Are We All Back on Campus?

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Different measures were enacted by the government of the Netherlands to combat the spread of the coronavirus over the course of two years. During this time there was a varying amount of online and on-campus education offered at the University of Twente. The measures affected people studying and working on campus, but no research has been done into these changes. This paper explores the relationship between the different measures enacted and campus occupancy at the University of Twente. This is done by using connection data collected from access points on the campus. Differences in campus usage between students and employees are explored as well as between housing and other facilities. We show that campus occupancy has not returned to pre-pandemic levels and that students were affected more than employees.

Additional Key Words and Phrases: Campus occupancy, COVID-19, coronavirus, pandemic, measures, restrictions

1 INTRODUCTION

During the coronavirus pandemic, different measures were enacted by the government of the Netherlands to reduce the spread of the virus. Over the course of approximately two years, many different measures were introduced, changed and lifted. The measures ranged from a full lockdown and closure of the University of Twente facilities to reduced maximum group sizes. For two years education was offered as a mix of online and offline with the proportion changing constantly as the measures changed. This affected the number of students studying on campus, employees at the university and people living on the campus. However, it is not known how the different measures contributed to these changes. There might be lockdowns in the 2022/23 academic year [8] in which case it would be good to know how they would affect the campus beforehand.
With the measures lifted for now, the university is returning to primarily on-campus education. But this change has not been instantaneous and some students and employees may still be reluctant to return to campus. Some reasons for this could be that they simply prefer studying or working remotely or because they do not feel safe coming to campus yet. Teachers have noticed that students are coming to campus less often or not at all [4] and this might impact their education [3]. It would therefore be good to know whether campus occupancy has reached the levels before the pandemic - if we are all back on campus. It may even be the case that campus occupancy already has or will soon pass the levels before the pandemic due to the number of students having increased in the first year of the pandemic [7].
This paper aims to answer the questions raised above by analyzing data from access points at the University of Twente campus. Data has been collected on the number of connected devices to these access points. This will be analyzed together with a timeline of measures to see how campus occupancy changed in reaction to specific measures. Further filtering will be applied to observe differences between students and employees and between housing and other facilities. In the end we will answer the question in the title: "Are we all back on campus?"
The paper is structured as follows: in Section 2 we introduce the research questions. An overview of research related to the effects of the pandemic is given in Section 3. The dataset used for this research is described in Section 4 and its limitations are also given. The various methodologies used in this research are explained in Section 5 and the results are described in Section 6. The quality of the results is discussed in Section 7 and ideas for future work are presented. Section 8 contains the conclusions.

2 PROBLEM STATEMENT

Although the pandemic and resulting countermeasures affected campus occupancy, it is not known how different measures contributed to this. Furthermore, even though the measures have been lifted it remains to be seen if occupancy has reached pre-COVID-19 levels.

2.1 Research questions

The question to be answered by this research is "How did coronavirus measures affect occupancy of the University of Twente campus?". This question is broken down into the following research questions.

(1) What measures were introduced over time that could have affected campus occupancy?
(2) How did campus occupancy change in relation to the measures?
(3) What differences can be seen between students and employees in the previous question?
(4) What differences can be seen between office/educational spaces and housing?
(5) How fast (if at all) did campus occupancy reach pre-COVID-19 levels after the lifting of measures?

3 RELATED WORK

Due to the measures only being lifted recently, there is very little research so far that covers the entire pandemic from start to finish. Furthermore this research project focuses on the campus of the University of Twente in relation to measures introduced by the Dutch government, which means research from other universities and especially from abroad would only be useful for a comparison. Research has been done at UC San Diego into internet usage changes by undergraduate students and it was found that internet traffic increased during lock-down as studies moved online [5]. The paper is, however, focused on student housing and only covers the time period of the first lockdown in the US.
Research into network traffic changes at the start of the pandemic was also done at the Politecnico di Torino in Italy [1]. They found

