PEDESTRIAN STUDY AT CHALMERS

PEDESTRIAN MOVEMENT AND CO-PRESENCE AT CAMPUS JOHANNEBERG

Spatial Morphology Group, SMoG
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CHALMERS

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PEDESTRIAN STUDY AT CAMPUS JOHANNEBERG

PROJECT DESCRIPTION

1. STUDYING PEDESTRIAN MOVEMENT AND CO-PRESENCE

University campuses, apart from being places of education, they are important social public spaces and cultural institutions. A variety of people mix in their open spaces; people of different ages, cultural and social backgrounds, interests, jobs, knowledge fields or educational status. They potentially share the same paths and take the same routes on their everyday trips within the campus, to go to work or to class, go to lunch, fika or an after-work gathering, leave work, go to the library and so on. They meet with friends and acquaintances or they pass by complete strangers. Different groups of colleagues, friends, classmates or peers meet on the outdoor spaces, shortly chat or have lunch, stand or sit, all the while being next to other groups of different status, or watch other people go by. Within these open spaces, people cross paths, share glances and mutual gazes while they are physically close or distant. They become aware of each other and understand the elements of the social environment of the campus. The more people are co-present in space and the more they use the same paths, the more likely is that they meet in these recurrent informal encounters, some possibly leading to actual interactions. It has been shown that by shaping people's perception and their individual as well as collective spatial experience, what is also conveyed is the identity and the social role of each building as a public institution. However open spaces do not always generate the rich and lively social fields that were described above. Often they do not attract movement and activity and remain empty and unused, creating a perception of neglect, degradation and even unsafety.

Urban research has long been investigating the reasons behind the observed different level of activity on different streets and public spaces. The role of the spatial environment has been at the focus of this investigation. Studies have shown that the intensity of pedestrian flows and co-present is highly dependent on spatial location and particularly on the centrality of this location in relation to its context (e.g. Whyte 1980, Gehl 1987, Hillier et al 1993; Peponis et al. 1997; Stavroulaki et al 2019; Berghauser Pont et al 2019; Read 1999; Berghauser Pont and Marcus 2015; Ozbil et al. 2011, 2015; Netto et al. 2012, 2018, Legeby 2013, Legeby et al 2015).

Fig 1. Chalmers campus, Johanneberg, source: https://cumulus.portal.chalmers.se

Fig 2. Chalmers campus, Johanneberg, source: https://cumulus.portal.chalmers.se

More central places will attract more people, which will attract more activities, which in turn will attract even more people, creating a multiplier effect (Hillier et al. 1993). How many people share public space is known to affect many socio-economic processes in cities such as social cohesion (e.g. Hanson 2001; Legeby 2013), urban vitality and local commercial markets (e.g. Bobkova et al. 2019; Scoppa et al 2015). On the other hand, architectural research in complex buildings (e.g. hospitals, offices buildings, retail shops, libraries, museums) has too investigated how the inner spatial structure and configuration influences users' movement, social interaction and patterns of use (e.g. Wineman et al. 2014; Peponis et al. 2007; Koch 2015, 2007; Koch and Steen 2012; Salier and McCulloh 2012; Zamani and Peponis 2010; Stavroulaki and Peponis 2003). A better understanding of how spatial structure influences the patterns of movement and co-presence of people in public space - be it urban space or public building - is thus central for the development of the built environment.

In environments, such as university campuses, where movement is highly goal-oriented, the interplay of spatial structure and the spatial distribution of destinations (e.g. entrances to schools, restaurants, libraries) is decisive on the distribution of movement flows. Spatial analysis can offer insights and explanations on where and why more intense pedestrian movement and co-presence is observed. In addition, it can help the assessments of future plans as to where higher movement flows can be expected and identify ways to increase the potential of designs to create outdoor spaces more inviting for social activity.

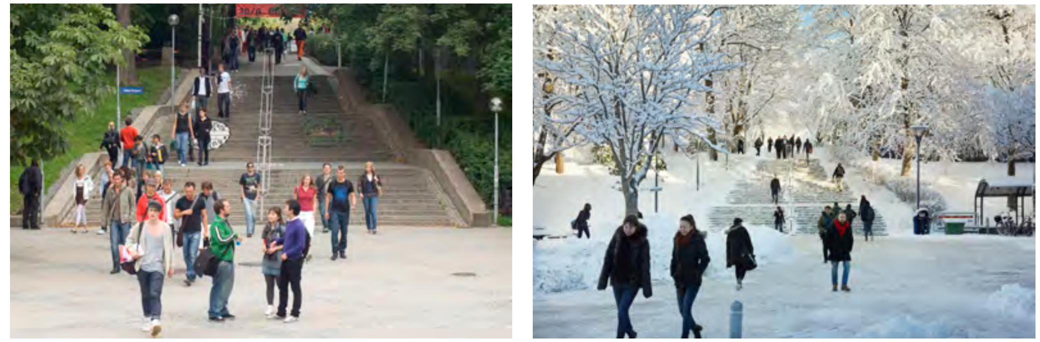

Fig 3. Chalmers campus, Johanneberg, source: https://cumulus.portal.chalmers.se

The present study of pedestrian movement at Chalmers campus Johanneberg maps and analyses the patterns of movement and co-presence in the outdoor spaces of the campus. The aim is to, first, understand how these patterns relate to the existing spatial structure of the campus, and, second, following this understanding, to assess the expected changes on the patterns of movement and co-presence at the future campus, based on the development masterplan "Chalmers 2019-2050, Campusplan. Människor och möten för en hållbar framtid".

The study followed three main steps. First, a large pedestrian survey tracking anonymised wi-fi signals from mobile phones was conducted for a week, from the 5th to the 11th of November on campus in order to collect empirical data on pedestrian movement and co-presence. For a week, 22 locations on the campus were recorded constantly, providing high-resolution output data for 34 walking paths and streets (see Fig 4). Intensity of movement flows on the selected paths (i.e. number of pedestrians) and co-presence at the selected nodes (i.e. number of people present, standing or passing by) were calculated from the aggregation of individual movements trails, for every hour of the week. Second, spatial and visual analysis was conducted in order to unveil the movement potentials created by the spatial structure and the distribution of destinations and attractions on the campus, in relation to the actual movement patterns recorded in the empirical data. Third, similar spatial analysis was also conducted for the future development plan of 2050 to highlight where movement and co-presence intensity can be most expected, and how this relates to the masterplan intentions.

This report presents the methodology and results of the pedestrian study in three sections following the research steps as described above. In the last section, conclusions and next steps are discussed. The report is complemented with an Appendix that includes the complete overview of the survey results.

PEDESTRIAN SURVEY

2. PEDESTRIAN SURVEY AT CAMPUS JOHANNEBERG

2.1. Method

The pedestrian survey was conducted during the first week of the second study period (Läsperiod 2), from Tuesday 5th, to Monday 11th of November 2019 . Twenty-two (22) locations were selected in collaboration with Chalmersfastigheter and Akademiska Hus to provide an overview of the pedestrian movement on the campus (Fig 4). The priorities were to cover the main east-west (e.g. Chalmers tvärgata) and north-south connections (e.g. Hörsalvägen, Rännvagen, Sven Hultins gata), the main entrances to the campus (e.g. from Chalmersplatsen, along Gibraltargatan) and the main intersections, small squares and sitting areas (e.g. intersections of Chalmers tvärgata to Hörsalvägen and Rännvagen, Teknologården at the Student union, Geniknölen). These locations are also related to key campus destinations that are, apart from the main university departments, the restaurants, cafes, pubs, public transport stops and the central library.

Wi-Fi sensors were placed at each of these locations and recorded people passing within a 40-50 m radius. Only people with enabled wi-fi on their mobile phones were recorded. Samples of Wi-Fi signals were collected when their devices were searching for wi-fi networks (so called wi-fi probe requests). Each sample included a timestamp (the exact time of the signal), a RSSI (Received Signal Strength Indication) that showed the distance of the signal to the sensor and an anonymized indicator of the mobile phone. This method was chosen not only because it is technically advanced and appropriate to collect anonymized big data (Schauer et al. 2014), but also because it can ensure the anonymity, it is GDRP compliant and can be used in all European cities. The same method was used from the Trafikontoret of the municipality of Gothenburg during the summer of 2019 to measure pedestrian movement in the city centre (https://stadsutveckling.goteborg.se/nyheter/sa-ror-sig-2-miljoner-fotgangare-i-centrala-goteborg/). The Spatial Morphology Group used this method as well to conduct a large international survey in London, Stockholm and Amsterdam in October 2017 (Stavroulaki et al 2018, 2019; Berghauser Pont et al 2019). Responsible for the technology and hardware of the survey and for the processing of the raw data were Bumbee labs, Stockholm (www.bumbeelabs.com).

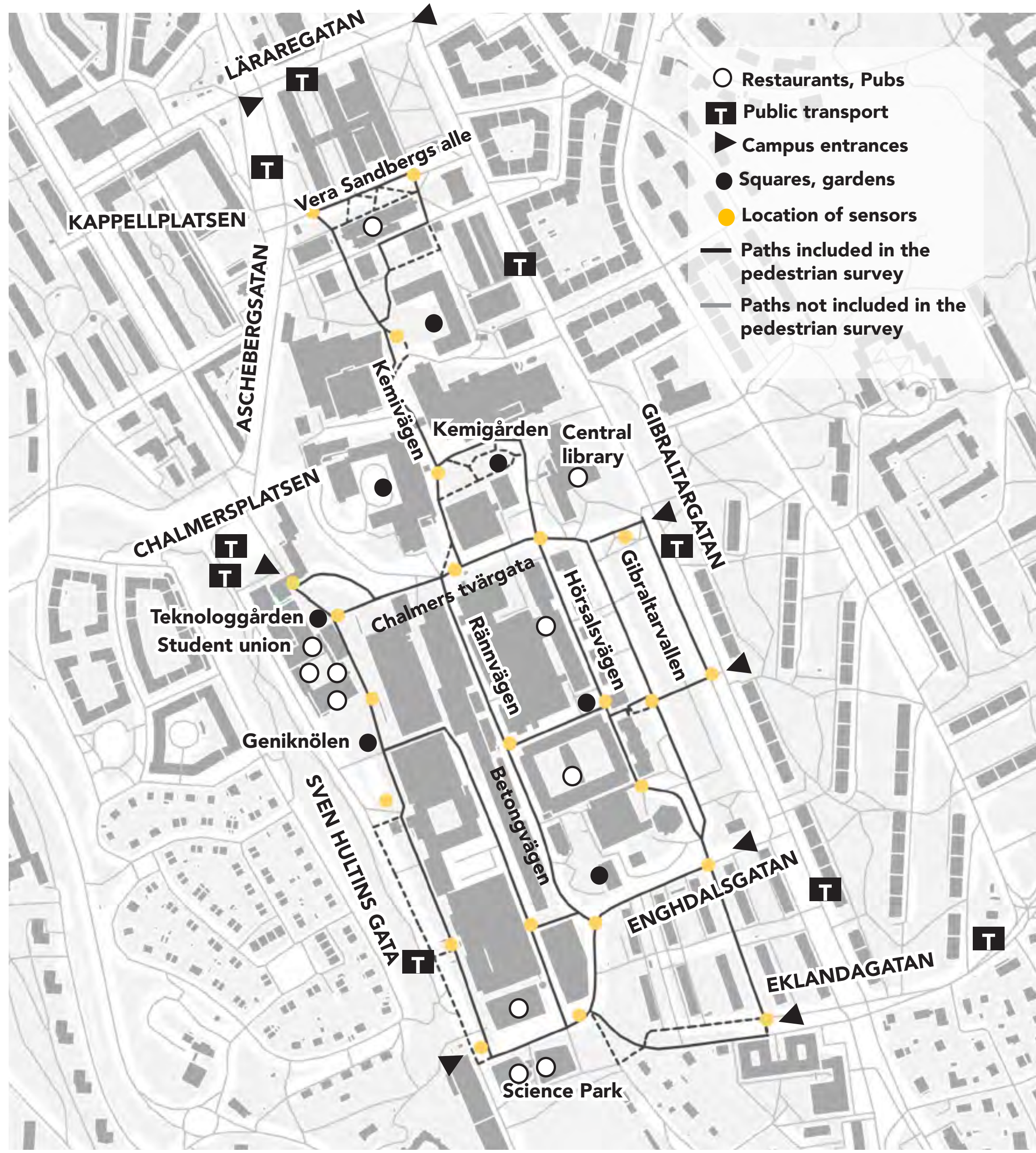

Fig 4. Campus plan showing the location of sensors and the paths included in the survey

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Students and staff of the campus were informed in advance about the survey taking place with website posts, newsletter items and direct emails from the responsible divisions. The boxes containing the wi-fi sensors (Fig 7) also had labels with informations about the survey as well as a QR code linking to more information on-line. Because not all people carry enabled wi-fi mobile phones, or some might carry two, parallel manual counts were conducted throughout the week to identify a scaling factor between the manual and the recorder counts. This method has been used in similar surveys in the past and the scaling factor has been shown to be similar across different neighborhoods and cities (Stavroulaki et al 2018, 2019). A threshold of 6km/h speed was used to distinguish pedestrians from cyclists.

The weather conditions were similar for all seven days. The weather was mostly gloomy and the temperature ranged from 2 to 6 degrees. There were only a few short periods of light rain. One major event, the Pub Crawl, happened on Thursday evening (7/11), when all student pubs held parties. During the week of the survey some construction works were partly obstructing movement at Sven Hultins gata from the entrance of SB2 to the Science park.

The collected empirical data record the trail of each anonymised mobile phone on the campus area. From the aggregation of individual movements trails, the intensity of movement flows in the 34 selected paths (i.e. number of pedestrians) (Fig 6) and co-presence in the 22 selected nodes (i.e. number of people present, standing or passing by) (Fig 5) were calculated, for every hour of the week.

2.2. Results

2.2.1.Temporal trends

The results reveal some clear general temporal trends in the way people move and gather within the campus. As expected, there is a major drop in the intensity of both movement and co-presence during the weekend (Fig 8). There is also an expected clear drop every evening around 19:00 and the intensity remains very low until the next morning around 7:00. An exception is Thursday evening when the intensity remains high in some paths and nodes because of the Pub Crawl event. Another exceptional peak is recorded on Saturday night to Sunday from 00:00 to 01:00 but only in the path 11 outside the club Gasquen. There are identifiable peaks of intensity in movement and co-presence in most selected paths and nodes during the morning when people arrive at the campus, the lunch hour, and the afternoon when people leave the campus (Fig 8, 9). There are two peaks in the morning one at 7:00-8:00 and one higher at 9:00-10:00. There are also two peaks related to lunch break, one at 11:00-12:00 and one at 12:00-13:00, but the intensity remains quite high until 14:00. Lastly, there are two peaks in the afternoon, one at 15:00-

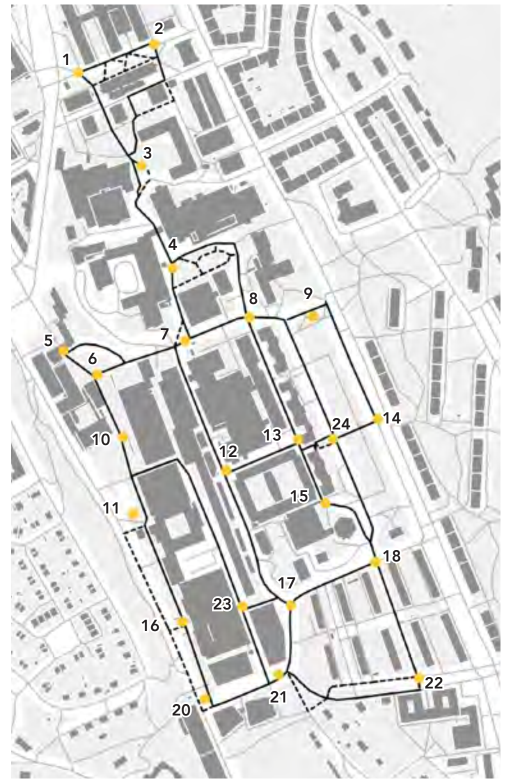

Fig 5. Measured nodes

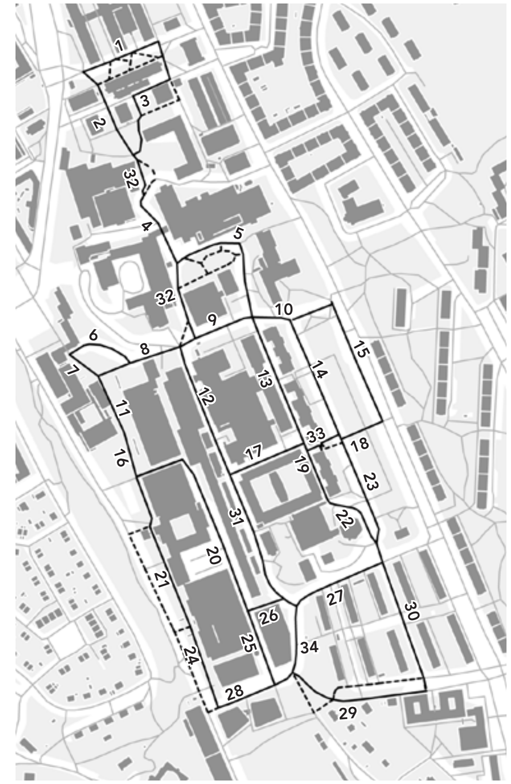

Fig 6. Measured paths

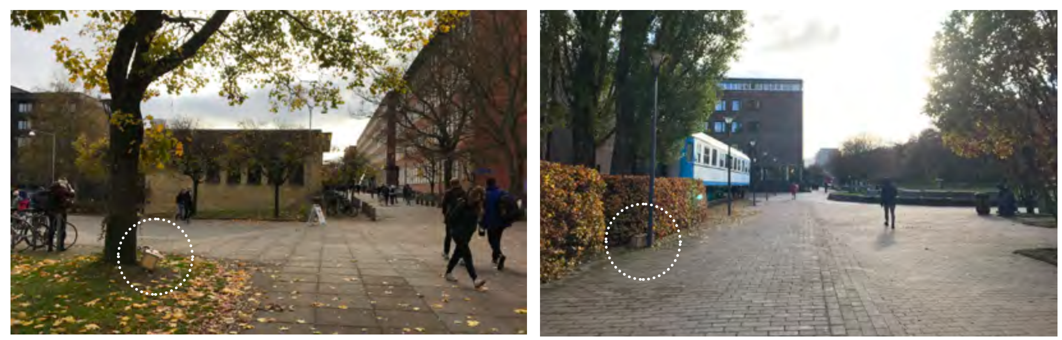

Fig 7. Photos of the survey week. Dotted circles show the boxes containing the wi-fi sensors.

