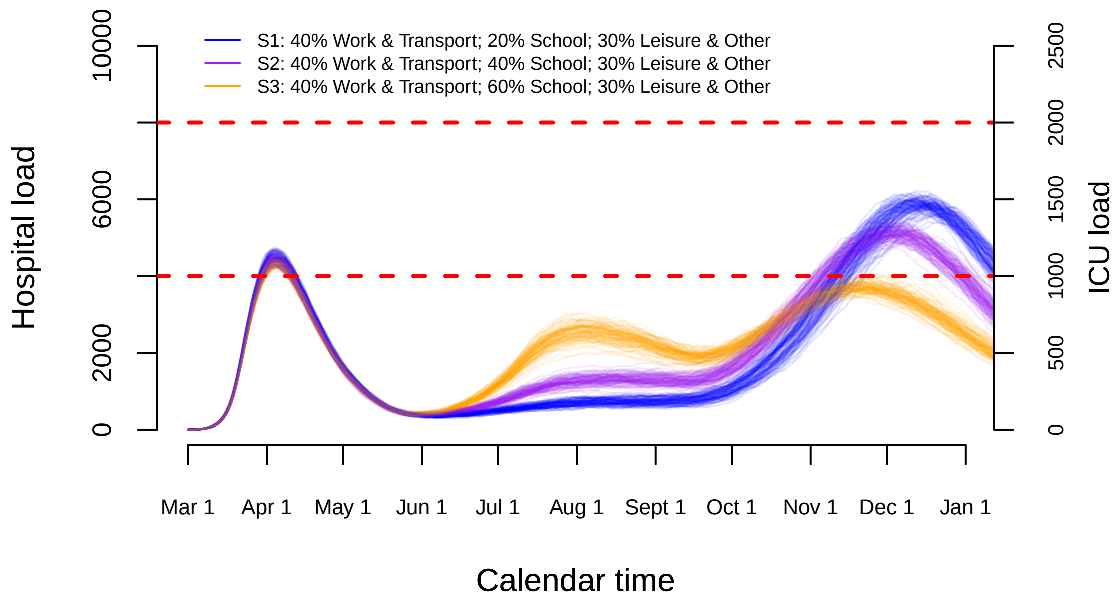

Figure 4: The time-dependent number of hospitalisations and ICU admissions in the three scenarios under the assumption of a Weibull distribution for the length of stay in the hospital (scale = 10.46, shape = 1.34). Red dashed lines indicate limits on the number of available ICU beds for COVID-19 patients (1000: normal COVID ICU capacity, and 2000 ICU beds: increased COVID ICU capacity).

Impact of contacts during leisure and other activities

In Figure 5, we show the stochastic realisations for three scenarios (S4-S6) in which we assume a partial re-opening of the schools as of September 1, 2020, 40% of school contacts between May 11 and July 1, 2020, and a gradual increase towards 40% of work and transportation contacts after May 4, 2020 (with full compliance after one week). Contacts during leisure and other activities are varied between 20% (S4 - blue lines), 30% (S5 - purple lines) or 40% (S6 - orange lines) and are thereafter kept constant during the entire year/period starting from May 11, 2020. *Note that scenario 2 and scenario 5 are equivalent.* In Figures 6 and 7, we present the cumulative number of hospitalisations and the hospital load for the scenarios S4-S6. Varying the leisure contacts implies that the third 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).

Impact of full re-opening of schools on September 1, 2020

In Figure 8, we present stochastic realisations of the model to predict the number of new hospitalisations under different scenarios upon relaxing the lockdown measures taken in the Belgian population as of May 4, 2020. 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. From May 4 onwards, we presume that work-related contacts will increase to 40% of the pre-pandemic number of contacts at work (or transmissibility is reduced to an extent