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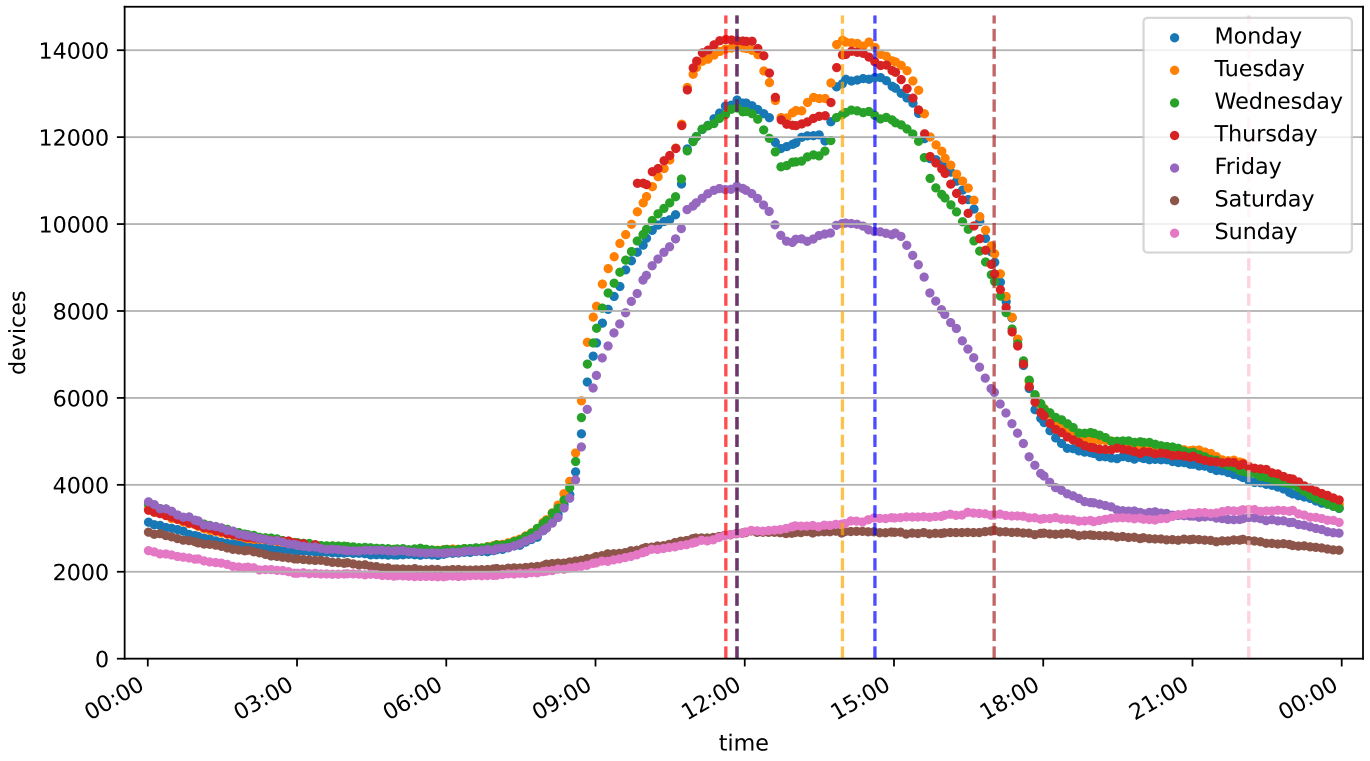

Fig. 1. Number of devices on the University of Twente campus during the week 16.09.2019-22.09.2019.

that incoming traffic increased due to online-only learning. But since the paper only covers the period of the first lockdown, it is not concerned with mixed online and on-campus education.

A higher-than-usual increase in global Internet traffic was also observed [2] as a result of the first wave of COVID-19 in 2020. An even higher increase in traffic was found for applications related to remote working and teleconferencing.

CampusCrowdMap [6] is a tool developed at the University of Twente which provides a real-time overview of campus occupancy. It shows an estimated number of people in each building and a crowdedness indicator per floor. It uses the same dataset that will be used for this research, but since the goal of this tool is to provide a real-time indicator of occupancy, it itself is not useful for historical analysis.