16:00 and one at 17:00-18:00. The highest peak overall is the lunch break peak at 11:00-12:00. These trends remain constant throughout all workdays showing a strong temporal factor that influences the movement and co-presence and is related to the main fixed everyday routines (go to work, go to lunch, leave work). Fig 8 shows Tuesday as a typical example and in the Appendix detailed diagrams for each workday are included (pages 54-62). These trends are not so clear during the weekend where the intensity is much lower and there are not major peaks.

2.2.2. Spatial trends

While the general temporal trends are proven decisive in the intensity of movement and co-presence on the campus, there are also very strong general spatial trends that remain stable throughout the week, also during the evenings and weekends. What is clear is that although the volume of people in the campus changes depending on the time or whether it is a workday or weekend, the distribution of these people follows constant spatial patterns. In simple words, paths that have the highest intensity of movement during the lunch peak hours, they do so every workday and they also have the highest intensity of movement during evenings and weekends (see for example paths 8,16,8,13,7,11 in Fig 8 and 9). Entrances to the campus that have the highest intensity during the morning peak, also have the highest intensity during the whole day and during the afternoon peak.

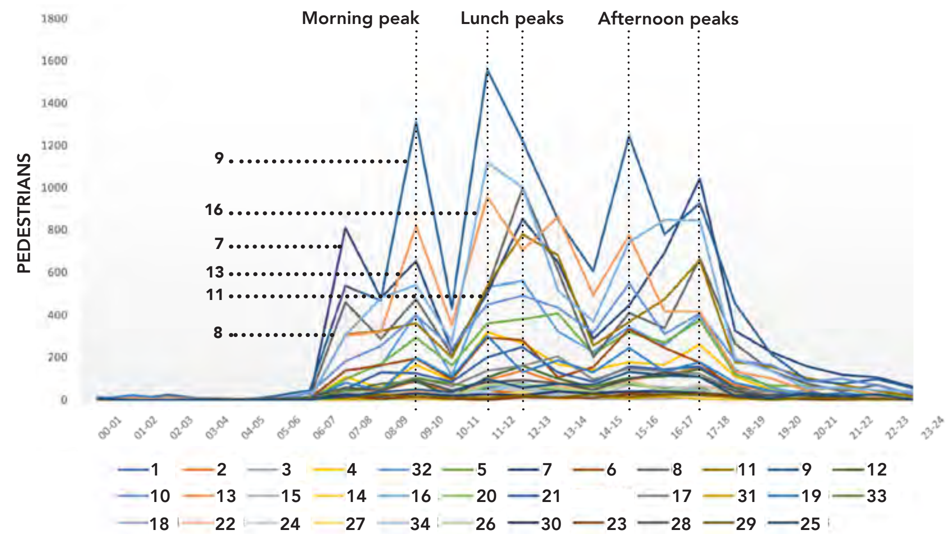

Fig 9. Fluctuation of pedestrian flows on each path per hour on a typical workday (Tuesday)

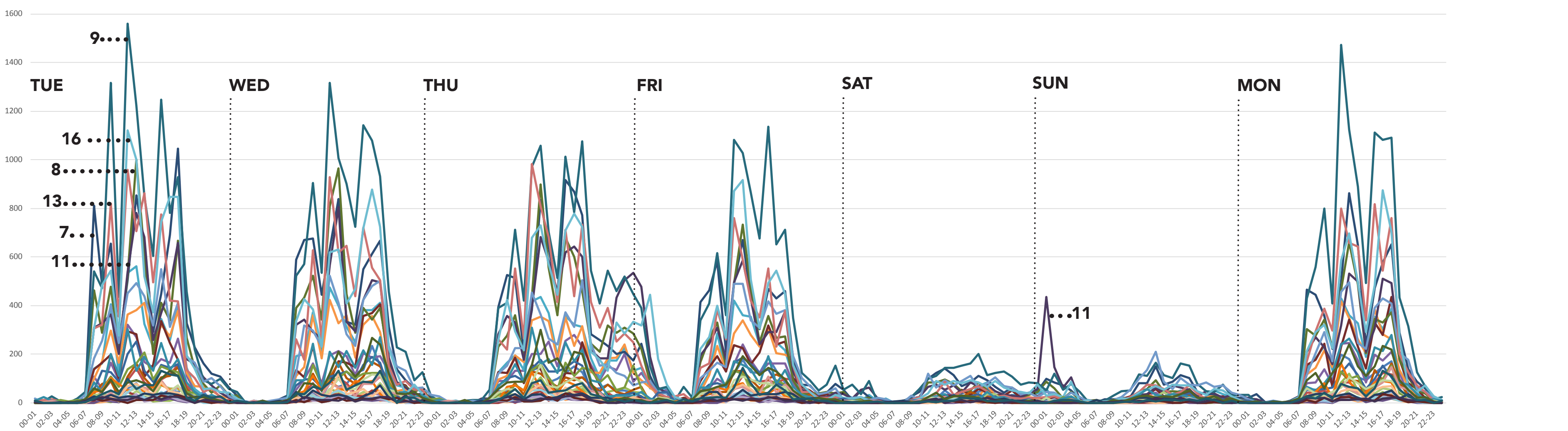

Fig 8. Fluctuation of pedestrian flows per hour during the whole survey

While there are variations and nuances, the main hierarchies between paths and nodes in relation to their movement and co-presence intensity do not significantly change because of time or day.

2.2.2.a Movement on Paths

The paths that consistently show the highest number of pedestrians, irrespectively of time and day, are: the whole Chalmers tvärgata, and especially between Hörsalsvägen and Rännvägen; Hörsalsvagen, from Chalmers tvärgata to Quarl Ankas Väg at the start of the EDIT building; and finally, the path connecting the Chalmersplatsen campus entrance and the Teknologården, through Geniknölen, to the entrance of the Architecture and Civil Engineering building (SB1) (Fig10). Consistently, the paths with very low intensity are: Rännvägen, from the Quarl Ankas Vägbuilding to Engdahlsgatan, most of Betongvägen; and Gibraltarvallen by the large parking area, especially towards Engdahlsgatan. Lower intensities are also recorded on Eklandagatan, Engdalhsgatan and the path connecting the small square outside CHABO to the entrance from Gibraltragatan. Besides the most visited paths, relatively high intensities are also recorded at Skeppgränd and the paths connecting Kemigården to Chalmers tvärgata and the central library. Also, on that list are the lower part of Kemivägen, Rannvägen from Chalmers tvärgata to Quarl Ankas Väg, Quarl Ankas Väg and Sven Hultins gata from the entrance of SB1 to the entrance of SB2 building, where also the stop of Bus 55 is located.

The results of movement intensities on the paths are consistent, whether looking at the average number of pedestrians during the workdays or the weekend (Fig 10, 11), or looking at the total number or people separately for each day (Fig 15 and Appendix p 50-51), or looking at the number of pedestrians at several times during each day (Fig 15, Fig 12 and Appendix p54-62).

However, there were some exceptions related to specific times or events. Some paths have been recorded to show greater temporal variations than others. One such example is Sven Hultins gata in front of Science park that shows very low intensity most of the day but much higher during the lunch and afternoon peaks. Usually, paths that show very low intensities remain low throughout the day. This path is an exception because there are three restaurants located on it and a number of offices within the Science park. Other exceptional temporal variations as already mentioned is the peak on Saturday night to Sunday (0:00-01:00) in front of pub Gasquen on the basement of Student Union, as well as the much higher intensities on Thursday evening in comparison to other evenings, due to the Pub Crawl event (Fig 13,14 in relation to Fig 12b). The higher intensities are recorded in relation to the location of the student pubs.

One path that showed consistently low intensities is the one connecting the entrance of SB2 and the Science Park (path 24). However, since during the week of the survey some construction works were partly obstructing movement at this path, the results might not represent its regular intensities.

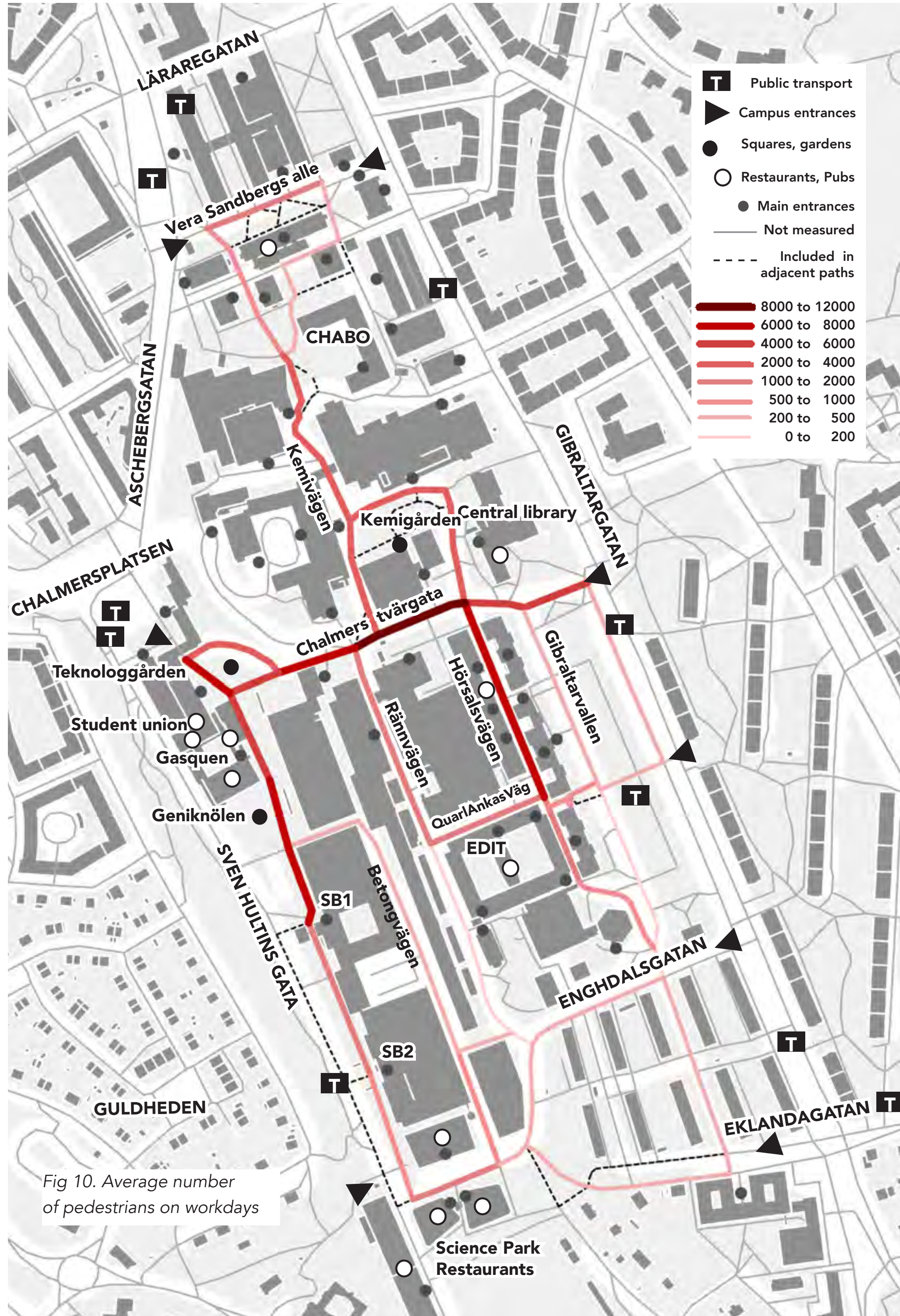

Fig 10. Average number of pedestrians on workdays

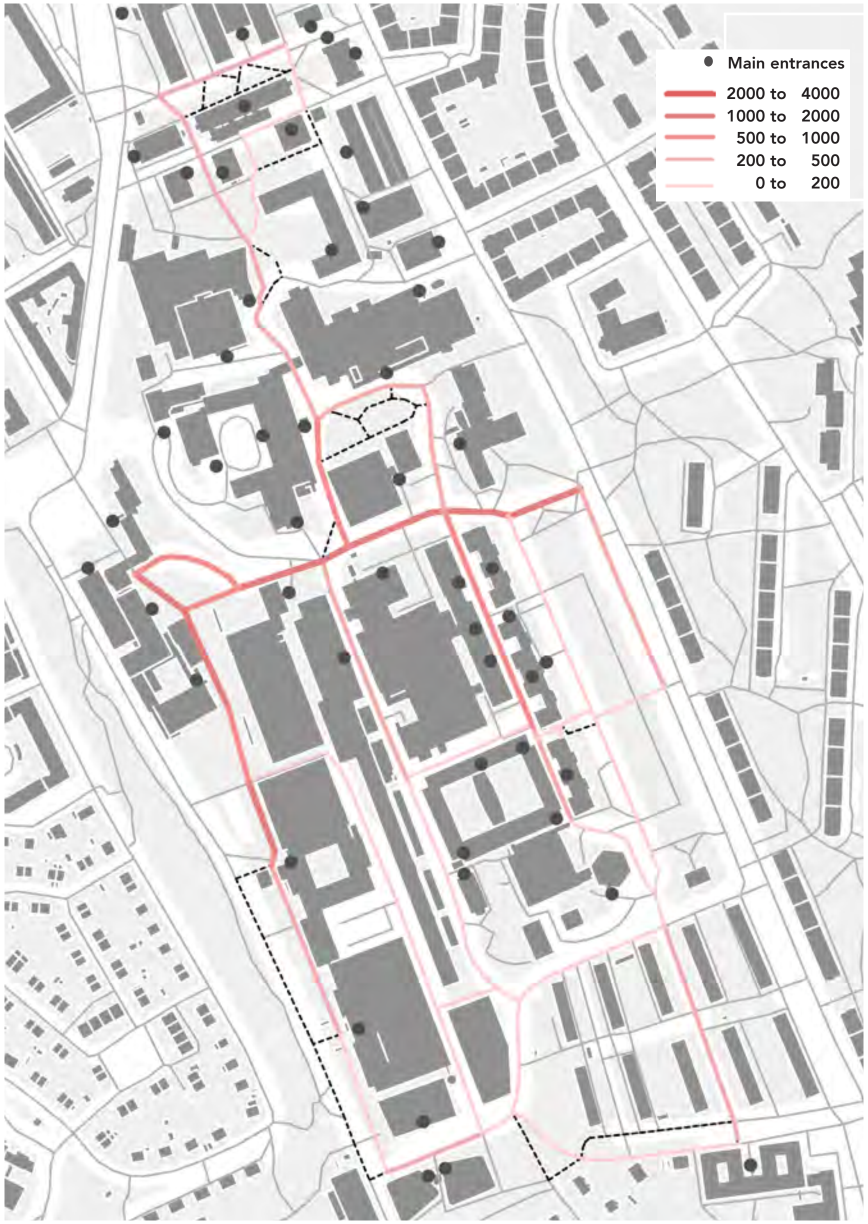

Fig 11. Average number of pedestrians on weekend

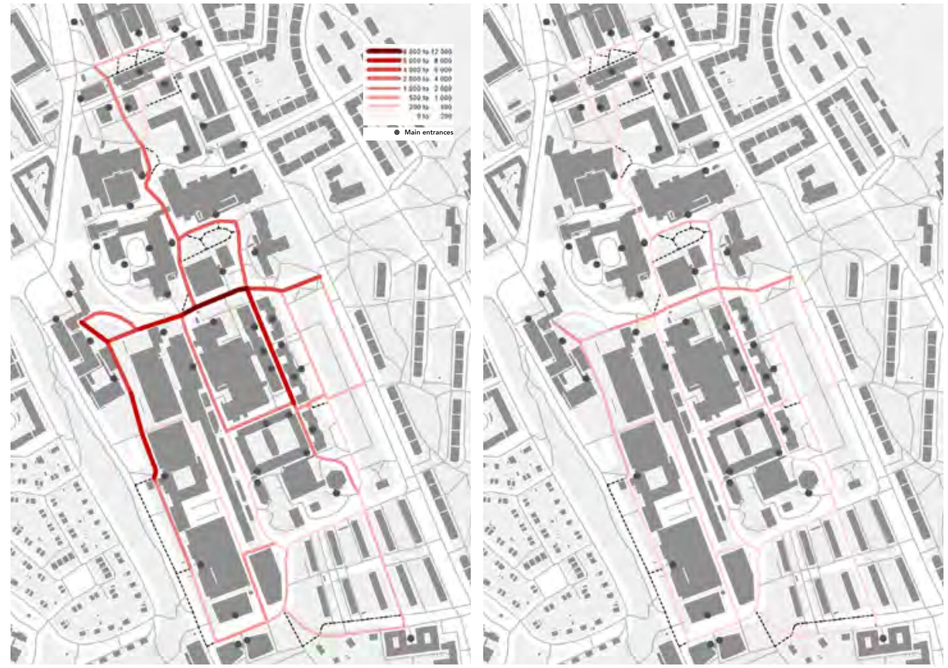

Fig 12. Day vs Night. Total no of pedestrians on Tuesday day (7:00-19:00) and night (19:00-7:00)

Fig 13. Total no of pedestrians during Pub Crawl, Thursday night (19:00-7:00)

Fig 14. No of pedestrians from 22:00 to 23:00, during Pub Crawl on Thursday night

