Amalie Ravnåmo

Removing Traffic Signals to Prioritise Sustainable Modes

A case study of an urban intersection in Norway

Masteroppgave i Bygg- og miljøteknikk
Veileder: Eirin Ryeng
Juni 2020

Masteroppgave

NTNU
Norges teknisk-naturvitenskapelige universitet
Fakultet for ingeniørvitenskap
Institutt for bygg- og miljøteknikk

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Sammendrag

Etter hvert som bevisstheten rundt klimaendringer øker vil det bli et større behov for å finne transportløsninger som tilfredsstiller kollektivtransport og myke trafikanter. Beslutningstakere i urbane områder må prioritere bærekraftig transport og forplikte seg til et skifte i reisemiddelfordeling. Dette krever at gange, sykling og kollektivtransport blir prioritert i urbane transportnettverk. Dessverre er ikke alltid disse trafikantgruppenes interesser sammenfallende. Signalregulering med prioriteringssystemer benyttes ofte for å forbedre framkommeligheten for busser gjennom bykjerner, men kan også oppfattes som unødvendige hindringer for fotgjengere. Tidligere forskning antyder at å fjerne signalregulering kan føre til forbedra trafikkavvikling, men det er ikke gitt at dette fortsatt stemmer hvis biler må vike for kryssende fotgjengere. Denne studien undersøker hvordan lyskryss påvirker reisetid for buss, kryssingstid for fotgjengere og fotgjengeres kryssingsatferd.

Studien ble gjennomført ved å studere et kryss i Trondheim. Byen har ei befolkning på rundt 200 000, og det studerte krysset ligger i ei trafikkert, nylig ombygd gate. Krysset ble filma tre dager i januar 2020 etter en prøveperiode på ett og et halvt år der trafikklysene var skrudd av. Det ble filma igjen i løpet av tre dager i februar 2020, to og ei halv uke etter at trafikklysene ble skrudd på igjen. Filmene ble analysert manuelt for å finne reisetid gjennom krysset for buss, kryssingstid for fotgjengere og fotgjengernes kryssingsatferd. I alt ble 460 busser og 2030 fotgjengere registrert gjennom krysset. Av dem ble reisetid registrert for alle bussene og 1 603 fotgjengere. Kryssingsatferd ble registrert for alle fotgjengerne.

Studien viser at gjeninnføring av trafikklys ikke gagna bussene, sjøl om de er prioriterte gjennom krysset. Fotgjengere ble hindra av signalregulering, og brukte i snitt mer enn dobbelt så lang tid på å krysse gata i den observerte tida med trafikklys. Fotgjengeratferd forandra seg lite med tanke på løping og kryssing utenfor gangfelt midt i kvartalet. Vikeatferd og rødlyskryssing ble også registrert. Dette viste at noen norske fotgjengere frivillig velger å vike for kjøretøy i gangfelt, og at en av fire fotgjengere krysser på rødt når krysset er signalregulert. Resultatene antyder at beslutningstakere bør vurdere å fjerne trafikklys i kryss for å prioritere bærekraftige reisemidler.

Summary

As the consciousness around climate change increases, there is an increasing need to find traffic solutions that bring the demands of active modes and public transport together. Urban area decision makers will need to prioritise sustainable transport and commit to a substantial shift in transport mode distribution. This requires that walking, cycling and public transport are given priority in urban transport networks. Unfortunately, their interests are not always compatible. Traffic signals with priority schemes are regularly used to prioritise buses through busy streets, but can also be viewed as an unecessary obstacles hindering free movement for pedestrians. Research suggests that removing traffic signals may improve traffic flow, but it is not given that it is possible if vehicles are required to yield for pedestrians in zebra crossings. This study investigates the impacts of traffic signals on bus travel time, pedestrian crossing time and pedestrian crossing behaviour.