4 DESCRIPTION OF DATA

The Library, ICT Services & Archive (LISA) department at the University of Twente is responsible for the Wi-Fi infrastructure on the university campus. They maintain a historical database of connections based on raw data collected from Wi-Fi controllers. An entry is added to the dataset for each connected device at each polling cycle. The entry contains, most importantly, a unique identifier for the device, an identifier of the access point, and the time of collection. The data starts from 2019.07.12 and is collected 5 times per hour, still ongoing. The exact times of collection vary slightly but are at around 1, 14, 27, 40 and 53 minutes. In each collection, the connected clients for each access point are recorded, but they are given random identifiers in each cycle to prevent tracking individual users. The database also contains location information about the access points, including coordinates and floor numbers. There are also tables with building and room shapes.

The dataset is stored as a PostgreSQL database and for storing and querying location data PostGIS is used, which is a PostgreSQL extension that adds support for geographic objects. The dataset is quite large - there are over a million entries per day on busy days and it covers close to three years at the time of writing.

Figure 1 shows the distribution of devices over a day for a week in September 2019. Each dot represents a time of data collection and there are y entries in the database for each dot. The vertical lines show when the maximum number of devices was reached each day (The maximums of Wednesday and Friday are at the same time of day). We can see patterns in campus occupancy, such as a dip around lunchtime on weekdays and much lower occupancy on weekends. The weekly maximum is likely to fall between 11 and 15 on one of the workdays and in the reference period it is between 10 and 14 thousand devices. The weekly minimum is around 6 in the morning on weekends.

4.1 Limitations

Since users get random identifiers each cycle it is not possible to identify the same user during the entire day. This means that it is not possible to count how many unique users were on campus

during the day, it is only possible to get the counts of devices at the times when data is collected from the access points.
Another limitation is that not all users get assigned identifiers - devices connected to open access points can not be traced to a user and users can also choose to remain anonymous.
Due to the above limitations, it was decided to only count devices and not try to approximate the number of users since it will always lead to incorrect results due to unidentified users. This does not significantly impact the results and conclusions of this research since it is just as good to observe changes in the number of devices as in the number of people - the amount of devices carried by people is unlikely to have changed much during the pandemic.
Another limitation is that the dataset does not include data over an entire year before the pandemic started. This means that there is no full reference year to compare to - the first semester of the 2019/20 academic year is the only available reference period. This limitation means that device counts in the second semesters during the pandemic have to be compared to reference numbers from the first semester. It might, however, be that each year there are more people on campus in the first semester (for example, new students that drop out over the course of the year) and then it would not be a fair comparison.
There are some irreparable gaps in the dataset which were caused by network outages and other technical issues. However, these gaps are few and far between and the only consequence are the occasional sudden drops to 0 connected devices in the weekly minimums in the following graphs.

5 METHODOLOGY

5.1 Timeline of measures

It was necessary to construct a timeline of measures introduced in the Netherlands to combat the spread of COVID-19 and pick out the measures that were likely to impact campus occupancy. The primary source for this timeline was email correspondence from the university sent to students and staff outlining changes in measures. The emails described measures that were more relevant for the university and thus less filtering was required. Along with measures, the dates of important pandemic events were also recorded to provide context. For each measure or event, a short description and start time were recorded. If there was a clear end date for a measure, this was also recorded.
The pandemic-related events were taken from a timeline constructed by *The New York Times* and articles from *DutchNews*. The website of *The Government of the Netherlands* was also used to verify the correctness of the emails and to clear doubts but it was rather limited since it is primarily intended to give an overview of current measures and not for a historic view. The full list of selected measures can be found in Appendix A.

5.2 Effect of measures on occupancy

A graph was constructed showing how the number of devices on campus changed over time, starting from the start of the dataset to provide the longest possible reference period. The graph was then connected to the one created in the first question to see what effect the measures had.

For constructing this graph the access point dataset was used. Since it records all connected clients in each cycle, it can be used to count the connected devices and see how this count changes over time. For the effects of measures, it is most interesting to know the maximum number of people on campus because a maximum over the expected would mean that measures are not followed and a maximum below the expected would mean that measures are more restrictive than expected. The maximum can be plotted for each day or the maximum of a week can be calculated to get a smoother result. The smoother weekly approach was chosen for this paper, but other potential approaches are outlined in Section 7. The weekly minimum was also plotted. Together with the maximum it provides a range of occupancy values during the week.
The resulting graph was also used to compare pre-pandemic levels to post-pandemic levels and since it showed that occupancy is lower than before the pandemic, another graph was constructed showing occupancy relative to the pre-pandemic levels.