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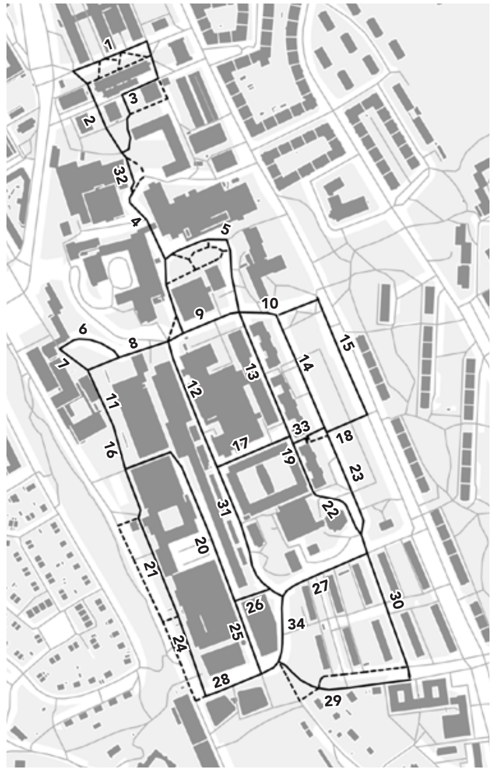
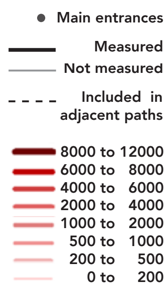
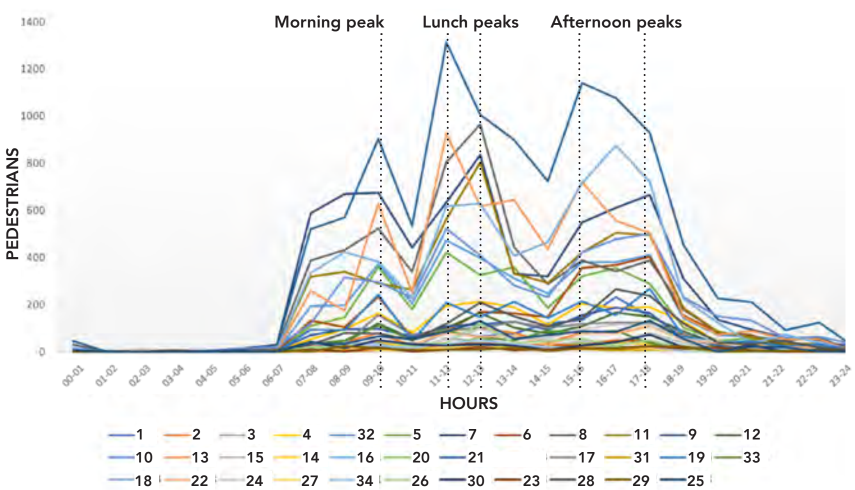
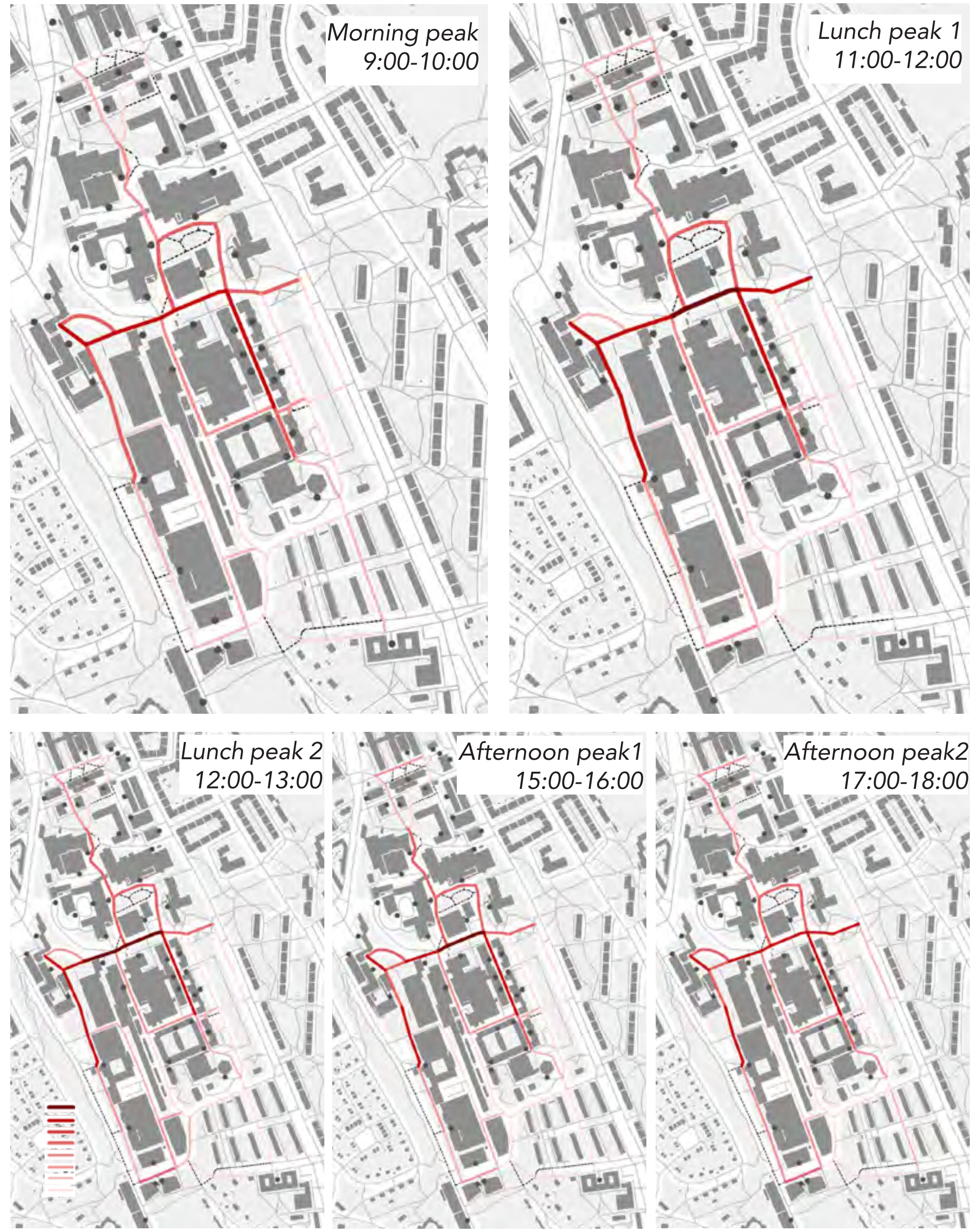
Fig 15. MOVEMENT PEAKS FLUCTUATIONS

WEDNESDAY 6-11-2019









2.2.2.b Co-presence at Nodes

Looking at co-presence at the selected nodes, the results are generally consistent with the movement intensities on the paths. The two intersections of Chalmers tvärgata to Hörsalvägen and to Rännvagen show the highest co-presence (Fig 16). They are followed by the Teknologården at the Student union, the small square in the intersection of Hörsalvägen and Quarl Ankas Väg, Geniknölen, Kemigården and the entrance point from Chalmersplatsen. If we compare the 6 entrance points to the campus included in this study, the higher number or people is recorded at the entrance from Chalmersplatsen, followed by the entrance from Gibraltragatan to Vera Sandbergs allé on the northern part of the Campus. The entrance to Vera Sandbergs allé from Aschebergsatan had slightly lower numbers of people, in the same range as the entrance to Chalmers tvärgata from Gibraltragatan. Even lower numbers were recorded at the entrances to Eklandagatan and Engdalhsgatan. The lowest numbers were recorded at the entrance to the parking area and the entrance at the Science park area including the stair from the hill of Guldheden.

Among the other nodes, especially interesting is the case of the intersection of Rännvägen to Quarl Ankas Väg, where extremely low co-presence was recorded, although it is surrounded by the two intersections of the highest co-presence (Rännvägen to Chalmers tvärgata and Quarl Ankas Väg to Hörsalvägen).

The hierarchies between nodes in terms of co-presence, as described above, are also consistent whether we look at the average co-presence in workdays and weekends (Fig 16 and 17) although during the weekend the differences are less clear since the overall intensities drop significantly. Also consistent are the total numbers measured separately on each day (Fig. 18, Appendix, p.66-67).

2.2.3. Summary of survey results

The results of the pedestrian survey showed clear temporal trends in the patterns of movement and co-presence related to the main fixed everyday routines (go to work, go to lunch, leave work). However, they also showed very strong general spatial trends that remain stable throughout the week, day and night, workdays and weekends. Although the volume of people in the campus changes depending on the time or whether it is a workday or weekend, their distribution follows constant spatial patterns. Consequently, the hierarchies of paths and nodes based on their relative movement intensity or co-presence remain generally stable. What is particularly interesting is that they remain stable also outside the working hours and days, in the evenings or during the weekends.

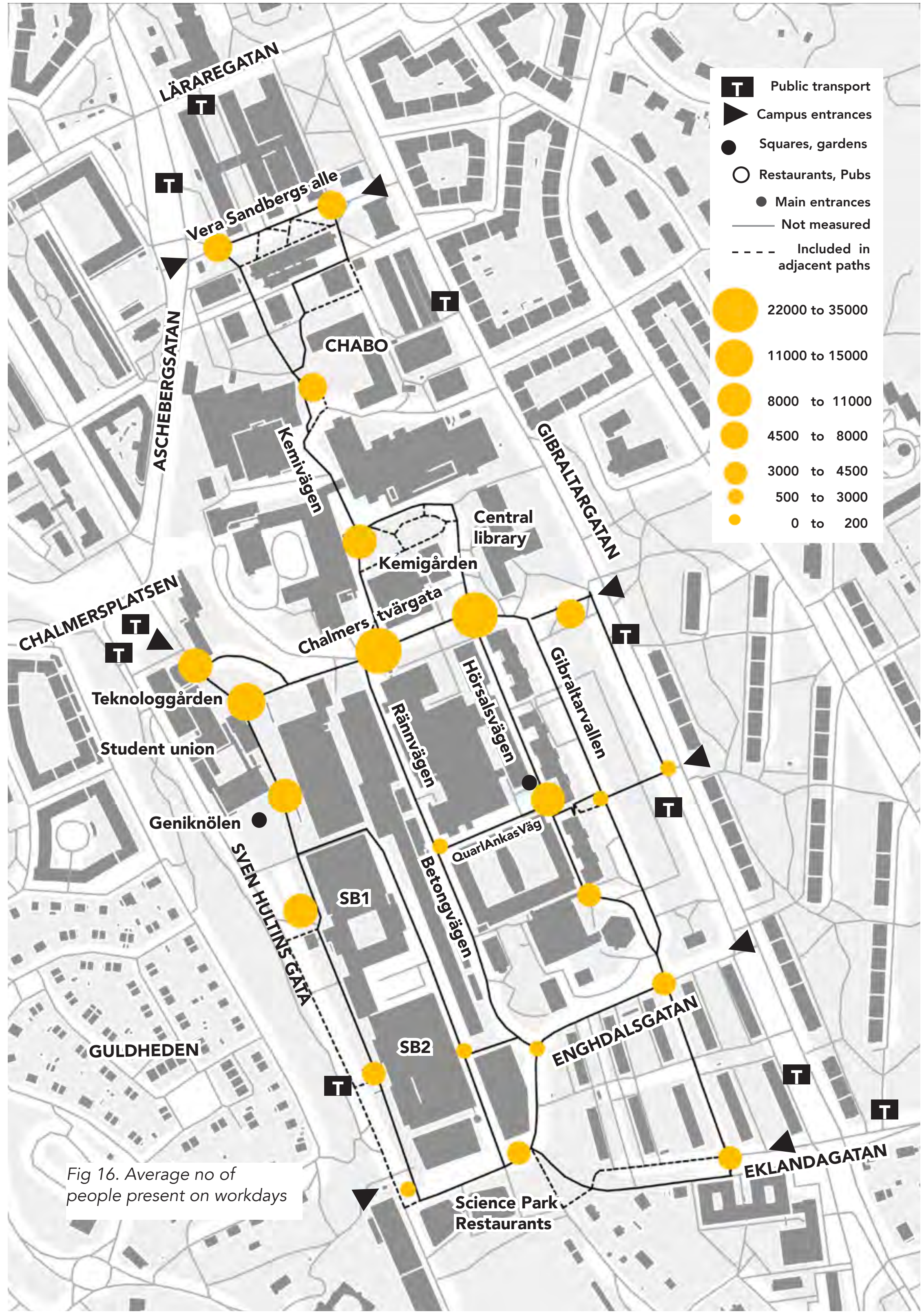


Fig 16. Average no of people present on workdays

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For example, Chalmers tvärgata with its intersections, the upper part of Hörsalsvägen, Chalmersplatsen entrance, the small square at the intersection of Hörsalsvägen and Quarl Ankas Väg still show the highest intensities even though the school is closed. This is particularly interesting because it shows that the spatial structure in itself has a strong effect on the distribution of pedestrian movement, irrespectively of specific activities and goal-oriented routines. This will be analysed in detail in the next section.

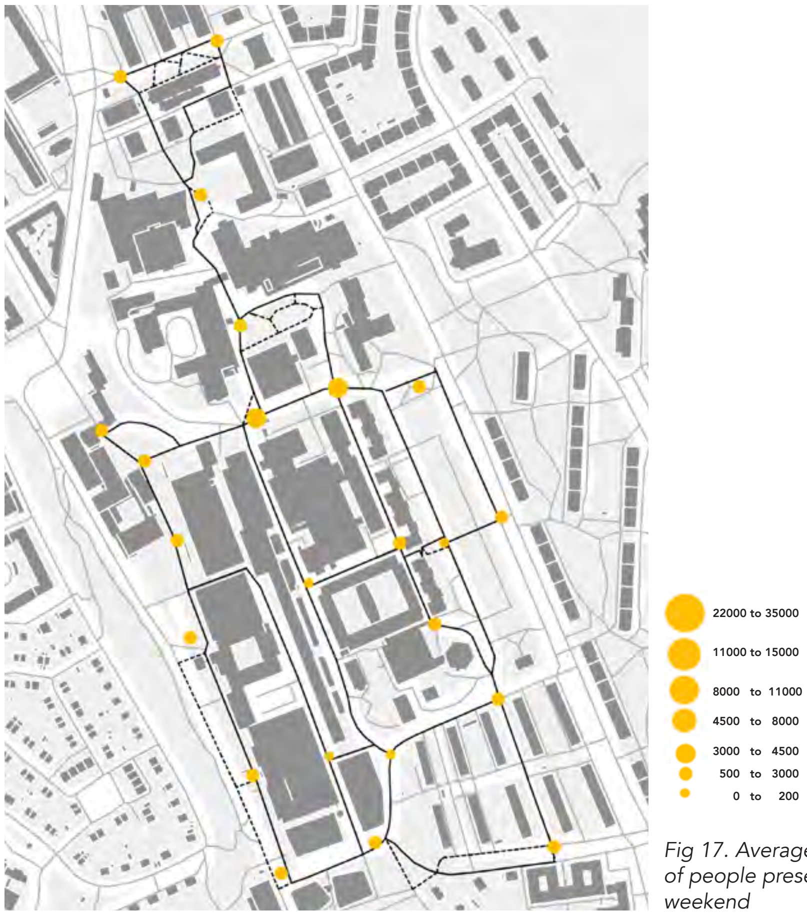

Fig 17. Average no of people present on weekend

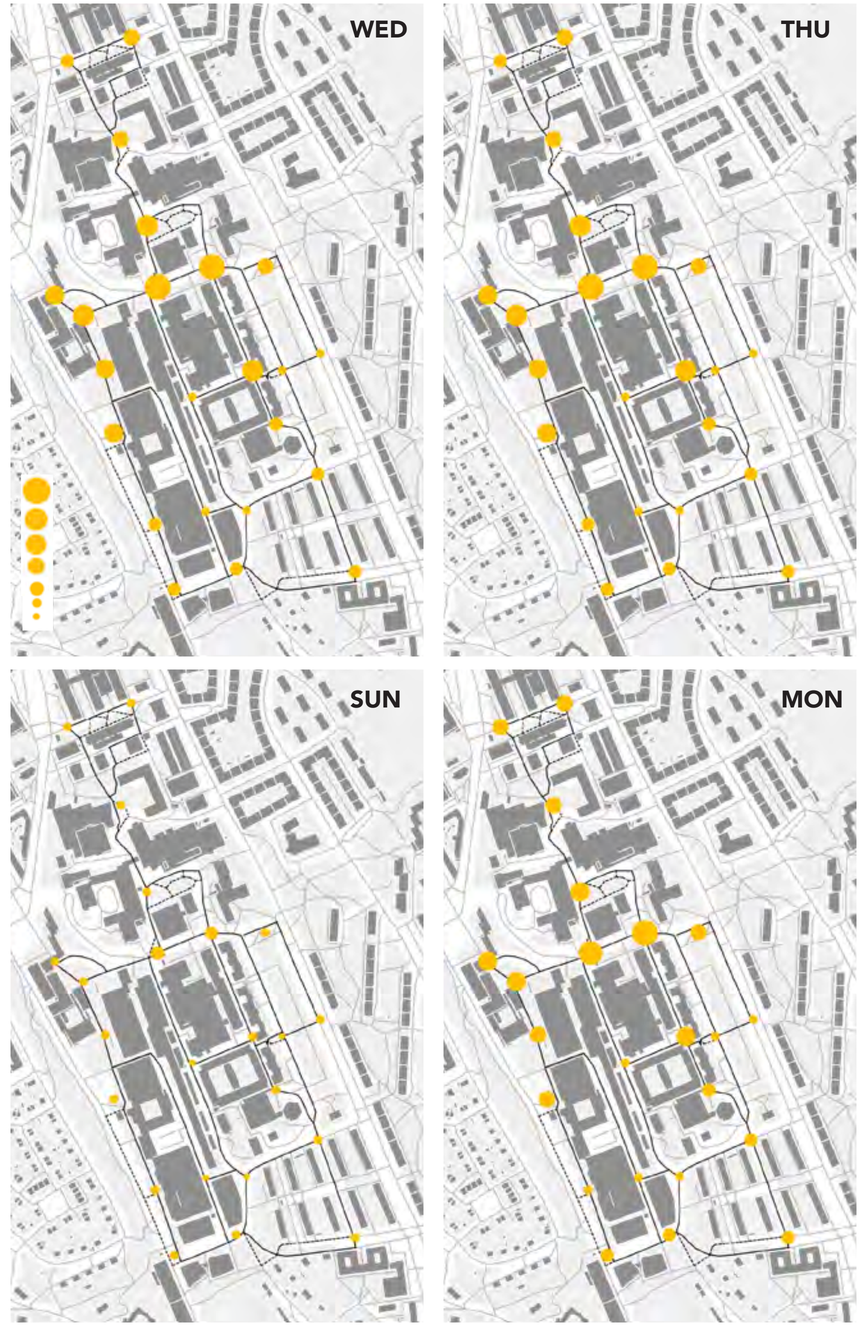

Fig 18. Total no of people present on typical workdays and Sunday

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SPATIAL STRUCTURE AND PEDESTRIAN MOVEMENT

3. SPATIAL STRUCTURE AND PEDESTRIAN MOVEMENT

The spatial analysis of the campus, focuses on the spatial structure and the spatial distribution of attractions, both of which have been shown in empirical scientific studies to drive pedestrian movement and co-presence (Hillier 1993, Stavroulaki et al 2019, Osbil et al 2011, 2015).