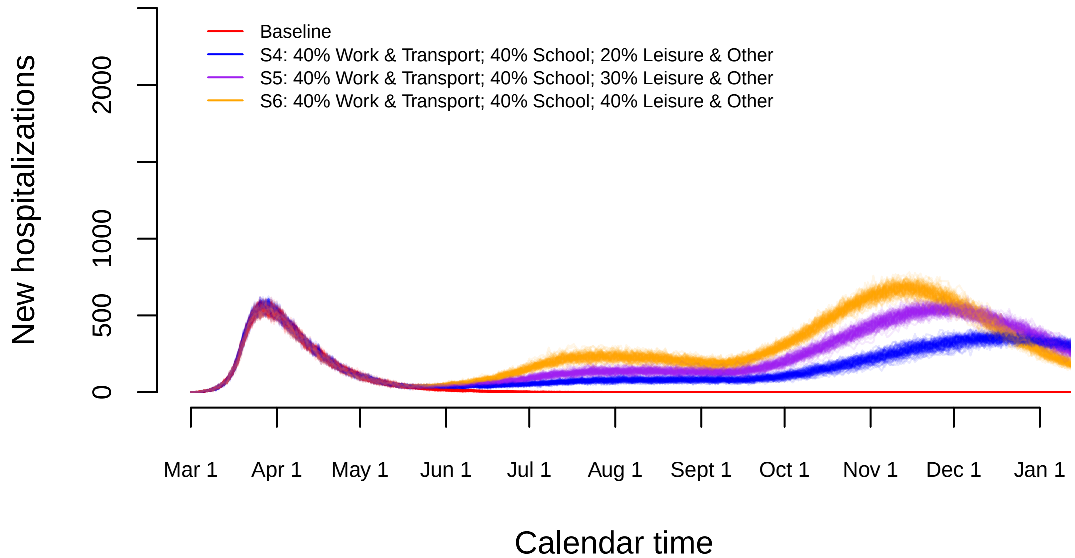

Figure 5: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools as of September 1, 2020 and with varying number of contacts during leisure and other activities.

equivalent with the assumed reduction in work-related contacts), and that the number of transport contacts and contacts during leisure and other activities respectively increase to to 40% and 30% of their pre-pandemic values (with full compliance after one week). Furthermore, the number of school-related contacts is assumed to be 20% (S7 - blue lines), 40% (S8 - purple lines) or 60% (S9 - orange lines) 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 reduction of all school-related contacts to 0%. A full re-opening of schools (in the sense that contact behaviour at schools resembles behaviour before the epidemic started) at September 1, 2020 leads to an important increase in the number of new COVID-19 hospitalisations, especially in those scenarios (blue and purple) in which the number of hospitalisations remained relatively low in the period between May 11, 2020 and September 1, 2020 (i.e., at 20% and 40% of school-related contacts in this period). This can be explained by the slow increase in population immunity, thereby leading to a substantial fraction of individuals still susceptible to infection at the start of the new school year. As it is very unlikely that schools will re-open fully, or at least with the number (and nature of) contacts similar to the ones before the lockdown measures were taken, the scenarios depicted in Figure 2 are considered to be more realistic as compared to the ones in Figure 8.

In Figures 9 and 10, we present the cumulative number of hospitalisations and the hospital load for the scenarios S7-S9. A full re-opening of schools after a relative low second peak in new hospitalisations implies hospitalisations in a third wave to exceed the critical threshold (S7).

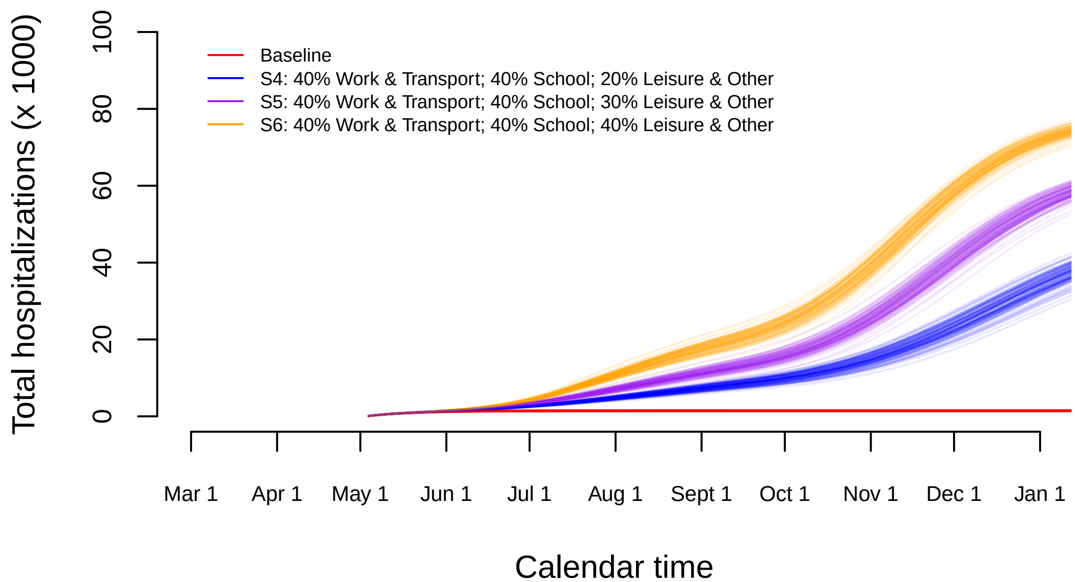

Figure 6: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020; partial re-opening of schools as of September 1, 2020 and with varying number of contacts during leisure and other activities.