5.3 Categorizing access points

Using the positions of rooms and the *list of lecture halls* and the list of project rooms from the *Resource Booker* it was possible to mark the areas on campus that are primarily used by students. Access points inside this area were labelled as student access points with the rest being labelled as employee. Some manual labelling was also done to include other places that are used more by students, for example, Educafe. Next, housing access points were identified for the next research question. These were excluded from this comparison altogether because they are neither student nor employee.
To see differences in the effects of measures the query counting all devices was adapted to count devices connected to student access points as students and others as employees over the same time frame.
The method for separating housing access points was similar to categorizing access points into student and employee. The difference being that access points were classified using manually drawn polygons that cover educational and office buildings and labelling everything else as housing.

6 RESULTS

6.1 Effect of measures on overall campus occupancy

6.1.1 Description of graphs. The results of combining the measure and device timelines can be seen in Figure 2. The graph shows the change in connected devices on campus over time. It covers the range from 2019.07.12 to 2022.06.10. On the x-axis are the dates and on the y-axis the number of devices. The values plotted are the maximum (blue) and minimum (orange) devices in a week. Relevant measures and events have also been plotted with red text. Measures that had a start and end time have been shaded blue to show the period when they were active and these measures are written in blue. Periods when wearing a mask was mandatory on campus have been shaded green. Figure 3 shows the same period and weekly maximums but with the values relative to the reference period. The complete list of measures and events can be found in A.

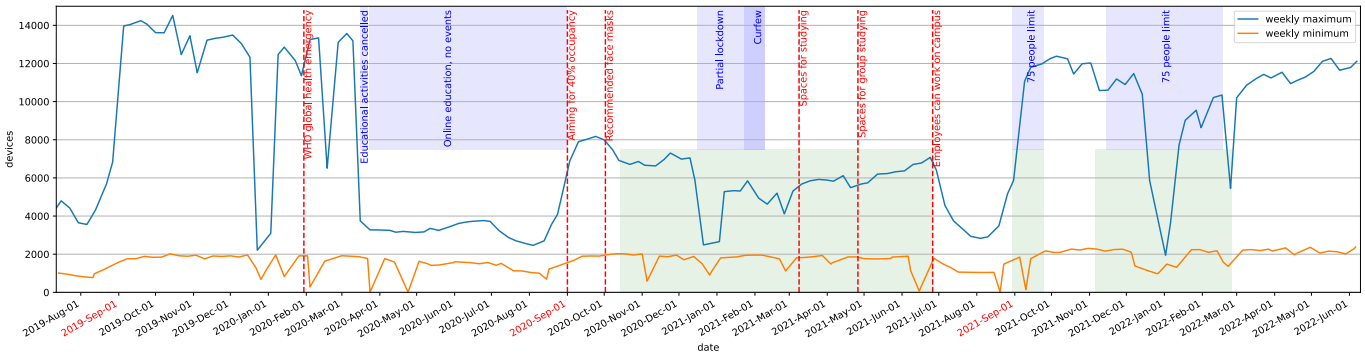

Fig. 2. Number of devices on the University of Twente campus before, during, and after the pandemic.