3.1 Spatial and visual analysis. Method.

The relation of spatial configuration and pedestrian movement and co-presence has been studied extensively, not least in the field of Space Syntax. Space Syntax introduced theoretical concepts, spatial representations and methods of spatial analysis to unveil the role of space as a generator of social life (Hillier and Hanson 1984; Hillier 1996); materializing in spatial cultures, in patterns of co-presence, flows of movement and interaction rituals, in conditions of inclusion and exclusion, social cohesion and segregation, social relations and norms of behavior (e.g. Hillier et al. 1993; Hillier et al. 1987; Hanson 2001; Peponis et al. 1989, 1997; Marcus 2015). Empirical studies have analysed and modeled such relations using empirical evidence and have revealed high dependency between the use of public place and its spatial location, and particularly between street centrality and pedestrian movement (e.g. Stavroulaki et al 2019; Berghauser Pont et al 2019; Peponis et al. 1997; Read 1999; Berghauser Pont and Marcus 2015; Ozbil et al. 2011, 2015; Netto et al. 2012) and co-presence (e.g. Netto et al 2018; Legeby 2013; Legeby et al 2015). Such studies have repeatedly reported a consistent relation between the two and have also generated theory, such as the theory of Natural movement (Hillier et al. 1993) which aimed to demonstrate the primacy of spatial configuration over attractions, when it comes to influencing the distribution of pedestrian movement in urban space. Places with high movement flows in turn invite more activities and attractions (e.g. shops and restaurants) which will attract more people, creating what is called a multiplier effect.

Centrality analysis is used extensively in such studies to show the potentials created by the spatial structure, layout and configuration to attract pedestrian movement and support the co-presence in space. A more central and well-connected street in the network is more probable to be visited or used by pedestrians. A more central square is more probable to have more visitors and increased co-presence. On the contrary, disconnected and segregated streets and squares, are associated with low pedestrian flows and co-presence. Although, the relation between spatial configuration and pedestrian movement is neither deterministic nor a cause-and-effect relation, nevertheless many studies have shown a strong probabilistic relation between the two. Of course, other factors play in, that in collaboration with spatial structure, also affect the intensity of pedestrian movement and co-presence, such as attractions, land and building uses, building and population density. Empirical studies, outside the field of Space syntax, also show a strong association of street connectivity and pedestrian walking (e.g. Park et al 2016, Dambaugh and King 2018, Holzer and Lokrem 2011, Kang et al. 2017).

In this study we use **Angular Betweenness centrality** to analyse the **centrality of the street network** and **Attraction Betweenness** to include the main building entrances, as proxies for attractions. In more detail, **Angular betweenness centrality** finds the shortest paths between all street segments in a network, meaning the paths that have the least angular deviation for a pedestrian. Then it calculates how many of these shortest paths pass through each and every street segment, showing each segment's importance in the short and long trips in the network. Angular Betweenness centrality has shown a strong correlation to pedestrian flows (e.g.Hillier and Iida 2005; Berghauser Pont et al. 2019). It is usually referred to as "through movement", because it highlights the streets that people need or tend to pass through to go from place to place in the city. High angular betweenness centrality shows that the street is a key mediator of many potential trips in the network, as for example a bridge connecting an island to the mainland.

We analysed Angular Betweenness centrality in two radii, one local (1km) and one global (5km), always including the urban context of the campus in the analysis. The lower radius of centrality highlights the hierarchies of streets in relation to their more local connections within the campus and reflects shorter pedestrian trips and more local scales of movement. The higher radius highlights the larger connections of the campus streets to the surrounding urban context and the whole city. Highly central streets in the global centrality analysis are essentially the streets that connect the campus to the rest of the city. A separate set of analyses included the inner building paths in the calculations to study their significance as alternative links of movement.

Attraction Betweenness includes origin and destination points in the spatial network analysis, in this case the building entrances. It calculates how many shortest paths that connect the building entrances pass through every street segment. The results show not only streets that are well-connected regarding the street network, but also in relation to the building entrances, which are the main origins and destinations of movement on the campus. Only the main entrances were included and not the back service doors. The entrances of private residential buildings were also not included.

We combined the network centrality analysis with visibility analysis using **VGA (Visibility Graph Analysis)** (Turner 2004; Turner et al 2001). The VGA breaks the analysed area in small tiles (i.e. 10cm x 10cm) and calculates all the mutual visual relations (i.e. direct visual connections) between all tiles. Two measures are used in this study, the Visual Integration and the Through Vision. **Visual Integration** calculates the visual centrality of each location, meaning how visually connected it is to all other locations, in other words how visible or visually prominent or how hidden it is from all other locations. A location with high visual integration also offers large overviews of the environment, and good orientation with wide and long vistas. **Through Vision** calculates how many lines of visibility pass through each location and it is a function of movement potentials in a layout (Turner 2007). The importance of buildings is evident for the visual centrality of each location as buildings are visibility boundaries and frame the pedestrians' fields of view.

3

3.2 Results of spatial and visual analysis

The streets that have high centrality in all global and local scales are first the ones that surround the campus and provide access from the rest of the city, i.e Gribraltargatan, Aschebergsgatan and Läraregatan (Fig 19, 20, 21, 22). They are followed by Sven Hultins gata, which is also a campus boundary although less connected to the rest of the city. Although Eklandagatan in general has a very high global centrality, when it comes into the campus its centrality drops. However, both Eklandagatan and Engdahlsgatan show high local centrality.

Chalmers tvärgata also shows very high centrality in all scales and is the more central street in the inner campus area. This means that it is not only a key street for the internal connections within the campus but is also a street that mediates larger connections to the urban surroundings and the whole city. The path consisting of Chalmer tvärgata to Chalmersplatsen and Aschebergsgatan is highlighted as an important path through the campus that can connect the Johanneberg neighborhood to Landala and Kapellplatsen. The importance of Chalmers tvärgata that is shown by the spatial analysis results is validated by the empirical data of the actual pedestrian flows presented in the previous section. Chalmers tvärgata is the street with the highest flows throughout the day and throughout the whole week, with no exception.

The central role of Chalmers tvärgata in all scales, and its potential to mediate the longer trips to and from the rest of the city with the shorter trips within the campus, in turn boosts the significance of the Chalmersplatsen entrance to the campus. Although other campus entrances are also located in highly central streets (e.g. Aschebergsgatan) and are also very close to public transport stops as Chalmersplatsen (e.g. Kapellplatsen), they do no show as high rates of people entering the campus. The main difference of Chalmersplatsen in relation to the spatial structure is that it directly connects to the most central street of the inner campus area, that is Chalmers tvärgata.

Fig 19. Street centrality, Global, 5km

3

This potential provided by the spatial structure is further supported by popular attractions (Student union) by the use of architectural design and signage to make this entrance the most recognized and representative entrance of Chalmers. The large width and high visual integration (Fig 22) of Chalmers tvärgata makes it the more central visual corridor on the campus, offering an overview of many locations along its length, long lateral vistas to side streets and long perspectives ahead. It is easy to find as it is visually well-connected. A pedestrian walking on the street is visible from many other locations and streets, and thus “sees” and is “seen” from many others. This helps orientation and also increases awareness of others.

Focusing on the local centrality within the campus (Fig 20), apart from Chalmers tvärgata, also Enklandagatan and Engdahlsgatan show high centrality. Eklandagatan also shows high Visual integration and high Through vision (Fig 21,22), although the dense vegetation in reality hinders the long views to the Science park area. However central these streets appear in the spatial and visual analysis, they show very low intensity of pedestrian movement. Engdahlsgatan is mainly a street for cars with little support for walking, such as provision of continuous sidewalks on both sides. There is potential created by structure on the local scale, but it is not supported enough with infrastructure for walking or with activities along the streets. At the end of these streets, the restaurants at the Science park attract some local movement, especially during the lunch break, but it seems to come mainly from within the campus and not Gibraltargatan (Fig 15).

Sven Hultins gata and especially the part connecting the Student union through Geniknölen has a high local street centrality, which was also reflected by the high intensity of pedestrian movement (Fig 23). Teknologgården also shows very high visual integration, as do all intersections of Chalmers Tvärgata (Fig 22). All these locations are associated with very high levels of co-presence as was described in the

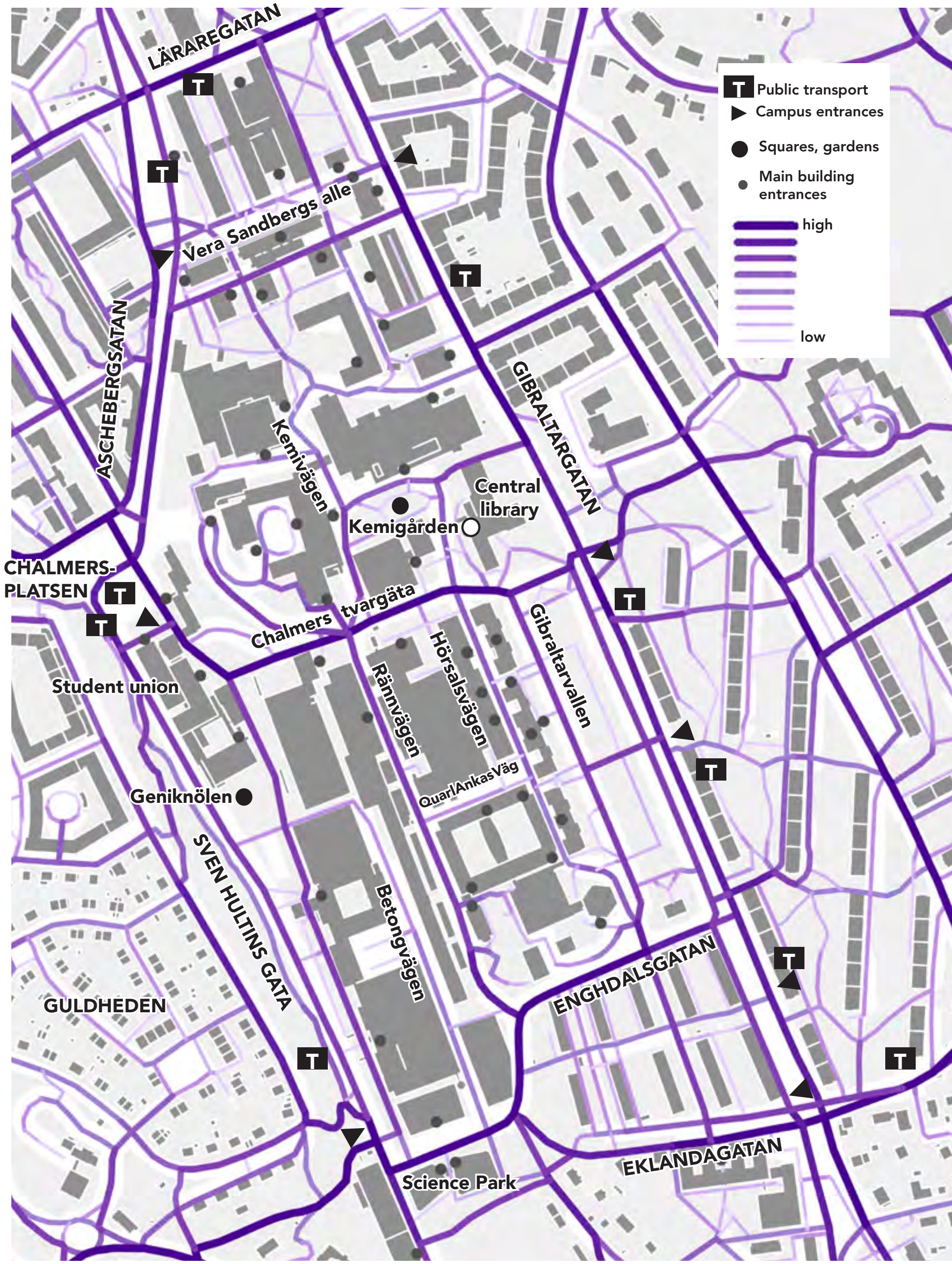


Fig 20. Street centrality, Local, 1km

previous section.
However, when looking at the four parallel north-south streets, Betongvägen, Rännvägen, Hörsalsvägen and Gibraltarvallen, only in the case of Betongvägen the level of street centrality matches the level of observed pedestrian flows. Hörsalsvägen has a low centrality in all its length, although very high pedestrian flows were consistently recorded on its northern part, from Chalmers tvärgata to Quarl Ankas väg. On the contrary, Rännvägen shows much higher centrality but much lower pedestrian flows. The same is true for Gibraltravallen. All four streets show approximately the same high levels of Through vision (Fig 21). Their visual integration is differentiated, but is again, not consistent with the levels of observed movement flows. This suggests that the centrality potentials created by the spatial structure are largely increased, or counteracted and skewed by other factors.

A strong distinguishing factor between these parallel streets is the different density of building entrances (Fig 20). Given that it is a university campus with an expected high-amount goal-oriented movement, the location of the building entrances, as origins and destinations of movement, is key.

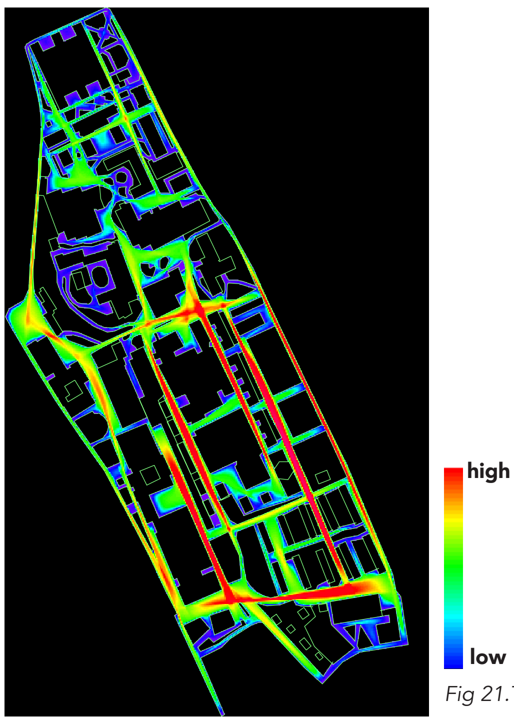


Fig 21.Through Vision

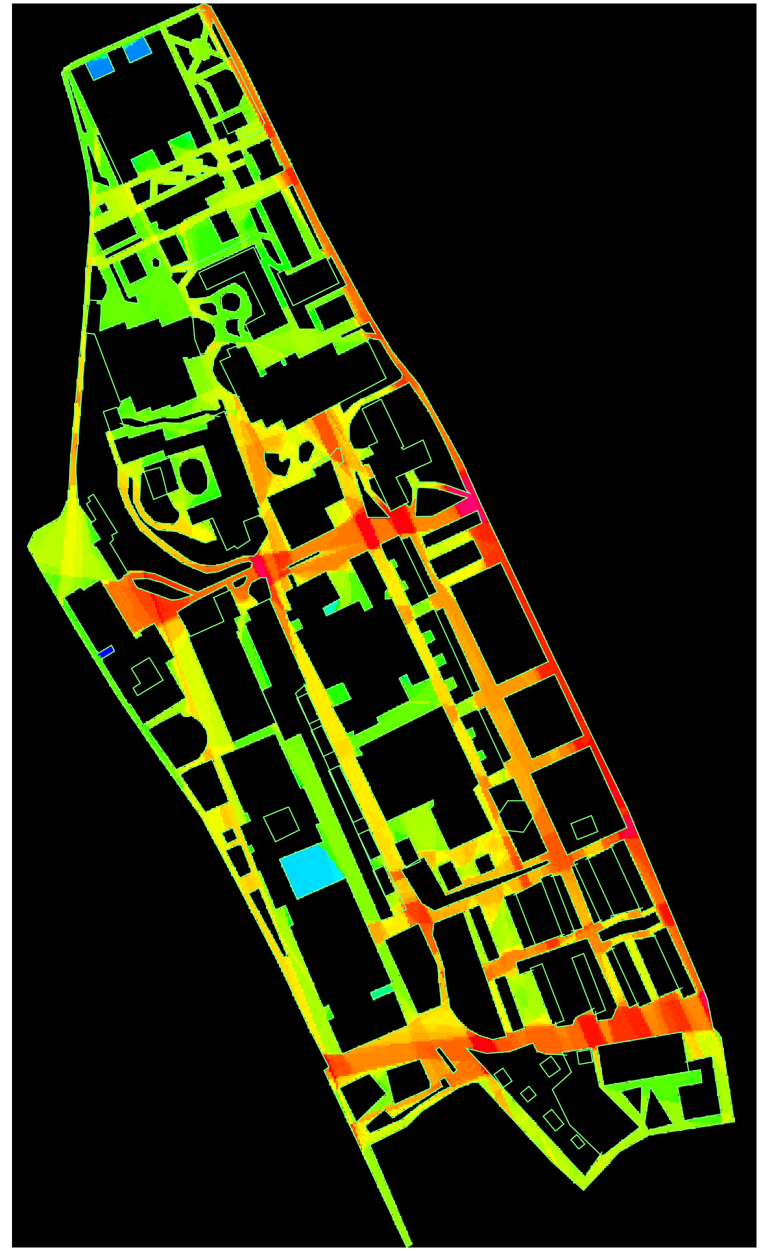


Fig 22.Visual Integration

The Attraction betweenness analysis shows that Hörsalvägen has very high centrality, when the main building entrances are included as origins and destinations of movement (Fig 24 to Fig 25). Also, highly central is Chalmers tvärgata and its link to Chalmersplatsen and Aschebergsgatan. The centrality of Gibraltravallen and Betongsvägen drops, since they offer little access to building entrances. Rännvägen's centrality also drops, but mainly in its lower part. The centrality of Enklandagatan and Engdahlsgatan is also significantly lower in comparison to the street centrality analysis, without taking into account the building entrances. On the contrary, Kemivägen, Skeppgränd and Kemigården towards Chalmers library show increased centrality in the Attraction betweenness analysis.