Impact of a partial re-opening of schools in a phased way

In this final section, we provide results from a partial re-opening of schools in different phases: (1) 20% of school contacts as of May 18, (2) 40% (S10 and S12) or 60% (S11)of school contacts as of June 2, and (3) 60% (S10 and S11) or 100% (S12) of schoold contacts as of September 1, 2020.

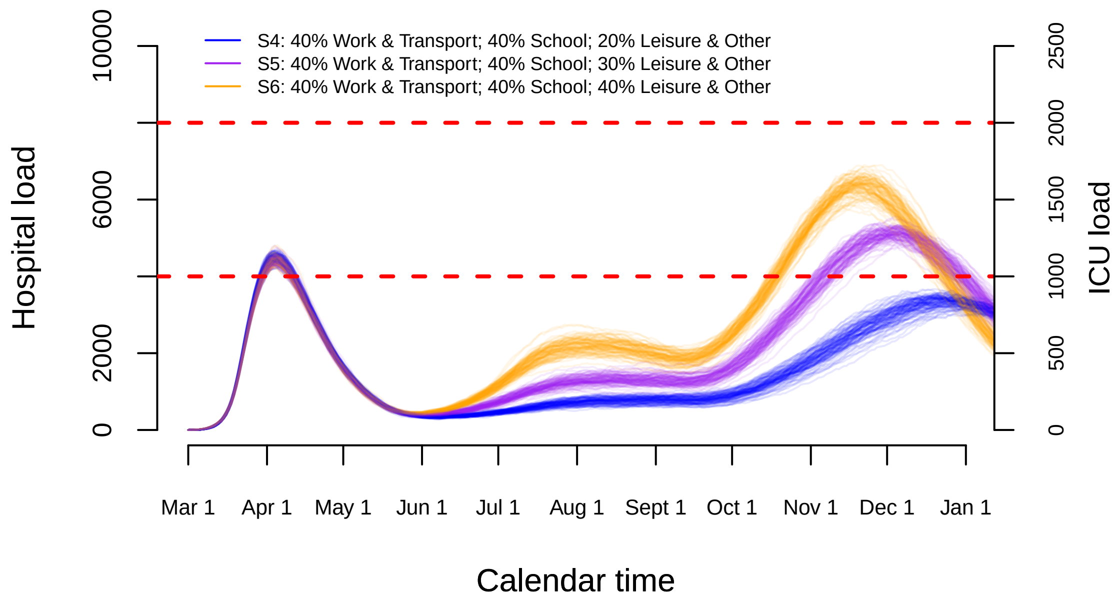

Figure 7: The time-dependent number of hospitalisations in the three scenarios under the assumption of a Weibull distribution for the time spent in the hospital (scale = 10.46, shape = 1.34); partial re-opening of schools as of September 1, 2020 and with varying number of contacts during leisure and 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).

Conclusions

Scenarios S7-S9 and S12 related to a full re-opening of schools after September 1 are not plausible since appropriate intervention measures will be put into place as soon as the third wave of COVID-19 infections takes off and the healthcare system is under great pressure (i.e., especially in S7 and S8). The same would happen if the number of leisure contacts will be increased further near the end of the year (not shown). Consequently, we generated predictions for scenarios S1 to S6 (with S2 and S5 equivalent) and S10 and S11 to provide an insight into subsequent COVID-19 waves, under the limitations and assumptions highlighted above, and to inform policy thereabout.