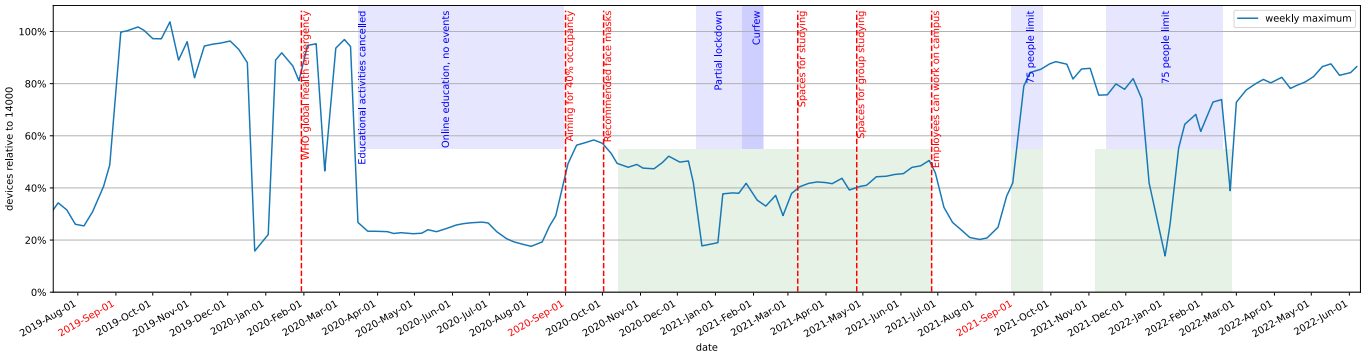

Fig. 3. Number of devices on the University of Twente campus before, during, and after the pandemic, relative to 14000 devices in the reference year.

6.1.2 Reference period. Due to the limited reference period, the first semester of the 2019/20 academic year will be used as a reference for a normal pre-pandemic year. During a normal year campus occupancy reaches 13 to 14 thousand devices and there are around 2000 connected devices at the lowest points during nighttime. There is a significant fall in occupancy during the winter break in the 2019/20 academic year and this can be used as a reference for the winter breaks in the next years. The amount of devices is between 2 and 3 thousand during a winter break in a normal year. Similarly occupancy falls to around 4000 devices during the summer or about 30% of the study period.

6.1.3 Online education - the 2019/20 academic year. The first and most obvious effect of a measure is the sharp fall in campus occupancy during the period of online-only education. The number of devices on campus fell by around 10000 devices - from over 13000 to over 3000 (almost 80%) which is about the same as the winter break in the reference period. While a fall was to be expected, some people were still visiting the campus. The device count falls to around 2000 during the nights meaning that around 1000 devices were still taken to campus on the busiest days even during online-only education.

6.1.4 Nuanced measures in the 2020/21 academic year. For the next (2020/21) academic year the university was aiming for 40% occupancy. This goal was achieved and even surpassed: at the busiest times occupancy was around 60% of the reference year. After wearing masks was made mandatory occupancy fell to around 7000 devices or 50%. If we take into account the approximately 2000 devices that are always on campus, during this period occupancy was around 40%. The lockdown and curfew around the start of 2021 do not appear to have had a clear effect on occupancy, the fall is more likely due to the winter break and is similar to the reference break. It seems, however, that people were slower to return campus after the break because there are 2000 fewer devices than before the break. This might be due to the lockdown and curfew, but this same pattern can also be observed in the 2021/22 winter break when the measures were less strict. In the second semester of the 2020/21 academic year, device numbers increase slowly with more spaces being offered for studying. It is hard to see clear trends in this academic year as the measures were more nuanced and none had a big impact on occupancy compared to the online period in the previous year.

6.1.5 Close to pre-pandemic in the 2021/22 academic year. In the 2021/22 academic year there are around 12000 devices on campus at the busiest times at the beginning of the year. This is 50% more than the previous year but 14% lower than the reference year. The first round of measures does not have a clear impact due to overlapping with the start of the academic year. The second round of measures including mandatory masks and room limits does, however, coincide with a 1 to 2 thousand device decrease. The number of devices eventually returns to 12000 indicating that the drop was indeed