The research was done by studying a case intersection in the city of Trondheim, Norway. The city has 200 000 inhabitants and the case intersection is situated in a busy, recently remodelled city centre street. The intersection was filmed during three days of January 2020 after a one and a half year long trial period with traffic signals turned off. It was filmed again three days of February 2020, two and a half weeks after reinstatement of traffic signals. The films were analysed manually to find bus travel time, pedestrian travel time and pedestrian behaviour through the intersection. In total, 460 buses and 2030 pedestrians were registered traveling through the case intersection. Of those, all the buses and 1 603 pedestrians were timed. All pedestrians were observed for crossing behaviour.

The study shows that the buses did not benefit from the reinstatement of the traffic signals, although they have priority through the intersection. Pedestrians were hindered by the traffic signals, spending on average more than twice the time to cross the street in the observed period with traffic signals. Pedestrian behaviour in terms of running and mid-block crossing did not change much after the change in traffic regulations. Yielding behaviour and red light crossings were also registered, showing that some Norwegian pedestrians voluntarily choose to yield for motorised traffic at zebra crossings and that one in four pedestrians cross the street on a red light when the intersection is signalised. Decision makers might therefore consider removing traffic signals in intersections with to prioritise sustainable modes.

Forord

I dette dokumentet vil du finne en masteroppgave innen hovedprofilen transport som avslutter fem års studier på studieprogrammet Bygg- og miljøteknikk ved NTNU i Trondheim. Oppgaven tilsvarer 30 studiepoeng. Førsteamanuensis Eirin Ryeng ved Institutt for bygg- og miljøteknikk har veiledet arbeidet med oppgaven. Masteroppgaven er utarbeida i samarbeid med Miljøpakken, ved sivilingeniør Aslak Heggland.

Masteroppgaven handler om effektene signalregulering har på bussers og fotgjengeres reisetid gjennom et kryss og fotgjengeres kryssingsatferd. Den består av artikkelen Removing Traffic Signals to Prioritise Sustainable Modes med tilhørende vedlegg (Appendix 1), et vedlegg som kort beskriver deler av arbeidet som ikke kunne tas med i artikkelen (Vedlegg 1 - Om arbeidet med oppgaven) og et vedlegg fra Professor Inge Hoff med informasjon rundt Covid 19-pandemien. Hvis artikkelen utgis vil Eirin Ryeng stå som medforfatter.

Takk til Eirin Ryeng for god veiledning og støtte i arbeidet med oppgaven. Det skal også rettes en takk til kontaktperson i Miljøpakken Aslak Heggland for interesse for oppgaven og hjelp til å finne krysset mitt. Takk til Byhaven for tilrettelegging og tillatelse til å filme fra deres vinduskarmer, og spesielt til driftsleder Ole Ivar Hammer, senterleder Elisabeth Høsflot Klæbo og de ansatte jeg lånte vinduskarmer hos. AtB, ved Kristian Heide, skal også takkes for å gi meg tilgang til et ekstra datasett som kom godt med i diskusjonen. Takk skal også rettes til Kristin Kråkenes for raske og gode svar på alle spørsmålene mine rundt styring av lyskrysset. Takk til alle andre som har bidratt i arbeidet med oppgaven!

Til sist, takk til familie og venner, og ikke minst til Lekegruppa for å ha sagt rungende ja til å bli med på galskap og morsomme sprell i ei tid som ellers kunne ha føltes mye tyngre.

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Amalie Ravnåmo

Innhold

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Abstract

Decision makers in urban areas might wish to further adapt transport systems in favour of more sustainable modes, like public transport, walking and cycling. This can be done by giving these modes priority, but the demands of active modes and public transport can be conflicting. Freedom of movement is important for walkability, while buses might benefit from stricter traffic regulations that can prioritise their mobility through congested areas. Earlier research suggests that traffic flow and travel time might be improved by removing traffic signals, but it is not given that it will work if one requires vehicles to yield for crossing pedestrians. This research investigates the impacts of traffic signals on travel times for buses and pedestrians as well as pedestrian crossing behaviour. A case intersection in Trondheim, Norway was used for this study, where video recordings of the intersection with and without traffic signals were manually analysed. In total, 460 buses and 2030 pedestrians were registered traveling through the intersection. Of those, all the buses and 1 603 pedestrians were timed. All pedestrians were observed for crossing behaviour. The study shows that removing traffic signals can result in reduced travel times for pedestrians without impacting pedestrian behaviour and bus travel times. Decision makers might therefore consider removing traffic signals in intersections to prioritise sustainable modes.