It is clear that the hierarchies of the streets as created by spatial structure alone, are reconfigured when building entrances are included as attractions and as origins and destinations of movement. The latter in many cases reflect more

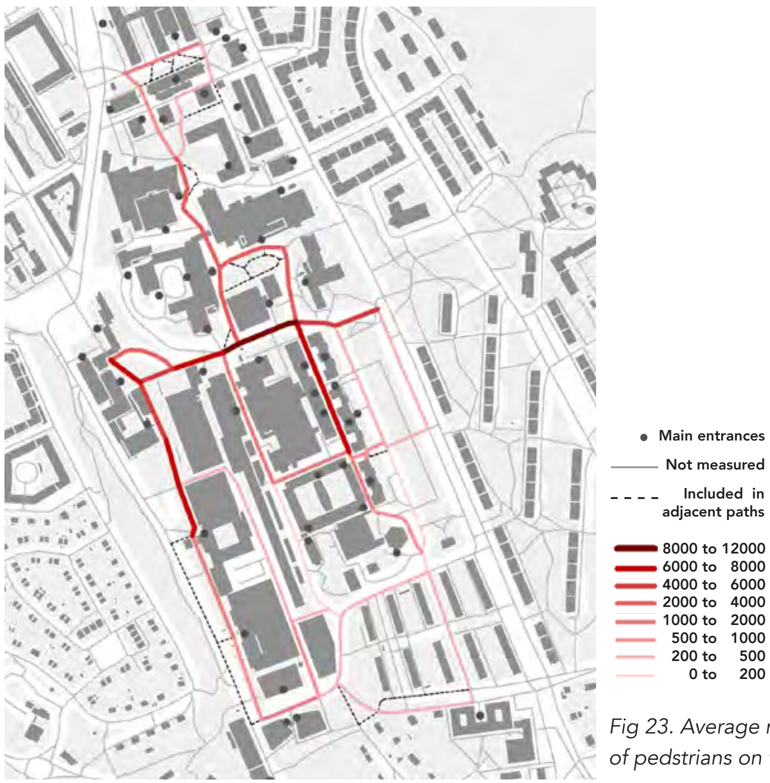


Fig 23. Average number of pedestrians on workdays

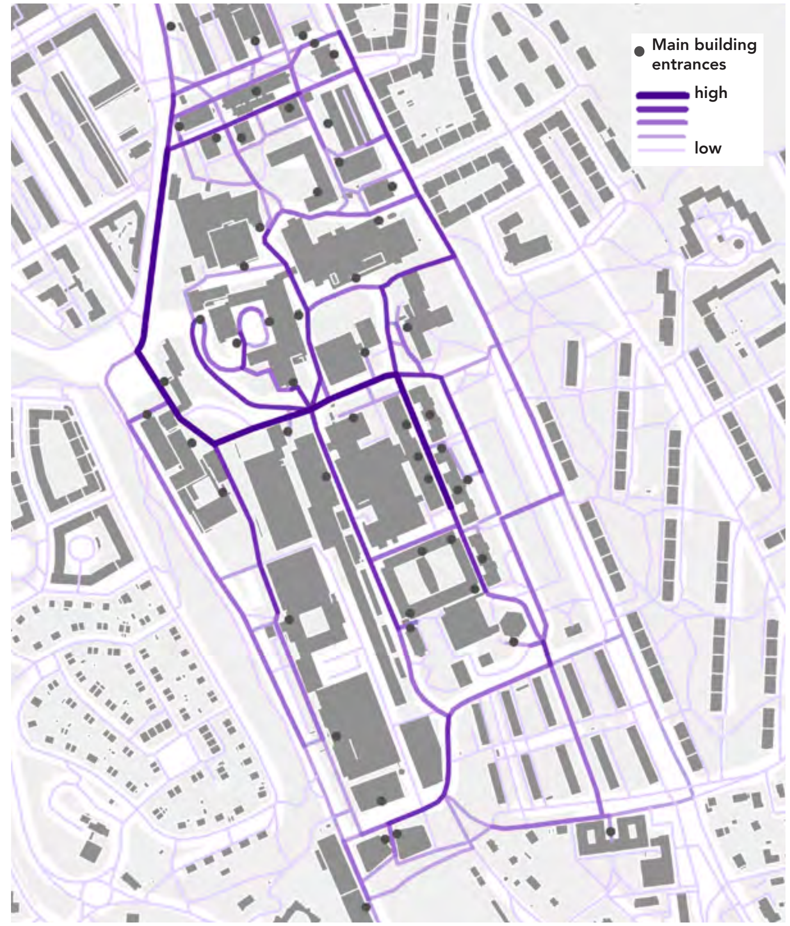


Fig 24. Attraction Betweenness centrality (attractions: building entrances)

accurately the distribution of movement flows on the campus area. As was discussed in the introduction, this can be related to the increased nature of goal-oriented movement expected in a campus environment, in comparison to other parts of the city, where the "natural movement" created by the spatial structure alone is the primary driver of pedestrian movement (Hillier 1993).

Using this input and the deeper understanding of how pedestrian movement and co-presence is guided by the collaboration of spatial structure with the distribution of building entrances, the next section studies the future campus of 2050, based on the proposed development plan. The same spatial analyses are used in order to first, assess the new potentials created by the new spatial structure alone, and second, to explore how these potentials can be enhanced by the distribution of the new building entrances.

4 FUTURE CAMPUS

4. FUTURE SPATIAL STRUCTURE AND EXPECTED CHANGES IN THE PATTERNS OF MOVEMENT

Using a before-after comparison of the 2050 plan to the existing situation, we can study the changes and new potentials created by the future spatial structure. In the future situation, the global centrality of the main streets connecting the campus to the rest of the city remain stable and high (Fig 26 to Fig 25). In the future plan, Eklandagatan gains a lot of centrality in the global scale, in contrast to Engdahlsgatan which centrality remains low.

The main changes to the spatial structure in all scales are observed in the area southern to Chalmers tvärgata, where with the replacement of buildings, new east-west links are created, significantly transforming the current spatial structure (Fig 26, 28). A new path with very high centrality in all scales is created connecting Gibraltragatan to Sven Hultins gata and the Student union crossing all east-west connections (Gibraltravallen, Hörsalsvägen, Rännvägen, Betonvägen) (See Fig 28, marked with dotted lines). Its centrality is at the same ranges as Chalmers tvärgata. Since, there is already a campus entrance from Gibraltragatan connected to this, it is expected to be a significant attractor of local and global movement in the campus. A new square is located along the new link with potentials of high "through movement".

What also changes significantly in comparison to the current structure is the centrality of Betongvagen, which in the future structure is highly increased. Betongvagen is transformed into a very important path in the new structure which directly connects to the Student union through the added diagonal path. Together with Rännvagen and the new east-west links they create a new centrality core,

Fig 25. Street centrality
Global, 5km
Existing situation

Fig 26. Street centrality
Global, 5km
2050

4

expanding the current centrality of Chalmers tvärgata to the southern parts of the campus. On the contrary, Hörsalsvägen's centrality does not increase in comparison and remains relatively low. All added east-west links have relatively high centrality and have a potential to create strong connections, which can be increased if they are extended through the SB buildings with inner-paths (Fig 32).

The street network centralities of the upper part of the campus, north of Chalmers tvärgata, are not that affected by the new spatial structure, since no new north-south or east-west links are added. Still Kemivägen is the primary way through. The visual centralities do not change in a significant way as well. What has the potential to create a new strong north-south link is the added inner path through the Chemistry building (Kemihuset) (Fig 32, circle 1) that continues Hörsalvägen to the north, reaching Läraregatan.

The analysis of the existing situation showed that although the spatial structure alone creates the potentials to attract movement and co-presence, the distribution of attractions, for example building entrances, as the origins and destinations of movement, has a strong impact as well.

It is not only a matter of how many entrances are located on each street that would make it an attractive destination; it is rather the ability of each street to provide legible "shortcuts" that effectively connect various close of distant entrances and be an essential part of the everyday movements between buildings.

Fig 27. Street centrality
Local, 1km
Existing situation

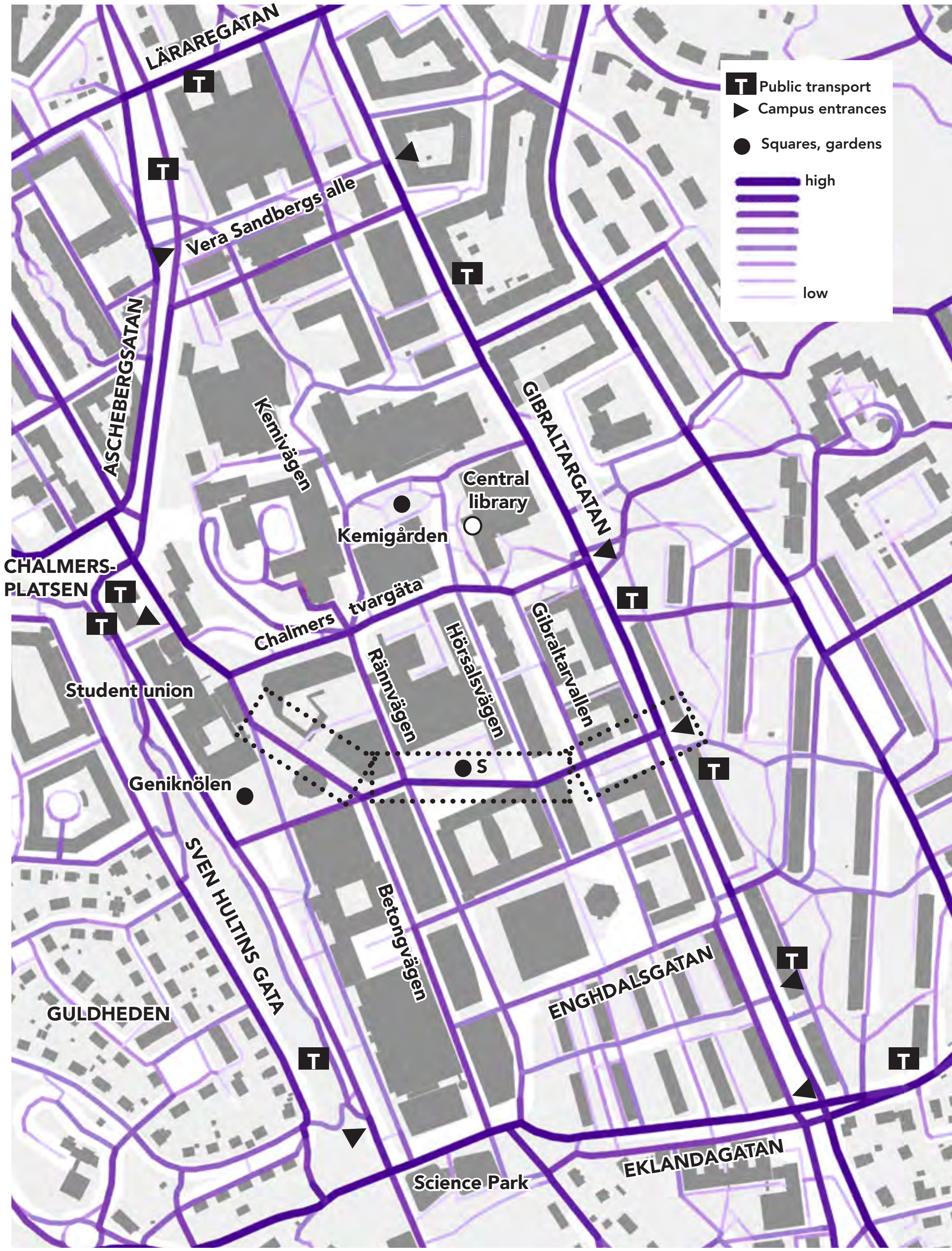


Fig 28. Street centrality, 2050, Local, 1km. The new high centrality path is marked with dotted lines

4

This centrality created by the collaboration of spatial structure and the distribution of entrances was calculated using Attraction betweenness analysis (see again Fig 29. for existing situation). It was shown that the presence of building entrances can boost the activity attracted by spatial centrality even further (e.g. Chalmers tvärgata) or support less central streets (e.g. Hörsalsvägen). On the other hand, the absence of attractions can counteract the centrality potentials created by structure (e.g. Rännvägen). The comparison of Hörsalsvägen and Rännvägen, two close, parallel and seemingly similar streets, was revealing; the, first, less-connected but dense with attractions (entrances to schools, restaurant, small square etc) attracted a lot more pedestrian movement, than its neighbor well-connected but empty of attractions, Rännvägen.

This kind of analysis, although it can only rely on a hypothetical set of building entrances can be very useful for the future situation as well. In the test presented in Figure 30, we made a intentional choice the buildings that face both Betongsvägen and Rännvägen. All entrances were added to Rännvägen, first, to reflect the stated intentions of Chalmersfastigheter and Akademiska Hus to further support Rännvägen to attract pedestrians and activities and, second, because it is more probable that this will be the case due to the height difference of the two streets. Betongvägen is currently facing the back side of the SB1-SB2 building and there seem to be no plan to add more entrances on that street.

As in the existing situation analysis, the results show that the street hierarchies created by the spatial structure alone (Fig 28) can potentially change when including entrances. Although the analysis is based on a hypothesis for the new entrances, it

Fig 29. Attraction Betweenness centrality Existing situation (attractions: building entrances)

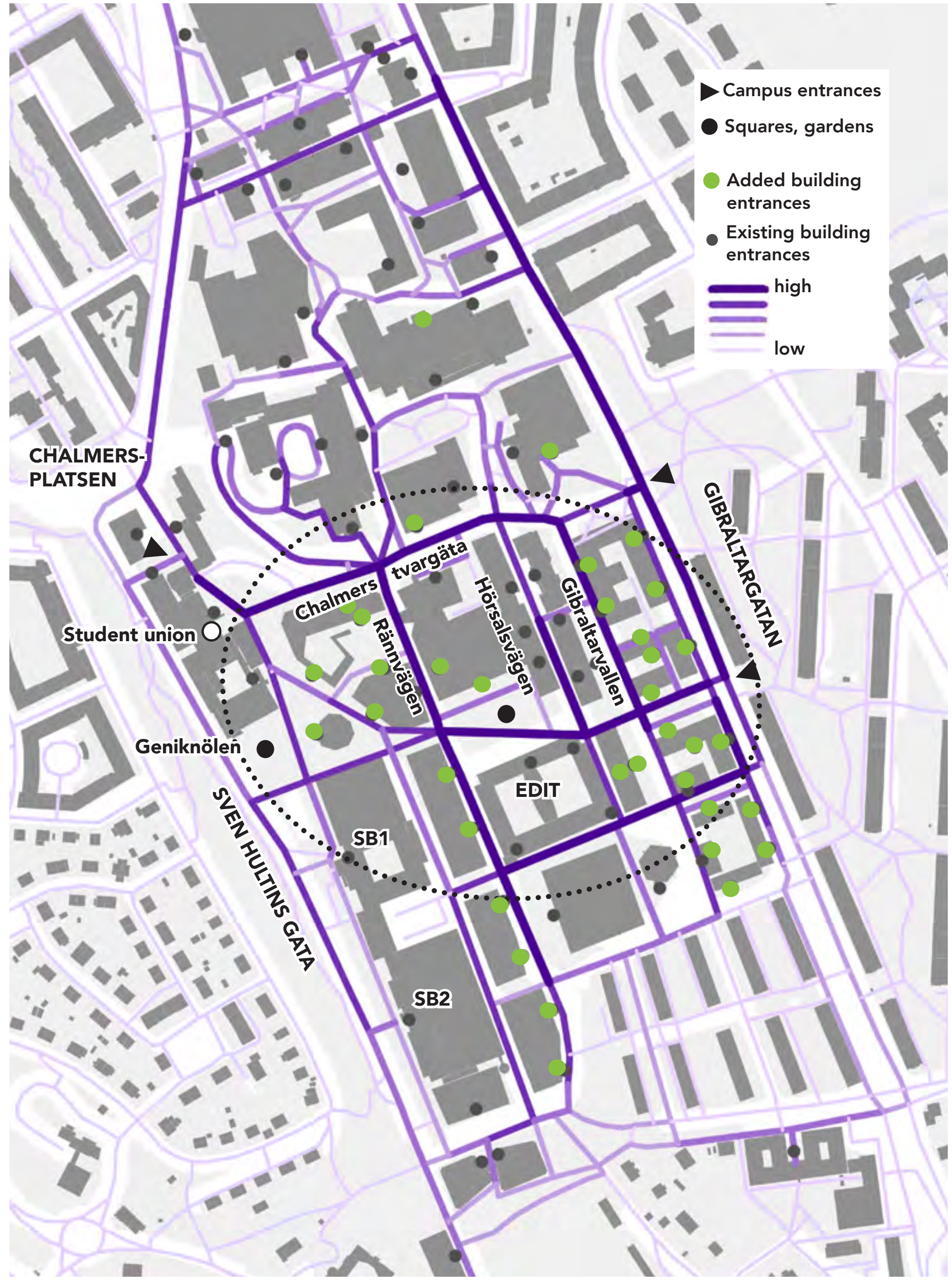


Fig 30 . Attraction Betweenness centrality 2050 (attractions: building entrances) nevertheless highlights the potential for a new centrality area to be created in the campus (Fig 30), in contrast to the existing situation where the centrality is mostly concentrated on three main streets (Fig 29).

This new area (dotted circle) extends from Chalmers tvargäta south to the end of the EDIT building and from Gibraltarvallen to Rännvägen and to the new diagonal link to the Student Union. The intentional support of Rännvägen with new building entrances as opposed to its parallel Betongvägen is reflected in the results. While the spatial structure creates similar centrality between the two (Fig 28), the distribution of attractions shifts the centrality to Rännvägen, creating a clear hierarchy between them. Rännvägen shows the potential to carry activity to the southern end of the campus, connecting directly to Science park area. More variations and nuances in the hierarchy of the streets can be created within the new centrality area with adding or removing attractions, in order to boost activity in certain streets and preserve quieter and more private areas in others.

The analysis shows that the centrality north of Chalmers tvärgata is not further supported by the new building entrances, in comparison to the existing situation. The main reason is that, as is already described, the spatial structure of the upper part of the campus remains largely unchanged in the future plans, except from the new inner-path link added through Kemihuset (Fig 32, 1).

Fig 31. Street centrality 1km, Including Inner paths in buildings Existing situation

Fig 32. Street centrality 1km, Including Inner paths in buildings (dotted circles) 2050

5 CONCLUSIONS and NEXT STEPS

5.1. CONCLUSIONS

The study of pedestrian movement at Chalmers campus Johanneberg mapped and analysed the patterns of movement and co-presence at the outdoor spaces of the campus. The aim was to, first, understand how these relate to and are driven by the existing spatial structure of the campus, and, second, to assess the expected changes on the patterns of movement and co-presence at the future campus, based on the development masterplan "Chalmers 2019-2050, Campusplan. Människor och möten för en hållbar framtid".