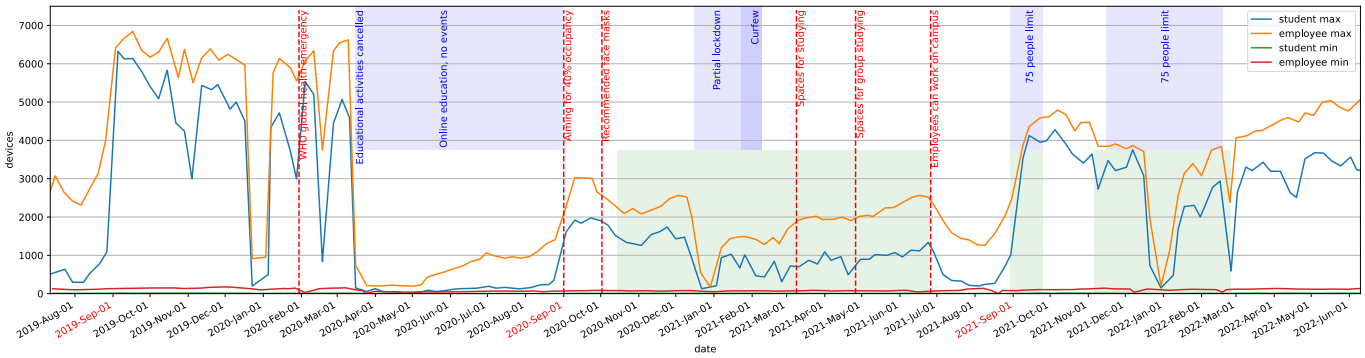

Fig. 4. Number of devices on the University of Twente campus before, during, and after the pandemic categorized as student and employee.

likely due to the measures. Unfortunately we cannot know what exactly caused it - the masks or room limits. Room limits of 75 people might not have much of an impact since most studying is done in smaller groups regardless and courses were likely planned with room limits in mind already.

6.1.6 Mandatory face masks. From the first and third periods when masks were mandatory it seems that occupancy dropped after the introduction of this measure and increased after it was lifted. Unfortunately there were other measures introduced around the same time so it might not be caused by masks alone.

6.2 Differences between students and employees

The graph showing how the numbers of student and employee devices changed during the same time frame can be seen in Figure 4. There are maximums and minimums for each category. During the reference period there are around 6 to 7 thousand employee devices and between 5 and 6 thousand student devices. The categorization appears to be accurate - there are very few devices at the lowest points because the buildings are empty at night. Some employees have the option to leave their devices on campus which explains the slightly higher maximum. The low minimums indicate that the approximately 2000 devices that are connected during the night are located in housing.

During the period of online education both students and employees were asked to stay home in the beginning, but we can see that around 1000 devices were connected employee access points towards the start of the 2020/21 academic year in contrast to close to none connected to student access points. It seemed in the previous graph that the 40% occupancy target had been passed but here we see that, when it comes to students, occupancy was only around 1/3 of the reference year.

In the previous graph it also seemed that the number of devices increased with the opening of study spaces for students, however, here we see that it was actually the amount of employee devices increasing. This suggests that students did not make significant use of the offered study spaces.

This graph provides more information about the drop in summer occupancy. The majority of devices during the summer belong to employees and attendance is likely lower than before the pandemic due to employees choosing to work remotely even if coming to campus is allowed.

During the pandemic the absolute difference between the number of student and employee devices stayed similar to before the pandemic - a difference of around 1000 devices. However, looking at the relative difference, there were 50% to 100% fewer students than employees on campus for a majority of the pandemic.

After the lifting of measures, the number of student devices rose to around 3500 which is 500 fewer than at the start of the 2021/22 academic year (when some measures were still in place) and around 63% of the student devices before the pandemic. The number of employee devices grew to 5000 which is higher than at the start of the year but around 75% of the reference period. Neither students nor employees have fully returned to campus, but employee numbers are closer to the numbers before the pandemic.

6.3 Effect on housing

Figure 5 shows the same period but with housing being separated from the rest of the campus. Weekly maximums and minimums are shown for each category. During the reference period there are 1 to 3 thousand devices in housing and around 10 to 12 thousand devices in the rest of the campus at the busiest times. There are a few hundred devices left in office and educational buildings overnight. There is no immediate drop in housing during the online education period although there is a gradual decrease. The 40% occupancy goal was a success at the start of the 2020/21 academic year as occupancy of office and educational buildings reached almost 5000: around 40% of the 12000 at the start of the reference year. It did, however, soon fall to around 3000 or only 27% of the 11000 in around the same time in the reference year.