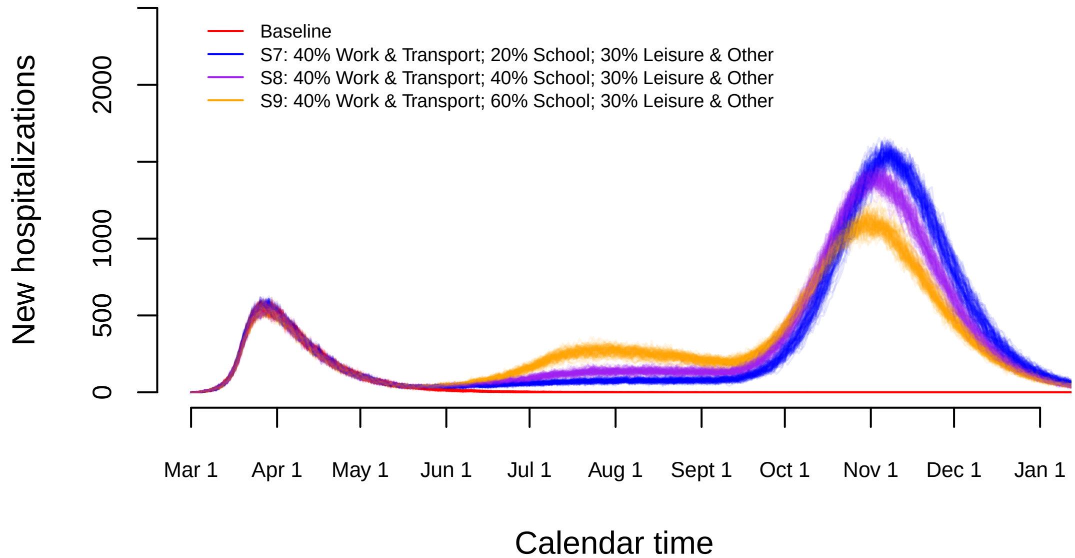

Figure 8: Long-term prediction of the number of new hospitalisations with a full re-opening of schools as of September 1, 2020.

Acknowledgements

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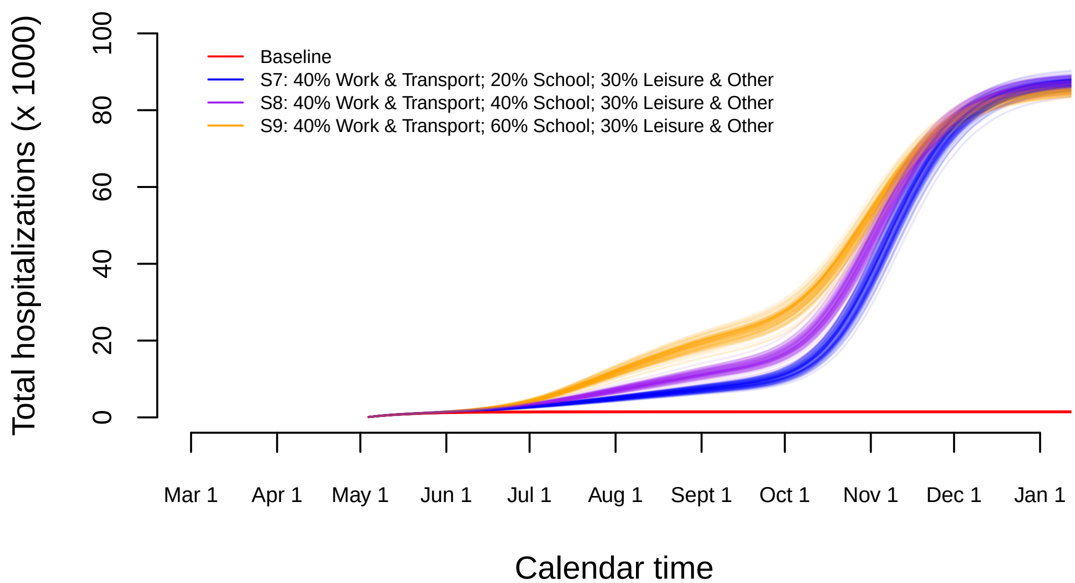

Figure 9: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020; full re-opening of schools as of September 1, 2020.