1 Introduction

The consciousness around climate change is increasing and the world is facing a need for change towards greener and more sustainable transportation. Ongoing urbanisation increases the need for sustainable transport choices in growing cities and decision makers will have to interfere with today's distribution of transport means. The Norwegian cities have committed to this by agreeing to work towards the Zero Growth Goal, where all growth in transport is to be in walking, cycling and public transport (Samferdselsdepartementet, et al., 2019). It is important to accommodate for all green transport means, but what do you do if their interests conflict?

Traffic regulation affects flow and accessibility differently for different transport modes. A reduction in traffic regulations might reduce travel time for active modes. Urban areas that accommodate for walking and cycling will emphasise freedom to move without unnecessary restrictions. However, for public transport it is important to have a certain predictability, speed, and punctuality to be able to provide services at adequate standards. Therefore, it might be beneficial for bus transport that there are traffic regulating means to prioritise the buses' level of service through crowded or congested areas. Traffic signals makes it possible to give buses special priority through town centres. Unfortunately, long waiting times can affect the pedestrians' compliance to the system (Koh, et al., 2014) and act as a barrier for walking (Ferrer, et al., 2015).

Traffic signals have several advantages in terms of safety. Signal regulation is often used to time separate traffic streams in intersections to remove or reduce conflicts. They are therefore, on average, safer than right-of-way intersections (Høye, et al., 2015). The risk of rear-end accidents increases, but since these accidents tend to be less severe, signalised intersections are considered very good for safety. Additionally, the predictability of a signalised intersection means that it is easy to use for all users. Feeling of safety increases in signalized intersections and vulnerable users of traffic tend to prefer signalised intersections (Norgate, 2012; Firth, 2011).

Traffic signals' effects on travel time are largely dependent on both the phase scheme, the traffic flow, distribution of traffic, and several conditions unique to every intersection. The measure is used to reduce delay and make navigating busy intersections easier, and it is effective when the traffic volume is high. Because of this, it is rarely introduced in streets with less than 500 vehicles per hour in peak traffic (Vegdirektoratet, 2012; Webster & Cobbe, 1966). Use of traffic signals may give efficient traffic flow at high volumes but could lead to unnecessary delays if implemented in intersections with less traffic or at low traffic hours (Webster & Cobbe, 1966).

One of the advantages to traffic signal regulation is that it can be adapted to prioritise one traffic group over others. Current Norwegian guidelines state that the phase scheme should be made with special attention towards the level of service for public transport (Vegdirektoratet, 2012). Signal regulation is regularly used to prioritise buses in town centres and on important bus corridors. There are several ways to achieve this. One of them is to utilise global positioning system and virtual detectors to extend green time when a bus approaches the signalised intersection (Hounsell, et al., 2007). This will reduce the probability of having to stop for a red light, effectively reducing travel times for most buses with little delay to other vehicles (Wahlstedt, 2011). Prioritisation can also be made conditional, so only late buses are given priority. Prioritising buses through intersections is useful to promote the use of public transport as an alternative to car in urban areas, as reduced travel time can increase attractiveness.

Not all pedestrians are willing to adhere to the restrictions of a signalised intersection. According to Koh, et al. (2014) 18% of Singaporean pedestrians cross the road on a red light, with more violators crossing in the direction towards transit stations. The most commonly stated reason for crossing the road on a red light is for convenience and to save time (Koh, et al., 2014; Ren, et al., 2011). Brosseau, et al. (2013) found that some pedestrians are violators no matter the waiting time, meaning that they will cross the road immediately whether the light is red or green. Still, the tendency is that there are more violations the longer the maximum waiting time is for pedestrians (Brosseau et al., 2013; Ren, et al., 2011). Unlike most of the countries these studies have been done in, Norwegian pedestrians are allowed to cross streets on a red light provided they don't disturb traffic or create dangerous situations. Crossing the road on a red light could therefore be common, and although it is not technically illegal it might increase accident risks.