Devices in housing follow a similar pattern during the winter break during lockdown as the reference break indicating that people celebrated the holidays similarly to before the pandemic - the decrease is likely due to people visiting family outside campus. However, during the pandemic summer breaks the minimum devices are higher than during the reference summer break likely due to people travelling less during the pandemic. In both summers during the pandemic, maximum occupancy of office and educational spaces was around 1000 devices lower than in the reference summer. This is despite the fact that there were no strict measures in force during the summers.

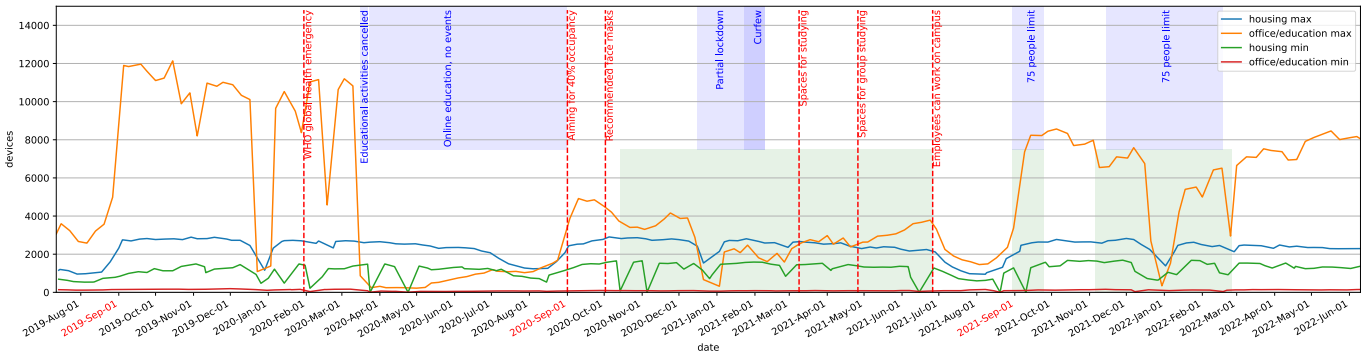

Fig. 5. Number of devices on the University of Twente campus before, during, and after the pandemic categorized as housing and office/education.

The maximum number of devices on campus stays constant except during the breaks. This would mean that the number of people living on campus has not been affected by the pandemic, which is expected since there is a constant shortage of housing. The minimum devices in housing are slightly higher during the pandemic which is simply the other side of the lower occupancy of office and educational buildings - more people stayed home during the day instead of going to another building on campus.
In the 2021/22 academic year occupancy of both housing and other spaces has been stable. However, if we look at the occupancy of only office and educational spaces, it is only about two thirds of the pre-pandemic occupancy. There were around 12000 devices before the pandemic compared to around 8000 after.

6.4 Are we all back on campus?

To answer the title of the paper: no, we are not all back on campus. At the time of writing, there have been slightly over 12000 devices connected at the busiest times since the lifting of measures on 18.02.2022. This is around 2000 devices lower than the busiest times before the pandemic in the reference period. If we assume that the number of people and devices stays constant during a normal year, there are around 14% fewer devices and people on campus at the busiest times after the pandemic than before it.

7 DISCUSSION AND POSSIBLE IMPROVEMENTS

All graphs are focused on the maximums and minimums per week, which omits a lot of data. Plotting the maximums and minimums per day would result in more information being shown at the cost of clarity. There may be a better way of visualizing the data with higher information density. It might also be interesting to, for example, plot the average of a week or the maximum daily minimum in a week.
Some measures might have been missed due to the use of emails as the primary source. However, the lack of inexplicable patterns in the data indicates that no important measures were missed.
The maximum number of devices varies by over 2000 even in the reference period which meant that serious conclusions can only be drawn about measures which had an impact of over 2000 devices.
For the student and employee comparison, access points are assumed to be used by employees by default. Most access points were categorized using the available list of classrooms and project rooms or by manually marking some areas as used primarily by students. Likely some access points were mistakenly categorized as employee due to lack of knowledge of all buildings on campus. More manual categorization would improve the accuracy of the comparison between students and employees.
During the pandemic, the university offered places for studying both individually and in groups. The effectiveness of these measures could be investigated by seeing if device numbers increased after the allocation of study spaces.