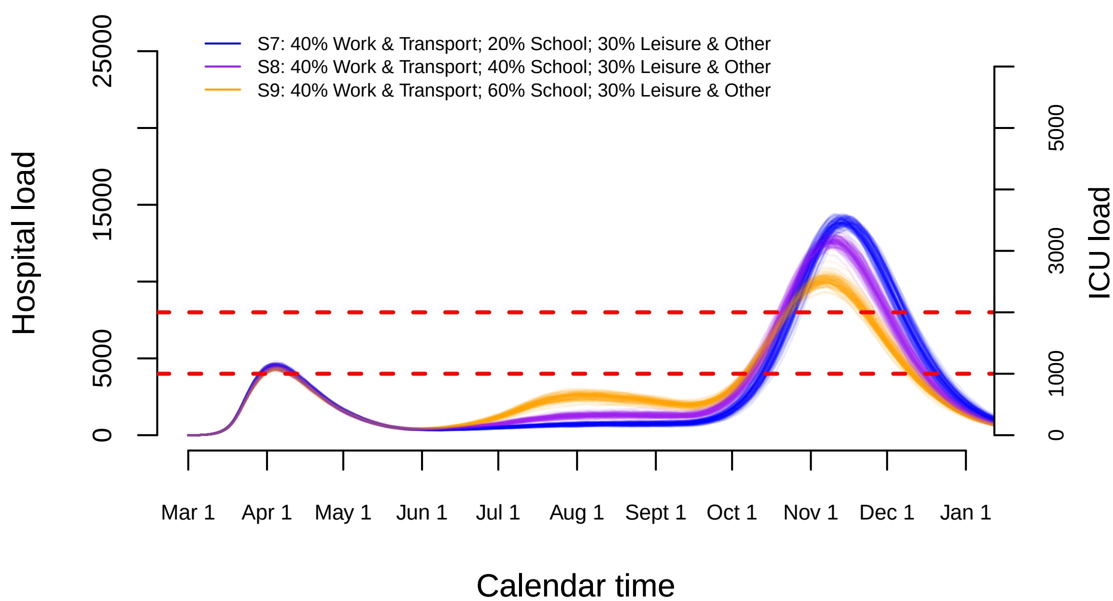

Figure 10: The time-dependent number of hospitalisations in the three scenarios under the assumption of a Weibull distribution for the time spent in the hospital (scale = 10.46, shape = 1.34); full re-opening of schools as of September 1, 2020. Red dashed lines indicate limits on the number of available ICU beds for COVID-19 patients (1000: normal COVID ICU capacity, and 2000 ICU beds: increased COVID ICU capacity).

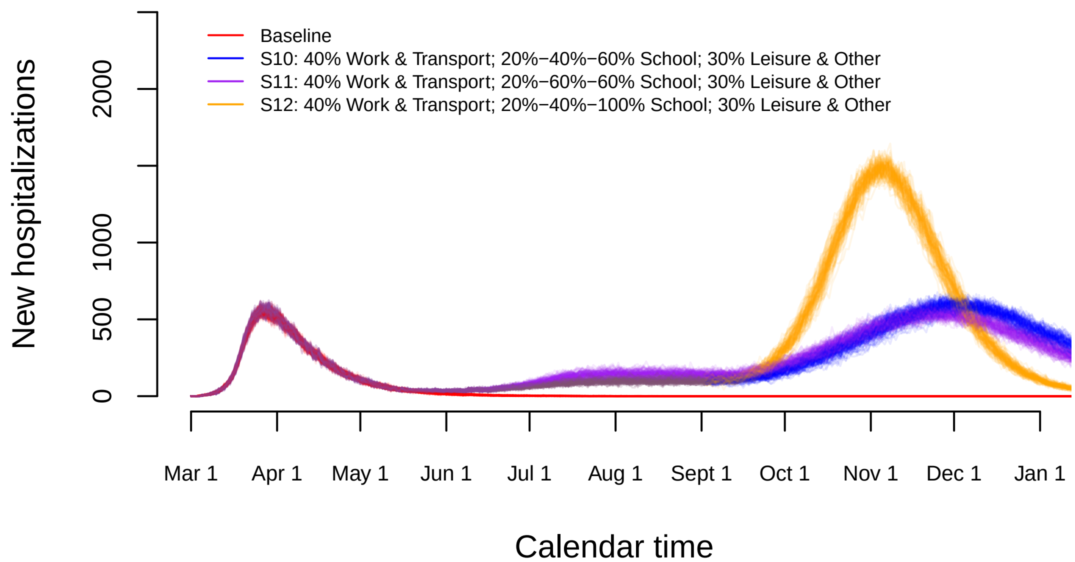

Figure 11: Long-term prediction of the number of new hospitalisations with a partial re-opening of schools in different phases.