Traffic culture impacts how effective different types of intersections are. Pedestrians are to a large extent prioritised in Norway compared to other countries since drivers are required to yield for pedestrians at zebra crossings (Sørensen, 2009). Hence, Norway also has a relatively high share of drivers who yield for pedestrians. A new study suggests that around 80% of Norwegian drivers will yield for pedestrians at zebra crossings (Høye, et al., 2016). That means that in a street with several zebra crossings and a steady flow of pedestrians, drivers might have to stop multiple times. This can result in delays that could reduce the service level of public transport through the city centre. According to Webster & Cobbe (1966) uncontrolled zebra crossings will increase delays with higher pedestrian flows, and signalised crossing will be better for pedestrian flows exceeding 1000 pedestrians per hour.

Walking is an important mode of transport for short distances. Increasing the walking mode share is essential to reach the zero-growth goal. In urban Norwegian areas the walking mode share is between 25-30%, with an average journey length of 2.2 km (Hjorthol, et al., 2014). Walking can be made more attractive by changing the traffic environment. For example, cohesive walkways and as few delays as possible make a route more agreeable for walking (Ferrer, et al., 2015). From a pedestrian point of view traffic signals might be considered a restrictive measure that hinders free movement and reduce accessibility (Hamilton-Baillie, 2008). Time is often considered the most important aspect of walking, but Middleton (2009) describes time spent walking as dependent on how the time can be enjoyed. Walking while thinking, planning or talking to someone is viewed as valuable time, while time spent waiting is considered more impactful and tedious because one becomes aware of the time (Middleton, 2009). Pedestrian delays in signalised intersections could therefore be considered disproportionally large because it interferes with the travel rhythm of walking.

Signalised intersections have advantages and disadvantages, but what will happen if the traffic signals are removed from an intersection? A faulty traffic signal near Bristol caused a sudden improvement on queues in the area. A study following the incident showed that removal of the traffic signals lead to a 50% reduction in journey times and higher throughput, without any reduction in the pedestrian traffic (Firth & Siraut, 2009).

Pedestrians did not change crossing behaviour and would generally spend as much time crossing as before, since few were utilising the facilitated crossings. The average crossing times still reduced by 20%, because the maximum wait times reduced. Further studies carried out in other nearby intersections showed similar results in varying degrees (Firth, 2011). Unlike in Norway, drivers are not required to yield for pedestrians in the UK. That influences the overall impact of deregulating intersections and prompts the question: Can traffic performance improve by removing traffic signals in Norway as well?

The research questions explored in this study are:

- How does traffic signals affect buses’ travel times through an intersection?
- How does traffic signals affect pedestrians’ travel times through an intersection?
- How does traffic signals affect pedestrian crossing behaviour?

The research questions are explored through a case study of a single intersection. The focus has been on buses and pedestrians, and although there have been bicyclists and other motorised vehicles through the intersection they have not been registered.

2 Method

To find out how traffic signals affect travel times and pedestrian behaviour in a busy intersection, a case intersection was observed with and without traffic signals. The case study was done on an intersection in the centre of Trondheim, a Norwegian city of approximately 200 000 inhabitants. The intersection has been a part of a remodelling and deregulating trial with an aim to prioritise green modes through the city centre. The traffic signals of three city centre intersections in a street named Olav Tryggvasons gate in Trondheim were turned off in 2018 as a part of the larger trial project, making the intersections right-of-way regulated. This caused public debate. The feedback, both from the public and the bus companies, were particularly concerned about safety, mid-block crossings and that buses were obstructed by pedestrians crossing the streets (Lunde, 2019). Therefore, it was politically decided that the traffic signals would be turned back on in January 2020. This presented an opportunity to investigate the effects of traffic signals alone, independently of all other implemented measures of the trial.

The case intersection is placed in a main bus through route in the city centre. The traffic moves predominately along an east-west axis through the street. The southern arm of the case intersection is a pedestrian street, making it a de facto T-intersection. The AADT of the intersection dropped from around 5 200 before the trial to 2 100 after the trial (Lunde, 2019). This was due to measures and restrictions made to lead cars outside this street and make it more inviting to cyclists and pedestrians. The street was changed from a four-lane to a two-lane street with a bicycle road. Cars were prohibited to drive through from the east and a bus stop situated directly east of the intersection was rebuilt without a turnout. This bus stop only services buses traveling westwards. The intersection has a high volume of pedestrians and has zebra crossings on both sides, see Figure 1.