The pedestrian survey gathered empirical data that offered an detailed overview of movement and co-presence during typical workdays and weekend, during day and night and during special events. The results showed that are there are strong temporal trends in the movement patterns that follow everyday routines (i.e. go to work or class, lunch break, leave campus) and explain the fluctuations in the intensities of movement and co-presence. The intensities are much higher on workdays than on weekend, on working hours than on evenings and nights, expect from special events, as was the Pub Crawl on the week of the survey. There are the same clear morning, lunch and afternoon peaks recorded in all workdays. However, while the general temporal trends are proven decisive, there are also very strong general spatial trends that remain stable throughout the week, also during the evenings and weekends. What is clear is that although the volume of people in the campus changes depending on the time or whether it is a workday or weekend, the distribution of these people follows constant spatial patterns. In simple words, paths and nodes that have the highest intensity of movement during the lunch peak hours (e.g. the whole Chalmers tvärgata, the northern part of Hörsalsvägen, Sven hultins gata from Chalmersplatsen to SB1 through Teknologården and Genikölen), they do so every workday and they also have the highest intensity of movement and co-presence during evenings and weekends. Entrances to the campus that have the highest intensity during the morning peak (e.g. Chalmersplatsen), also have the highest intensity during the whole day.

As the analysis of the existing spatial structure showed, movement and co-presence are driven by a combination of the street's or location's spatial and visual centrality and the spatial distribution of building entrances (i.e. attractions) as the origins and destinations of movement. This can be related to the goal-oriented nature of movement within a university campus in comparison to other parts of the city. It is not only a matter of how many entrances are located on each street that makes it a more attractive destination; it is rather the ability of each street to provide legible "shortcuts" that effectively connect various close of distant entrances and be an essential part of the everyday movements between buildings. Also, streets that are central in all scales of movement, from global to local, such as Chalmers tvärgata are key movement corridors. They are not only significant for the internal connections within the campus but they also mediate larger connections to the urban environment and the rest of the city. Streets like that have the potential to be used from people of the surrounding neighborhoods as shortcuts and ways through.

Based on the assessment of the current situation, a projection of how movement and co-presence patterns might be affected by the new development plans of the campus was made. The new spatial structure designed for the future campus of 2050 further supports Chalmers tvargäta as a central east-west movement corridor. However, more parallel east-west connections are added on the south creating a more connected grid-like structure. In combination to planned new buildings and entrances, there is potential for a new centrality core area on the south part of the campus, in contrast to the existing situation where the centrality is mostly concentrated on three main streets. Emphasis is put on a new link connecting the existing parking entrance from Gibraltargatan to Sven Hultins gata and the Student union crossing all east-west connections (Gibraltravallen, Hörsalsvägen, Rännvägen, Betonvägen), with centrality potentially at the ranges of Chalmers tvärgata. A new square is planned midway with potentials of high "through movement". The distribution of the main building entrances will be key in supporting the potentials created by the spatial structure and also on creating the subtler hierarchies between streets, as for example between Rännvägen and Betongvägen. The new plans do not significantly transform the northern part of the campus where Kemivägen continues to be the main north-south movement corridor and the collector of east-west lateral movements. An interesting potential to create a second longer north-south corridor is created by an inner-path through the Chemistry building (Kemihuset) that can extend Hörsalsvägen all the way up to Läraregatan.

5.2. NEXT STEPS

When imagining the future situation of the campus, what needs to be clear is that as the distribution of attractions, for example the building entrances, can support or counteract the centrality potentials created by the spatial structure, also the building forms, the ground floor plans, the street dimensions and proportions and the overall architectural and urban design of the new environment, have a significant role to play in materializing or hindering these potentials. A clear and consistent brief should be given to all participant architects, urban designers and engineers, regarding the masterplan visions for the future movement and co-presence patterns, for example regarding where movement and activity should be supported or where quieter and more private spaces should be reserved.

The pedestrian survey conducted within this study offered a baseline with empirical data on where and how people move and gather on the campus today. This is not only valuable in each own right, but can be utilized further to post-evaluate the future developments, if similar follow-up pedestrian surveys are done after these take place. Before-and-after empirical studies will offer concrete evidence of the impact of the new developments on the patterns of movement and co-presence on the campus.

Gathering empirical data from the campus on a long-term perspective with repeated and longitudinal surveys or continuous monitoring can be extended to other types of empirics, such as environmental data (e.g. air quality, microclimate), data on energy consumption, or data on the campus' flora and fauna. Such data can be used to assess measures taken to address issues, such as energy consumption, or to design strategies, such as effective greening to support ecosystem services; all in line with the social-ecological sustainability goals of Chalmers.

The study of movement and co-presence on the campus can be extended to the building interiors, not least to the ground floors, which are often part of the movement flows and have an important role as the indoor public places of social gathering. Another extension can be the study office spaces, and highlight the impact of the office layouts on, for example, generating everyday serendipitous encounters and informal 'corridor' meetings and interactions, which have been shown to strengthen collaboration within and across disciplines and divisions, facilitate the flow of information in parallel with the formal communication channels, create social bonding, spread and embed the organisational and social culture, and lead to the emergence of new creative ideas (e.g. Peponis et al. 2007; Wineman et al. 2009, 2014; Salier and McCulloh 2012; Rashid et al. 2006).

Last but not least, a similar pedestrian survey can be conducted on Lindholmen campus to, first, map and assess the existing situation in terms of movement and co-presence, and, second, pre-evaluate potential future development plans for the Lindholmen area.

REFERENCES

Berghauser Pont M., Stavroulaki G., Marcus L. (2019). Development of urban types based on network centrality, built density and their impact on pedestrian movement. Environment and Planning B: Urban analytics and city science 46(8) pp.1549–1564.

Berghauser Pont, M. and Marcus, L. (2015). What can typology explain that configuration cannot? Proceedings of the 10th Space Syntax Symposium (SSS10), London: UCL

Gehl, J., (1987), Life Between Buildings: Using Public Space, Island press

Hanson, J., (2000) Urban transformations: a history of design, Urban Design International, 5, pp.97-122.
Hillier, B. (1996). Space is the machine. A configurational theory of architecture. Cambridge: Cambridge University Press

Hillier, B., Hanson, J. (1984). The social logic of space, Cambridge: Cambridge University Press

Hillier, B. and Iida, S. (2005). Network and psychological effects in urban movement. Proceedings of the 5th International Space Syntax Symposium. Delft: University of Technology.

Hillier, B., A. Penn, J. Hanson, T. Grajewski, J. Xu (1993). Natural movement: or, configuration and attraction in urban pedestrian movement. Environment and Planning B: Planning and Design, vol. 20, 29-66.

Koch, D. (2007). Structuring Fashion: Department Stores as Situating Spatial Practice.
Axl Books, ISBN: 978-91-975901-8-1

Koch, D. and Steen, J. (2012). DECOMPOSING PROGRAMMES. Re-Coding hospital work with spatially syntactic information. Proceedings of the Eighth International Space Syntax Symposium, Santiago, Chile

Legeby, A. (2013). Patterns of co-presence. Spatial configuration and social segregation. Stockholm: KTH University

Legeby, A., Berghauser Pont, M., Marcus, L., (2015) Street Interaction and Social Inclusion. Suburban Urbanities Suburbs and the Life of the High Street (ed. Vaughan L) London: UCL Press, pp. 239-262 doi:10.2307/j.ctt1g69z0m

Marcus, L., (2015). Interaction rituals and co-presence – linking humans to humans in space syntax theory, Proceedings of the 10th Space Syntax Symposium, London: UCL

Netto, Vinicius & Meirelles, Joao & Pinheiro, Maíra & Lorea, Henrique. (2018). A temporal geography of encounters. Cybergeo. 10.4000/cybergeo.28985.

Netto, V., Sabayo, R., Vargas, J., Figueiredo, L., Freitas, C. and Pinheiro. M. (2012) 'The convergence of patterns in the city: (Isolating) the effects of architectural morphology on movement and activity'. In: Greene, M., Reyes, J. and Castro, A. (eds.), Proceedings of the 8th International Space Syntax Symposium, Santiago de Chile: PUC

Ozbil, A., Peponis, J., and Stone, B. (2011). Understanding the link between street connectivity, land use and pedestrian flows. Urban Design International. 16 pp 125-141.

Ozbil, A., Yesiltepe, D. and Argin, G. (2015) Modeling Walkability: the effects of street design, street-network configuration and land-use on pedestrian movement. AlZ ITU Journal of Faculty of Architecture. 12. 189-207.

Peponis, J, Bafna, S., Bajaj, R., Bromberg, J., Congdon, C., Rashid, M., Warmels, S., Zhang, Y., Zimring, C. (2007). Designing Space to Support Knowledge Work. Environment and Behavior, ENVIRON BEHAV. 39. 815-840. 10.1177/0013916506297216.

Peponis, J., Ross, C. and Rashid, M. (1997). The structure of urban space, movement and co-presence: The case of Atlanta. Geoforum. 28, Issues 3–4, 341-358
Read S, (1999), Space syntax and the Dutch city. Environment and Planning B: Planning and Design 26. 251-264.

Rashid, M., Kampschroer, K., & Wineman, J., Zimring, C. (2006). Spatial layout and face-to-face interaction in offices - A study of the mechanisms of spatial effects on face-to-face interaction. Environment and Planning B: Planning and Design. 33. 825-844. 10.1068/b31123.

Read S, (1999), Space syntax and the Dutch city. Environment and Planning B: Planning and Design 26. 251-264.

Sailer, K., McCulloh, I. (2012). Social networks and spatial configuration—How office layouts drive social interaction. Social Networks, Vol. 34, Issue 1. 47-58. https://doi.org/10.1016/j.socnet.2011.05.005.

Schauer, L., Werner, M., Marcus, P. (2014). Estimating Crowd Densities and Pedestrian Flows Using Wi-Fi and Bluetooth. MobiQuitous 2014 - 11th International Conference on Mobile and Ubiquitous Systems: Computing, Networking and Services. 10.4108/icst.mobiquitous.2014.257870

Stavroulaki, G., Bolin, D., Berghauser Pont, M., Marcus L., Hakansson, E. (2019). Statistical modelling and analysis of big data on pedestrian movement. Proceedings of 12th International Space Syntax symposium. Beijing: Jiaotong University, pp. 79.1-79-24.

Stavroulaki, G. and Peponis, J., (2003). The spatial construction of seeing at Castelvecchio, Proceedings of the 4th International Space Syntax Symposium. London: UCL

Whyte, W., (1980) The Social Life of Small Public Spaces, Washington, D.C : Conservation Foundation 1980

Wineman, J., Hwang, Y., Kabo, F., Owen-Smith, J., Davis, G. (2014). Spatial layout, Social structure and innovation in organizations. Environment and Planning B Planning and Design. 10.1068/b130074p.

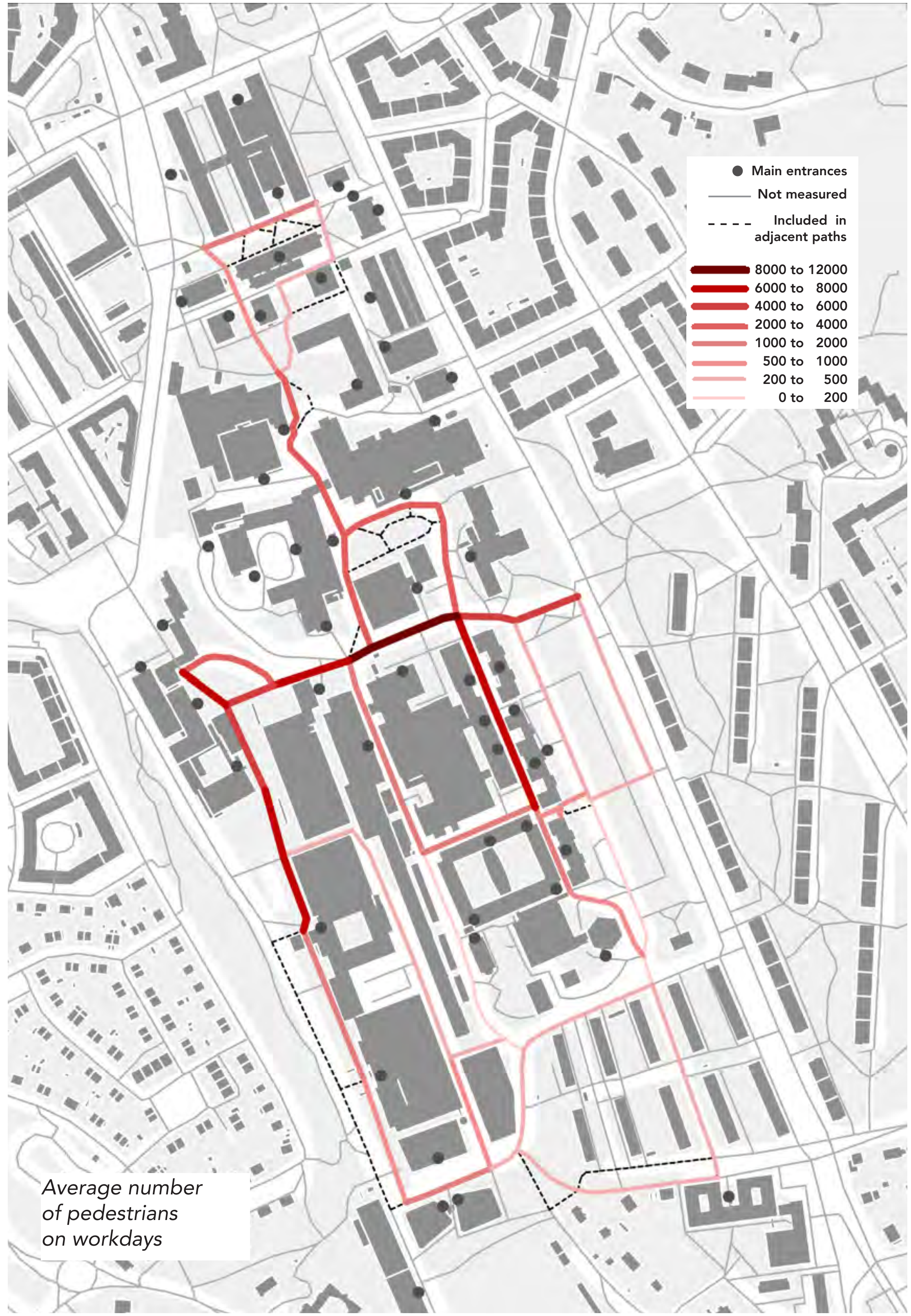
Zamani P. and Peponis J., (2010), Co-visibility and pedagogy: innovation and challenge at the High Museum of Art, Journal of Architecture, 15, 853-879

APPENDIX

PEDESTRIAN SURVEY

PEDESTRIAN FLOWS: WORKDAYS vs WEEKEND

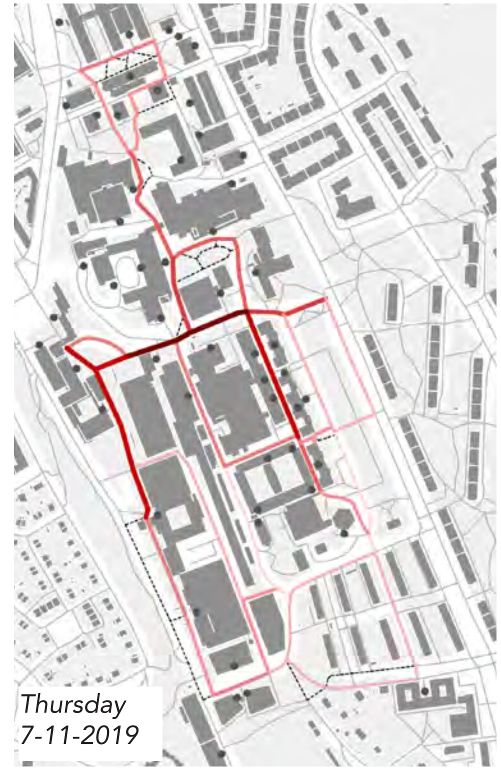
Average number of pedestrians on weekend

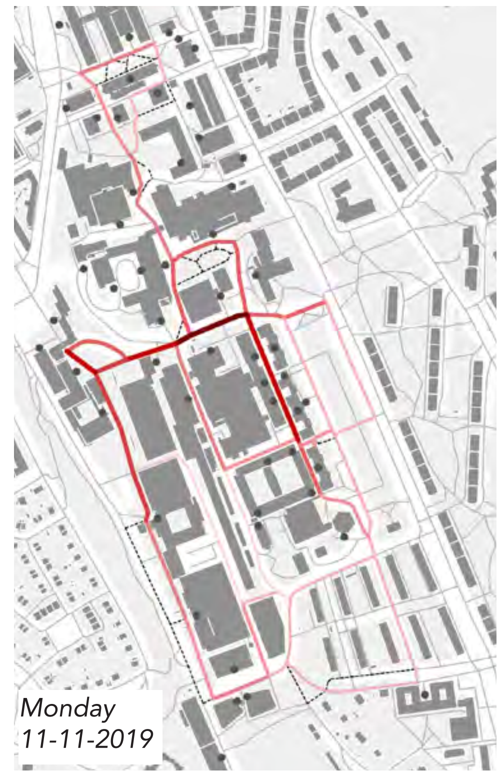


Average number of pedestrians on workdays

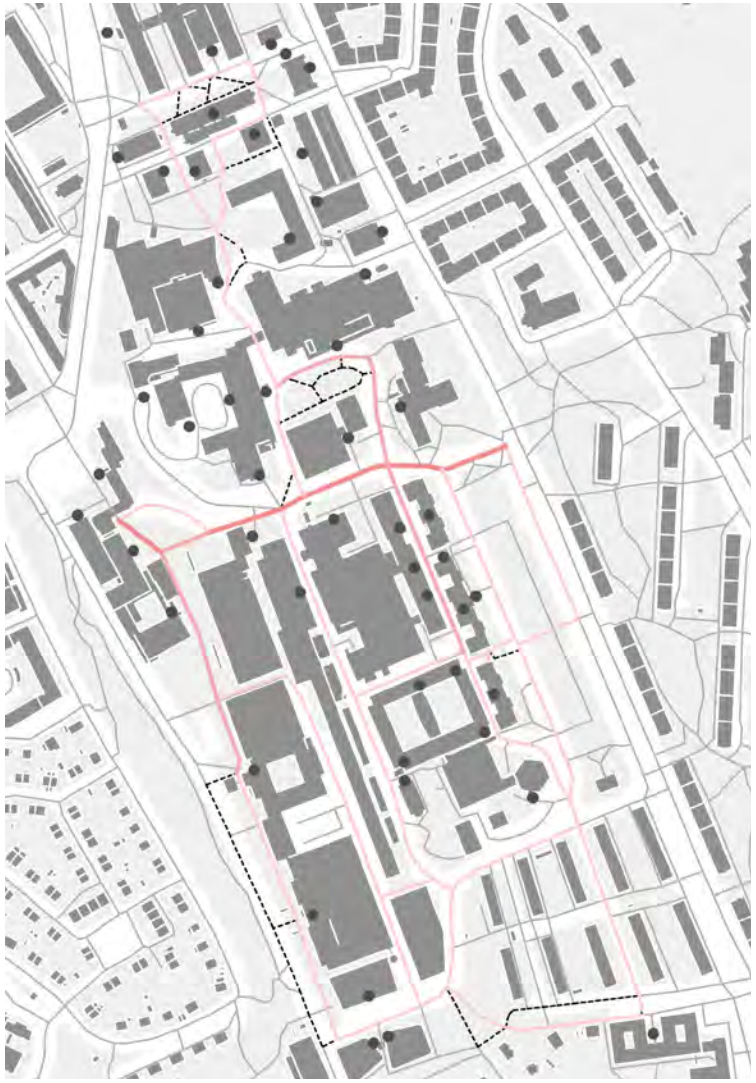
TOTAL PEDESTRIANS PER DAY

● Main entrances
Not measured
Included in adjacent paths
8000 to 12000
6000 to 8000
4000 to 6000
2000 to 4000
1000 to 2000
500 to 1000
200 to 500
0 to 200