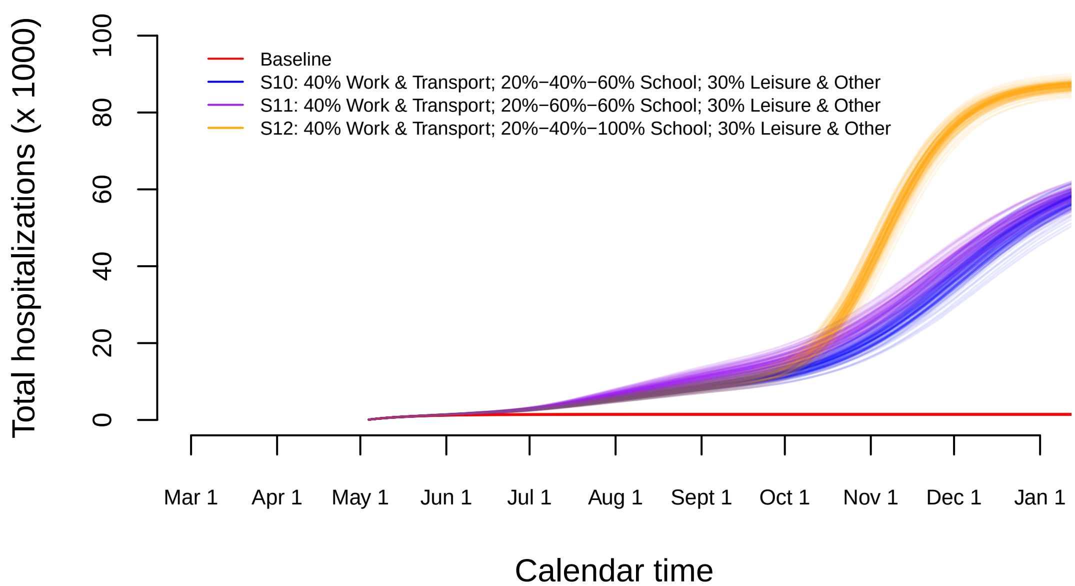

Figure 12: The cumulative number of hospitalisations in the different scenarios starting from May 4, 2020.

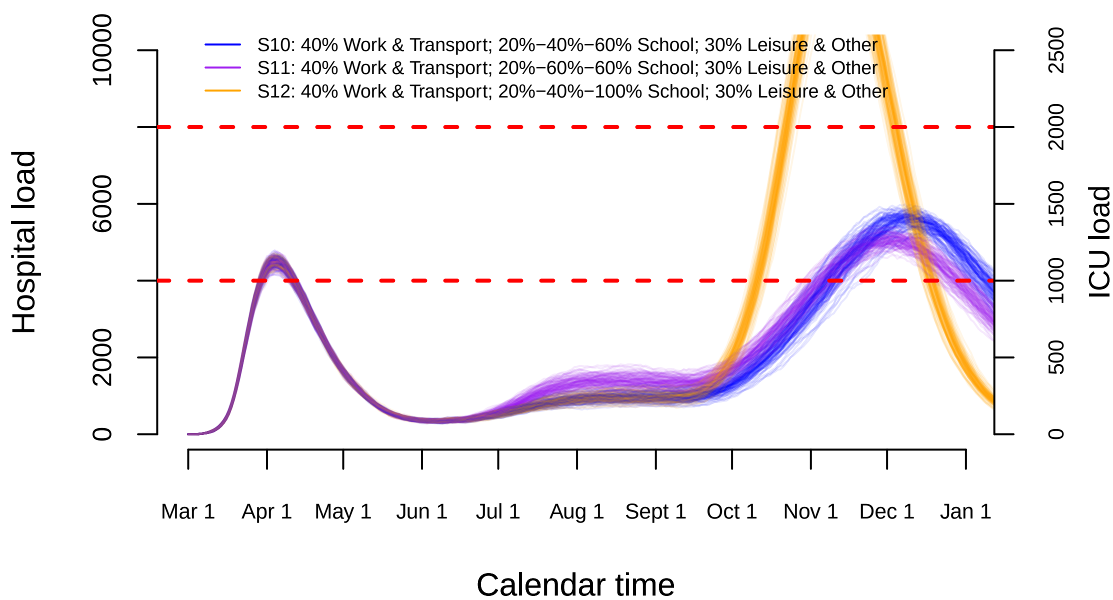

Figure 13: The time-dependent number of hospitalisations and ICU admissions in the three scenarios under the assumption of a Weibull distribution for the length of stay in the hospital (scale = 10.46, shape = 1.34). Red dashed lines indicate limits on the number of available ICU beds for COVID-19 patients (1000: normal COVID ICU capacity, and 2000 ICU beds: increased COVID ICU capacity).