The reinstated traffic signals are programmed to prioritise buses. The priority system uses real time global positioning system, cameras, and sensors in the ground to make a prediction of when the bus will arrive at the intersection. The priority system can result in a prolonged green phase or a shortened red phase for the incoming buses. The request for priority happens automatically and there is no difference in prioritisation level based on bus size, passenger numbers or if they are behind schedule. Buses are simply prioritised over other vehicles. Regarding the pedestrians, the installed signals are push button controlled with a maximum waiting time of 60 seconds from push until pedestrians are given green phase. There are no legal restrictions controlling the waiting times for pedestrians or buses, except that the cycle time should not exceed 120 seconds. The recommendations simply state that the programme should give special consideration to pedestrians *and* public transport (Vegdirektoratet, 2012).

The analysis was based upon manual registrations of filmed events. The video recordings were made during three weekdays in January 2020 without traffic signals and three weekdays in February 2020 with traffic signals, two and a half weeks after they were turned on again.

The intersection was recorded with two cameras placed on exterior windowsills on the third floor of a building overlooking the intersection. The placement of the cameras was made to ensure a decent view of the street. The altitude above street level was necessary to ensure the pedestrians' privacy. In addition, the cameras recorded with low resolution, so that no one could be recognised. Conversations with the Norwegian Data Protection Services ensured that no special permissions were needed to film. In total, 30 hours were filmed. Selected periods were chosen from these to represent the situations with and without signals, see Table 1.

Table 1: Analysed periods

ANALYSED PERIODS						
	Without traffic signals			**With traffic signals**		
	Day	Date	Time	Day	Date	Time
Non-peak traffic	Tuesday	21.01.2020	13:25-14:25	Tuesday	11.02.2020	13:25-14:25
Peak traffic	Thursday	23.01.2020	07:45-08:00	Tuesday	11.02.2020	07:45-08:00
	Tuesday	21.01.2020	15:55-16:10	Thursday	13.02.2020	15:55-16:00

The registrations were done manually by watching the chosen recordings. Pedestrians and motorised vehicles were counted. Direction and turning movements were also registered for all pedestrians and motorised vehicles. Additional registrations for buses and pedestrians were made to answer the research questions. For buses, the registrations were bus type, travel time, and time spent on embarking/disembarking at the bus stop. For pedestrians, the additional registrations were travel time, mid-block crossings, red light crossings, running behaviour, and yielding behaviour.

To find the bus travel time, start- and stop lines were chosen to represent the beginning and end of the intersection, see Figure 1. For each direction, the chosen start line was in the middle of the block. An imagined line between lampposts was chosen as the start line for buses driving eastwards. For buses traveling westwards, the start line was chosen to be the nearest end of a zebra crossing across the bicycle lane. The end line was in both directions considered to be the far end of the zebra crossing markings at the other end of the intersection. The distances the travel times are registered over are not equal. This is due to limited view to the west and the importance of capturing the whole bus stop in the east. Therefore, the distance travel time is measured over is around 63 meters for buses traveling eastwards and around 78 meters for buses traveling westwards. All the travel times were registered from the bus fronts.