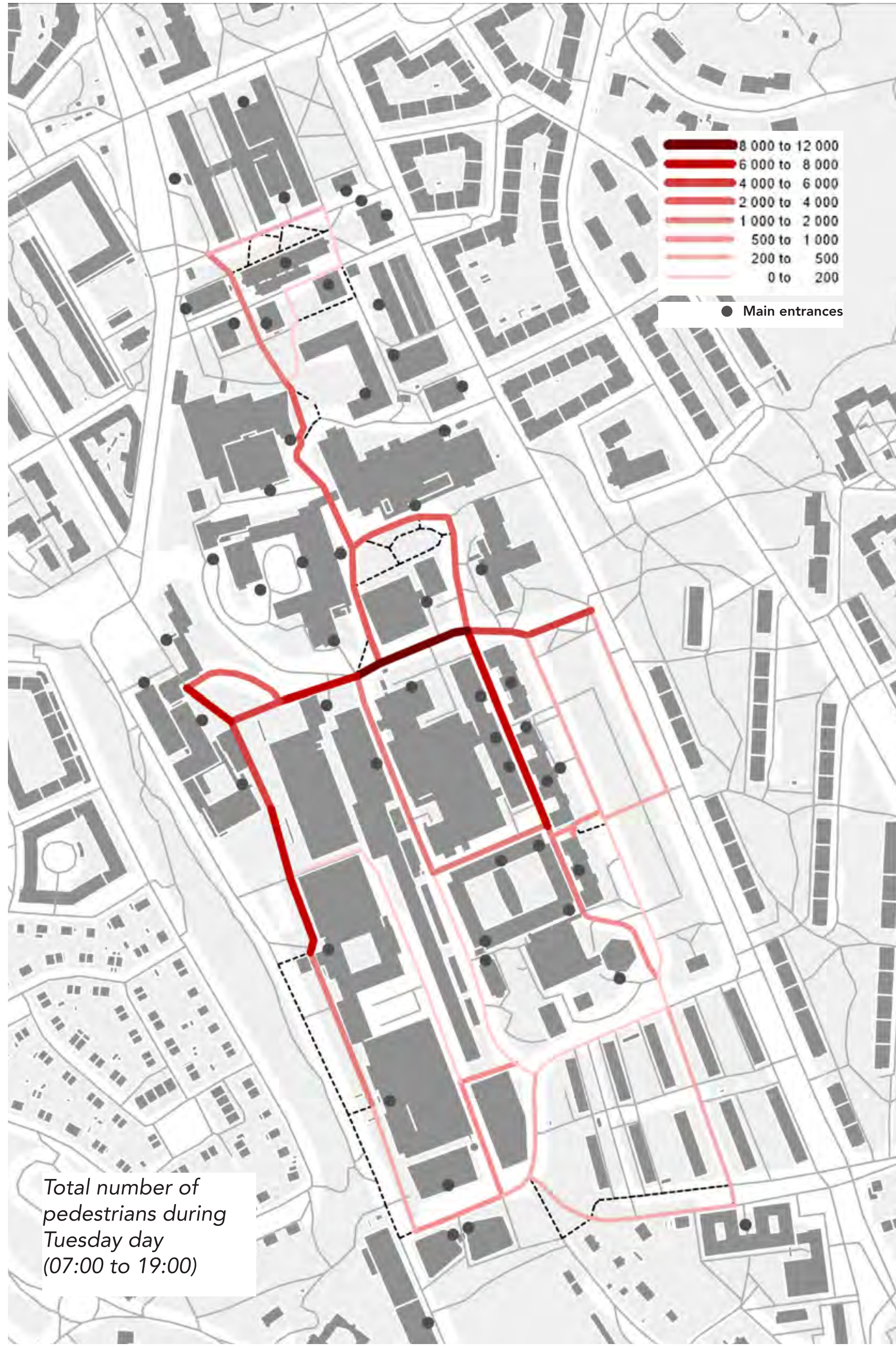




DAY vs NIGHT ON A TYPICAL WORKDAY
Tuesday 05-11-2019



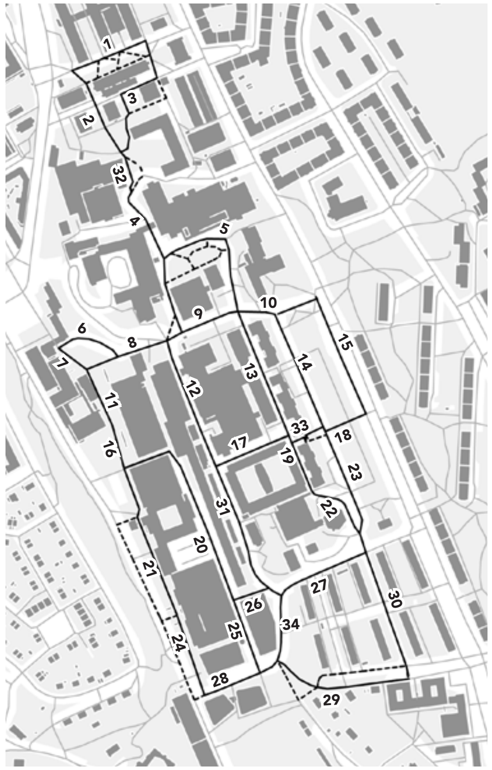
Total number of pedestrians during Tuesday night (19:00 to 07:00)



Total number of pedestrians during Tuesday day (07:00 to 19:00)

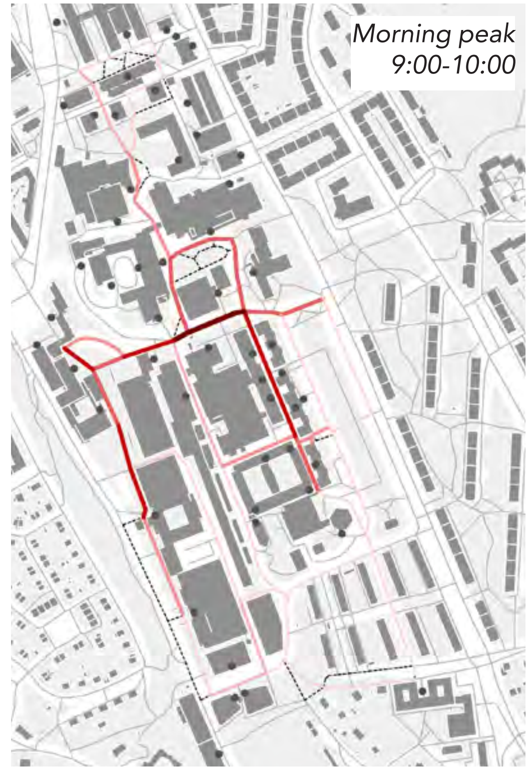
MOVEMENT PEAKS FLUCTUATIONS

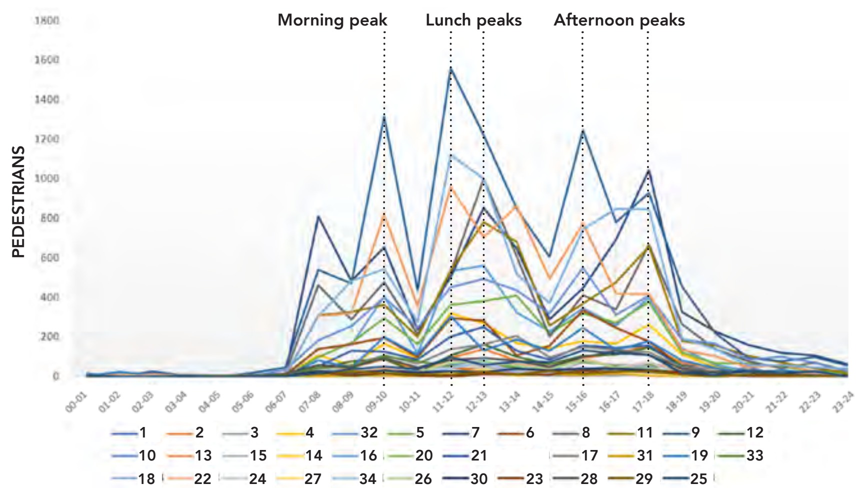
TUESDAY 5-11-2019



● Main entrances
Measured
Not measured
Included in adjacent paths

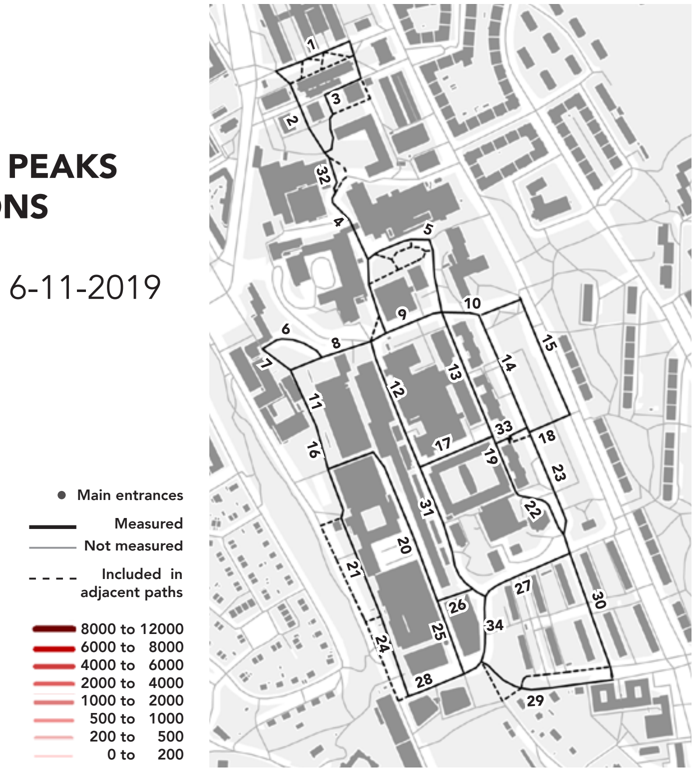
8000 to 12000
6000 to 8000
4000 to 6000
2000 to 4000
1000 to 2000
500 to 1000
200 to 500
0 to 200