8 CONCLUSIONS

The main conclusion and takeaway is that despite the lifting of measures and the pandemic being regarded as over, there are fewer people on campus than before the pandemic. Since the lifting of measures campus occupancy has been at most 85%. For office and educational spaces occupancy has been at most 70%. Only around 65% of students have returned to campus compared to 75% of employees.
The switch to online education had the biggest impact on campus occupancy, reducing the number of student devices by nearly 100%. While the number of employee devices initially fell, around 1000 employee devices were brought to campus towards the end of the online period.
The 40% occupancy goal in the 2020/21 academic year was successful for about a month but after new measures needed to be introduced, occupancy fell and did not pass 30% during that year.
Neither mandatory masks nor room limits nor study spaces had a significant impact on campus occupancy except for around 1000 devices being gone on extended winter breaks. The partial lockdown and curfew around the winter break also did not significantly affect occupancy, which makes it a success because it was intended to cause little disruption to education.
While both students and employees were seriously affected by the coronavirus, attendance by students was much lower than that of employees. There were 50% to close to 100% fewer student than employee devices during the 2020/21 academic year which is much lower than the at most 20% gap before the pandemic.
The only effect of the pandemic on housing was that people travelled

away from the campus less during the summer breaks. The amount of people living on campus is very close to before the pandemic.

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A MEASURE TIMELINE

Table 1. All measures that may have impacted occupancy and events for context

Start date	End date	Measures and events
31.12.2019		Cases being treated in China
11.02.2020		First death in China
20.01.2020		Cases outside China
30.01.2020		WHO global health emergency
11.02.2020		Named COVID-19
14.02.2020		First death in Europe - France
23.02.2020		Lockdown in Italy
12.03.2020		Government advice - Large lectures should be avoided; open days cancelled
13.03.2020		Exams on the 13th cancelled; no events with more than 100 people; designlab, sportscenter closed
16.03.2020	20.03.2020	Education cancelled
17.03.2020		EU travel ban from outside EU
18.03.2020		Buildings closed for students; study spaces in Spiegel
23.03.2020	31.08.2020	Online-only education; no events
17.04.2020		Opening laboratories for research over time
02.04.2020		1‘000‘000 cases globally
26.04.2020		200‘000 deaths globally
15.06.2020		Limited working on campus allowed; small rare meetings
01.06.2020		Face masks on public transport
02.06.2020		Vrijhof open with reservations; laboratiories at 40% of regular capacity
01.09.2020		Aiming for 40% occupancy; tutorials over lectures
02.10.2020		Face masks recommended
14.10.2020		Mandatory face masks
1.11.2020		Travel advice for Germany: only necessary trips but university trips allowed
16.12.2020	09.02.2021	Lockdown, but some educational activities still allowed (exams, practicals)
13.01.2021		Study places in the library, Horst, not in Spiegel
23.01.2021	09.02.2021	Curfew 21-4.30, exams exempt
09.03.2021		More study spaces - library; Horst; Spiegel; Bastille; Ravelijn
26.04.2021		Spaces for studying in groups (8-10) in Carre; Cubicus; Horst; Ravelijn; Technohal
06.05.2021		Self tests can be ordered
05.06.2021		More education on campus, training courses
26.06.2021		No face masks; employees can work on campus
30.08.2021		No 1.5m distance required at the university; face masks mandatory; max 75 people in a room, excluding teachers
25.09.2021		Neither 1.5m nor masks required; no room limits except based on ventillation
06.11.2021		Face masks mandatory
15.11.2021		75 people limit, excluding exams
18.12.2021	14.01.2022	Only activities that require campus facilities allowed; study spaces in the library
21.12.2021	09.01.2022	Campus restaurants closed
27.12.2021	31.12.2021	Study places in Spiegel
03.01.2022	07.01.2022	Study places in Spiegel
14.01.2022	25.01.2022	Masks also required when sitting
25.02.2022		Face masks not mandatory
15.02.2022		Working from office half-time
18.02.2022		No maximum room sizes
16.03.2022		No work from home advice; high infections; request to record lectures