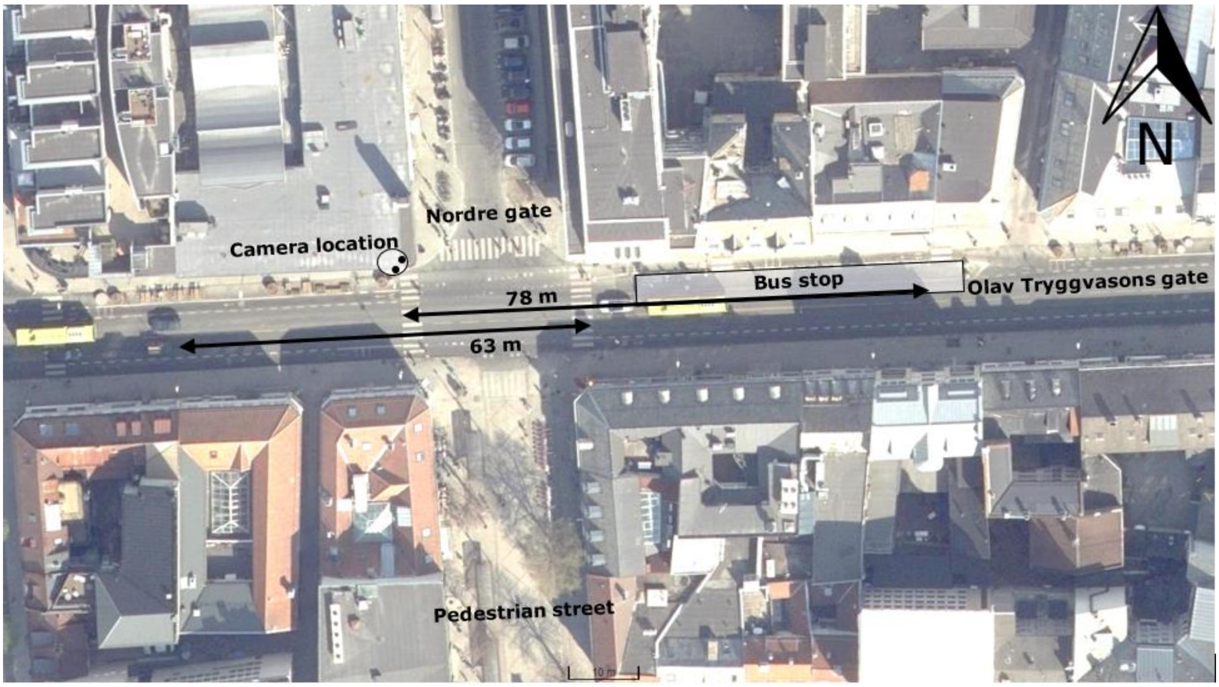

Figure 1: Overview of case intersection showing camera location, bus stop location and sections used for bus travel time registrations

The time needed to load/unload the buses traveling westwards will vary, both depending on time of day and between individual buses. This time should not be included in the travel time, as these delays are not due to the traffic situation in the intersection. Time used to load/unload is registered by taking the time from the bus has stopped at the bus stop until it gives signal that it is ready to go. Whether the bus is ready is not always easily seen on video since the bus drivers are inconsequent in their use of signals. Because of this, several indicators are used to determine when the embarking is done, like turn signals, turning on driving lights, and shutting the doors. In the cases where the bus has stopped several times to pick up more passengers, the extra time is registered as embarking time unless it is merely utilisation of waiting time due to traffic.

Several aspects affect the accuracy of these travel time registrations. Synchronisation of the videos from both cameras is important for the registration of buses coming from west because it is impossible to see the whole measuring distance on one camera. Additionally, it can be challenging to be entirely consequent at starting the registration in the same exact spot for every bus. This is due to the start line being far away from the camera, varying video quality and lighting conditions and small changes in camera angle between the days of recording. These variations are assumed to be in the magnitude of one second. The work was done alternating between videos of different conditions in an attempt of minimising these errors in registration.

Pedestrian travel time and behaviour is registered in the same time intervals as the bus travel time. Distance to the kerb, pressing the pedestrian crossing button and body language are used as indicators of a wish to cross the road. The travel time is registered from the pedestrian is within 0.5 – 1.5 meters of the kerb and until it has set a foot on the opposite kerb. In a few exceptional cases where the pedestrian clearly is waiting to cross the road a little further away from the kerb this waiting time is also registered.

Pedestrians move more freely than other traffic, and it is challenging to define the travel time through the intersection in the same way for all of them. Yet, the same method is used for registering all pedestrians, alternating between videos with and without traffic signals. The building on which the cameras were placed have a hanging bay window obstructing the view of some of the pedestrians waiting on the northern side of the western zebra crossing, see Figure 2. Therefore, travel times were not registered from pedestrians emerging from below the bay window. The same goes for pedestrians crossing the road mid-block and pedestrians walking to and from the bus stop east of the intersection. The former because the distance to the cameras made it difficult to register the time with accuracy, and the latter because the crossing distance is so much shorter between the bus stop and the southern kerb than kerb to kerb.