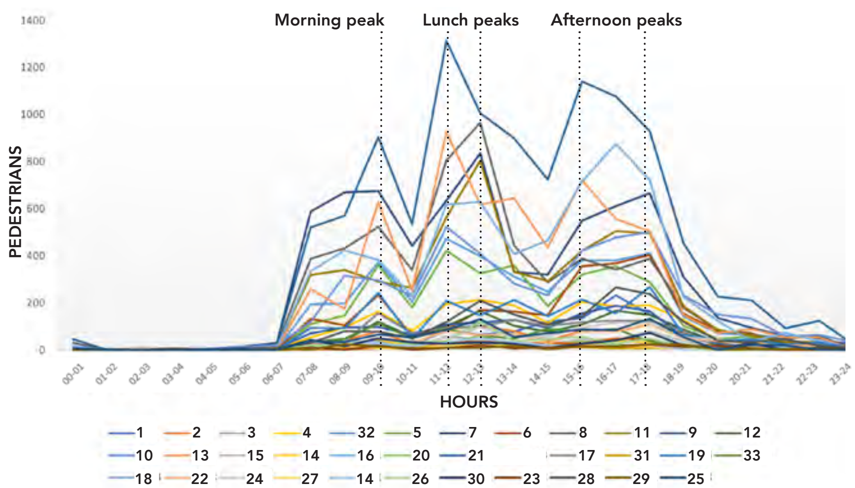


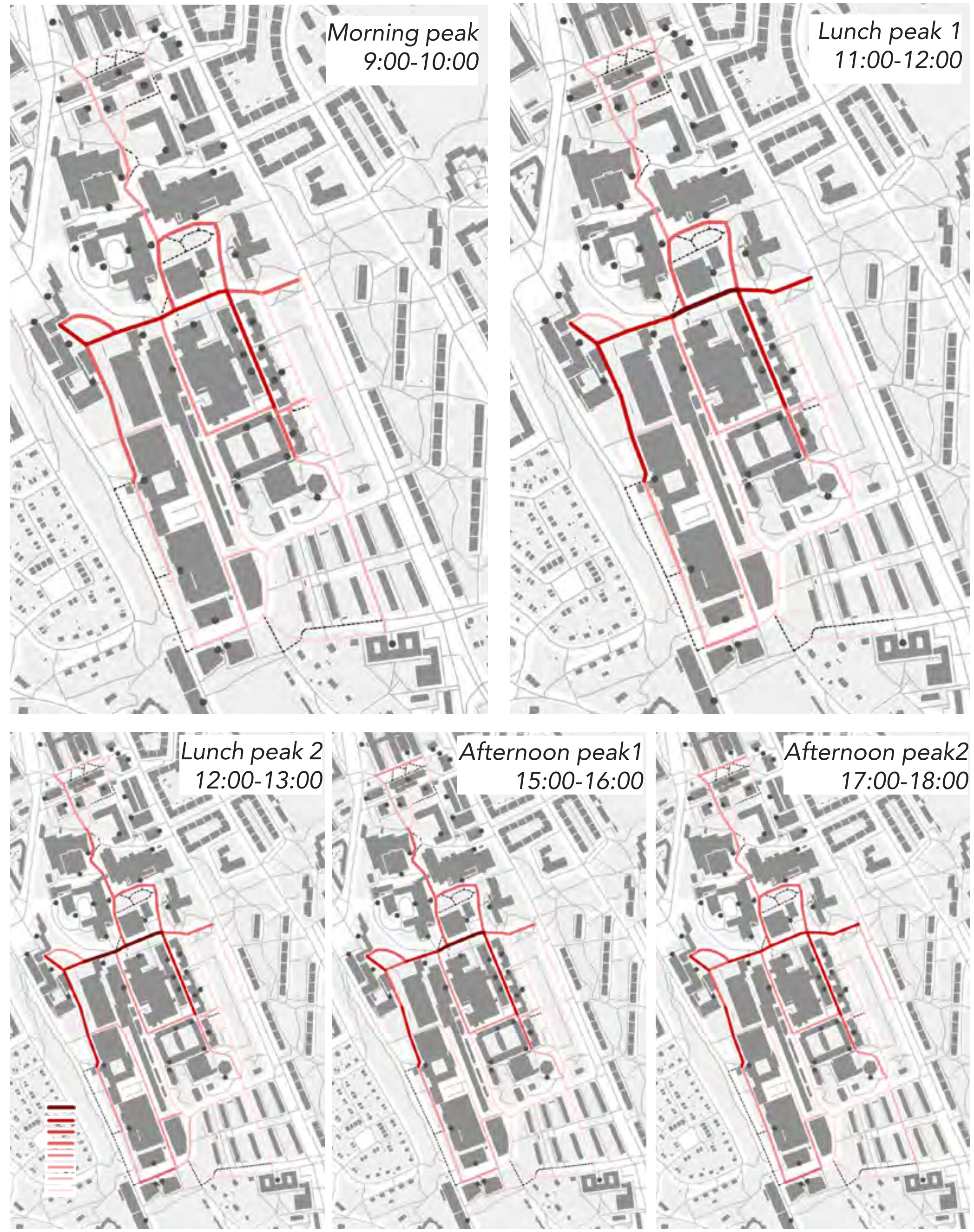


MOVEMENT PEAKS FLUCTUATIONS

WEDNESDAY 6-11-2019

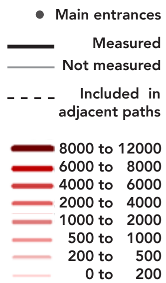


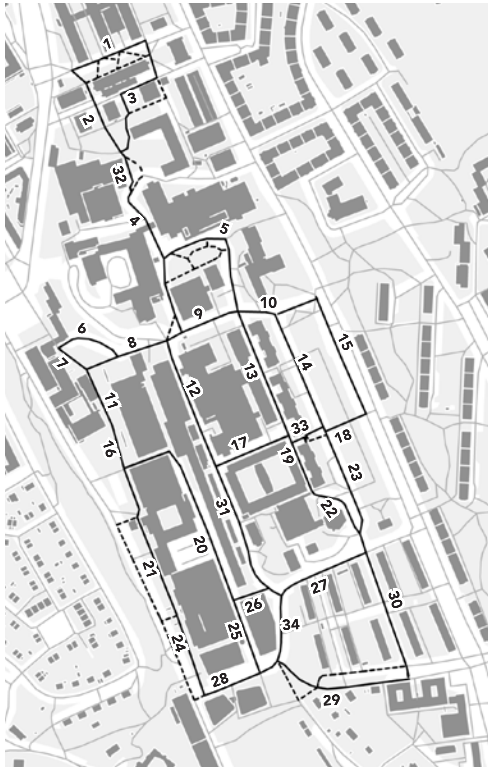


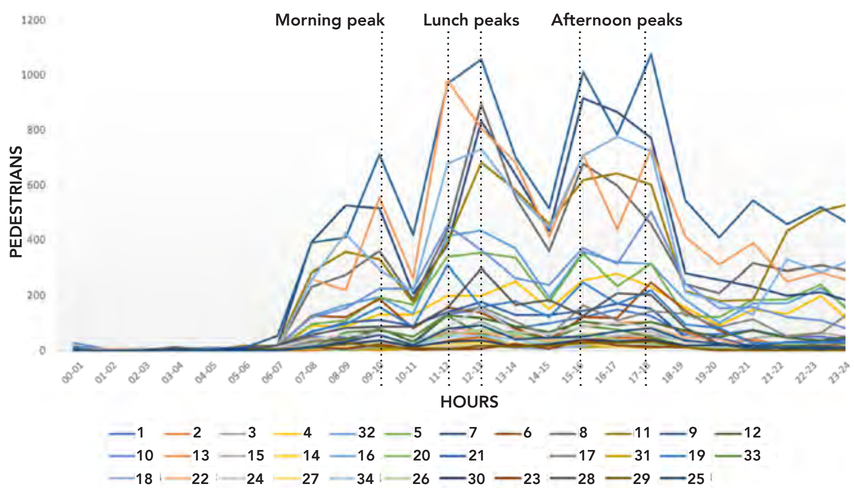


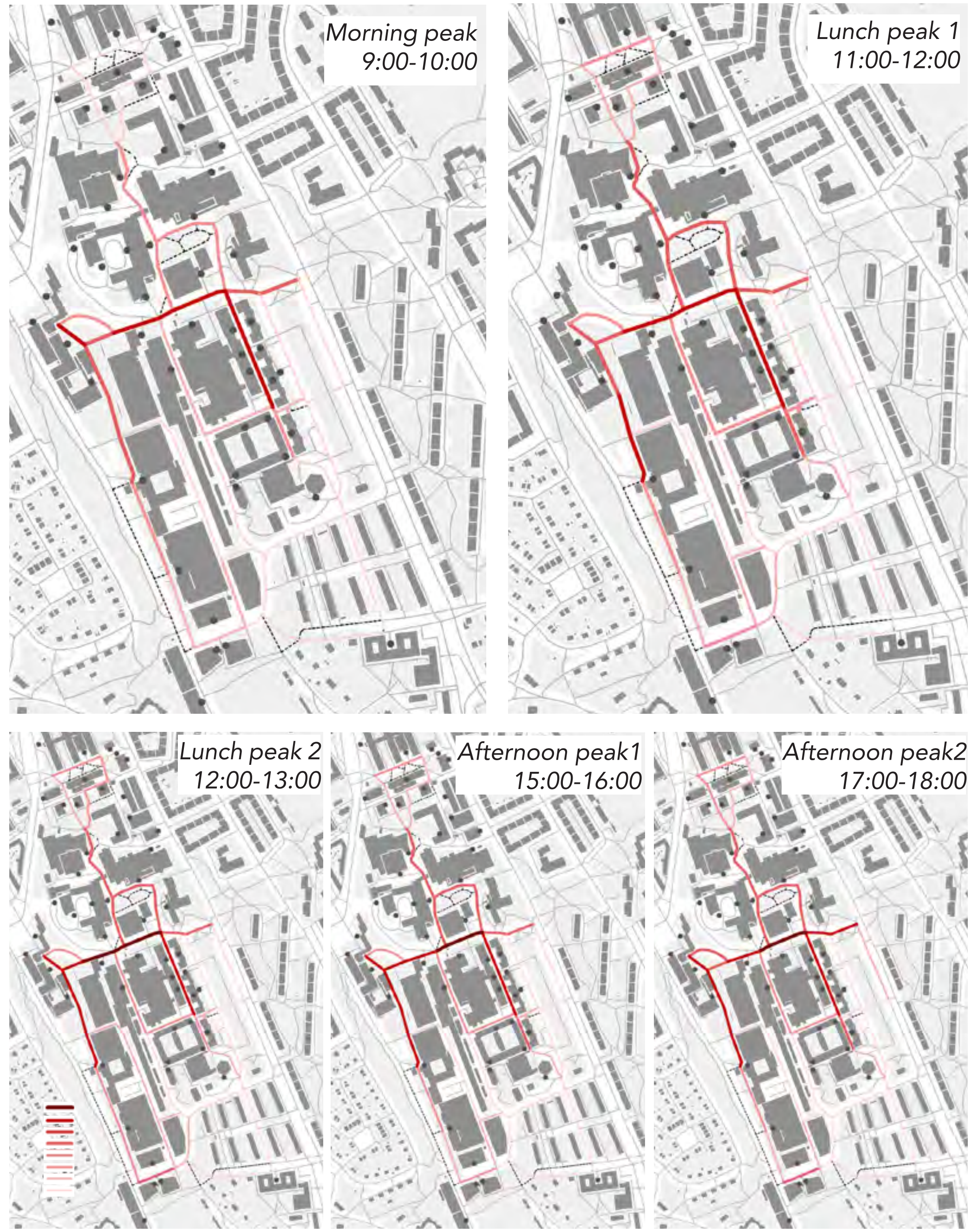
MOVEMENT PEAKS FLUCTUATIONS

THURSDAY 7-11-2019



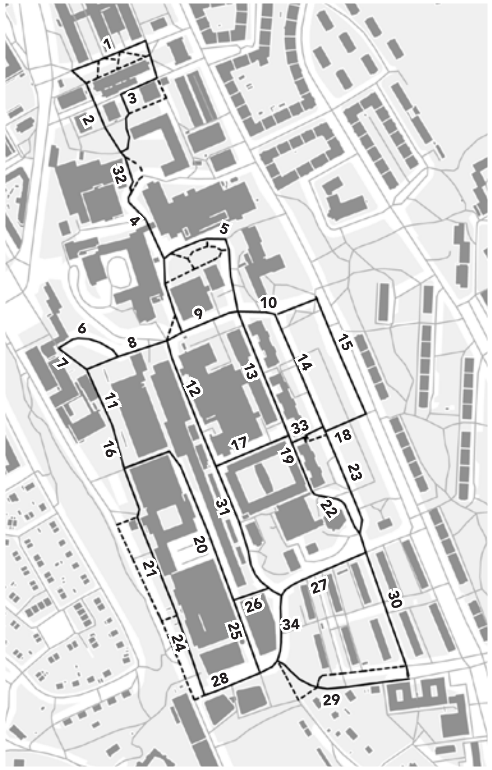




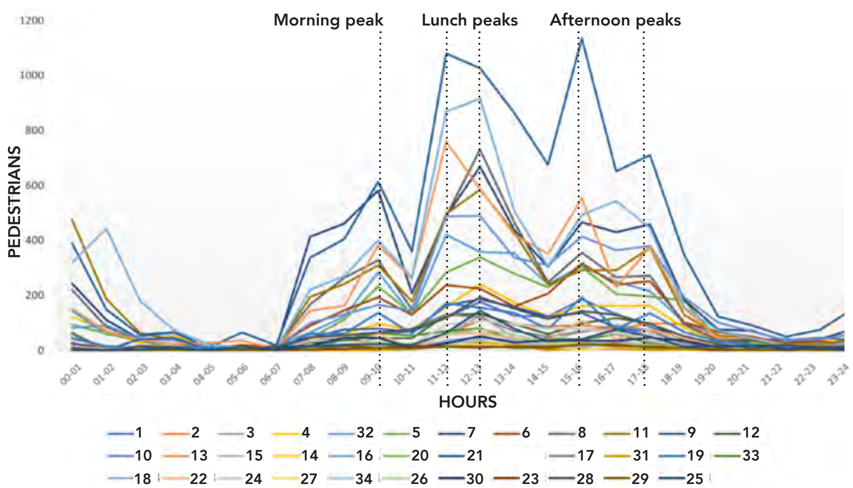


MOVEMENT PEAKS FLUCTUATIONS

FRIDAY 8-11-2019

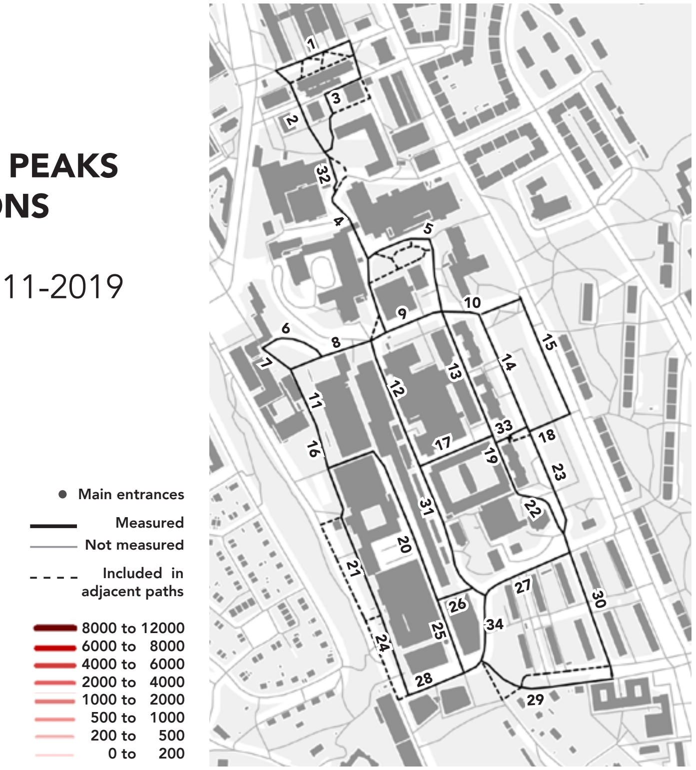


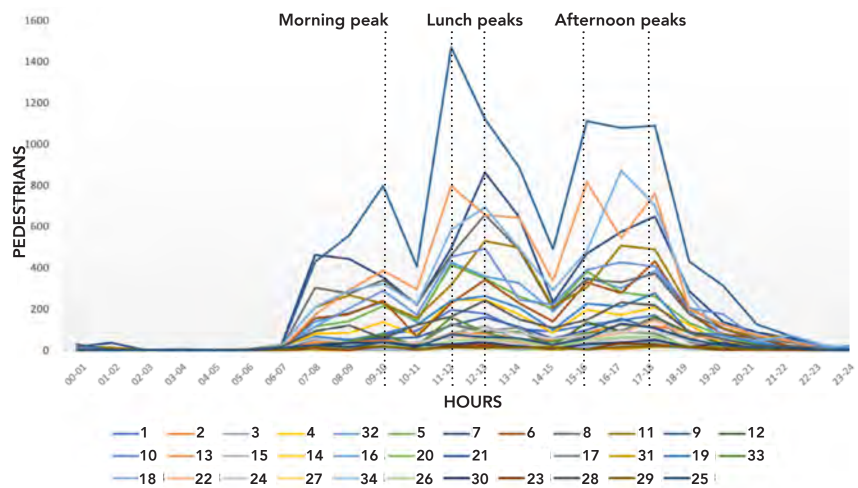
- Main entrances
- Measured
- Not measured
- Included in adjacent paths
- 8000 to 12000
- 6000 to 8000
- 4000 to 6000
- 2000 to 4000
- 1000 to 2000
- 500 to 1000
- 200 to 500
- 0 to 200

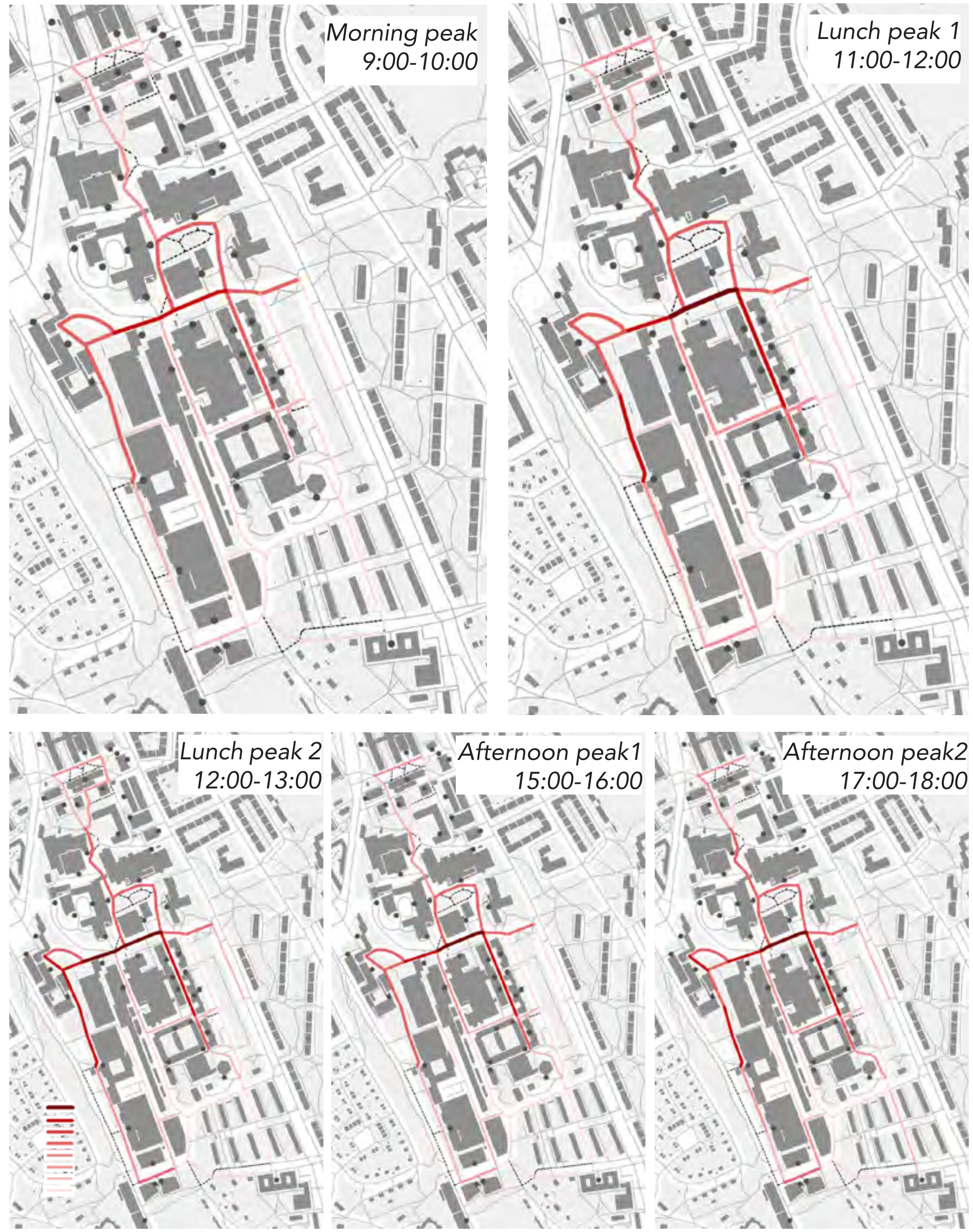


MOVEMENT PEAKS FLUCTUATIONS

MONDAY 11-11-2019



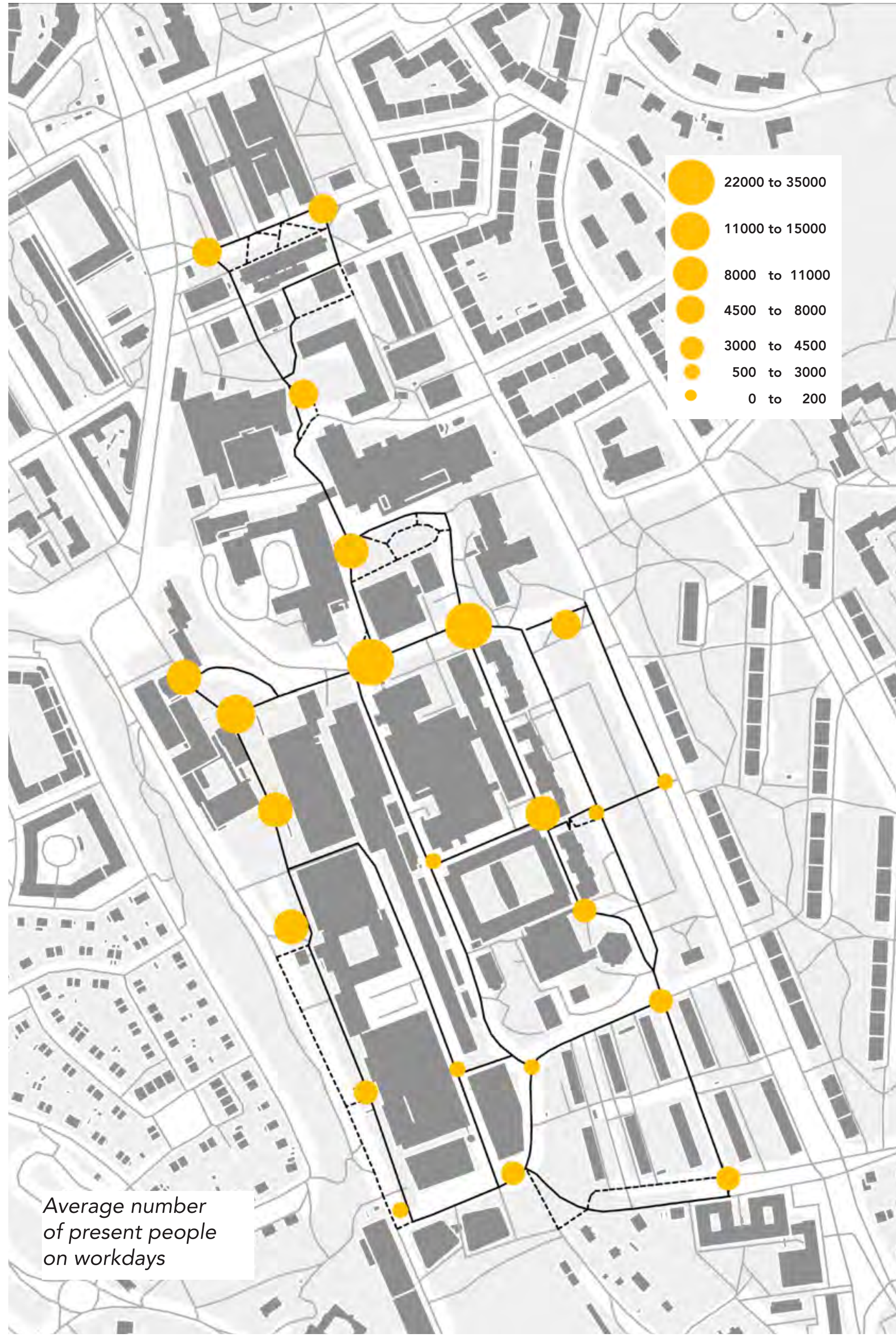




PRESENCE IN NODES: WORKDAYS vs WEEKEND

STANDING AND PASSING PEOPLE
IN CAMPUS ENTRANCES, INTERSECTIONS AND SMALL SQUARES

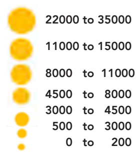
Average number of present people on weekend



Average number of present people on workdays

TOTAL PRESENCE PER DAY

TOTAL STANDING AND PASSING PEOPLE



Spatial Morphology Group, SMoG
2019-2020