Figure 2: Camera view of the western part of the case intersection. Note that the camera is placed north of the street and that some pedestrians could be hidden below the bay window seen in the forefront

The registrations were put into tables with filter functions to extract data for statistical analysis. The travel time data sets are analysed with unpaired, two-sided Student's t-tests. That is chosen because it is a simple way of determining whether the differences between two different situations are statistically significant. The chi-squared test is used to analyse pedestrian behaviour by comparing the observed behaviour before and after to a theoretical, equal distribution. That can also determine whether the observed difference between the situations is significant.

The travel time registrations have several sources to inaccuracies that may have affected the general results. The recording periods, 21st to 23rd of January and 11th to 13th of February, had striking differences in weather and light conditions. The weather of the first recording period was exceptionally bad, with wind, snow, and sleet. This affects both the video quality and the traffic. There is registered less traffic in this period, which makes sense considering the bad weather. The morning and afternoon recordings from January are very dark, both due to the time of year and that the automatic light adjustment on the cameras was turned off. Because of this, the videos from peak hours are dark and pixelated which leads to more uncertainty concerning the data registrations from these videos. At about the same time as the reinstatement of the traffic signals, some of the regional buses and airport buses got new routes through the city centre omitting the case street. This may have affected the results, but the effect is assumed to be quite small since there is still registered more buses in the after period than before the change happened.

3 Results

The analysis was made out of 460 registrations of buses and 2 030 registrations of pedestrians, of which 1 603 were timed while crossing. The rest of the pedestrians were only registered in terms of crossing behaviour. The observations were distributed like summarised in Table 2.

Table 2: Registrations done in case study

REGISTRATIONS						
	Without traffic signals			**With traffic signals**		
	Buses	Pedestrians	Non-timed pedestrians	Buses	Pedestrians	Non-timed pedestrians
All registrations	212	812	205	248	1218	217
Non-peak traffic	105	545	111	160	850	115
Peak traffic	107	267	94	88	368	102

The registrations were sorted, and the average and standard deviation were calculated. The Student's t-test was performed on the travel times to see whether the differences in travel time are statistically significant. Table 3 and Table 4 present the travel time results comparing the junction with and without traffic signals.

Table 3: Travel times through the intersection for buses in seconds. P-values lower than 0.05 are marked in bold. Eastwards and westwards times cannot be compared

TRAVEL TIMES THROUGH THE INTERSECTION											
	Without traffic signals					**With traffic signals**					**t-test**
BUSES	Avg.	S.D.	Min	Max	N	Avg.	S.D.	Min	Max	N	p-value
EASTWARDS	12.7	6.4	4	38	106	15.9	11.3	6	50	133	0.055
Peak	14.4	7.3	6	38	52	16.4	11.6	6	50	51	0.296
Non-peak	11.0	4.9	4	28	54	13.7	8.5	6	44	82	**0.024**
All local buses	13.5	6.9	6	38	77	12.4	7.0	6	41	106	0.312
Peak	16.4	7.9	6	38	36	13.9	8.0	6	41	41	0.163
Non-peak	10.9	4.6	7	28	41	11.5	6.1	6	39	65	0.545
Metro buses	14.2	7.1	7	29	22	12.3	6.0	6	28	28	0.332
Peak	17.9	7.7	7	29	9	15.7	6.3	8	28	9	0.538
Non-peak	11.6	5.3	7	28	13	10.7	5.1	6	27	19	0.635
Other buses	10.5	4.1	4	25	29	24.1	14.0	6	50	25	**0.000**
WESTWARDS	33.2	15.8	9	104	105	37.0	18.6	12	139	115	0.104
Peak	36.0	17.4	11	104	55	32.7	15.3	12	82	37	0.347
Non-peak	30.1	13.2	9	63	50	39.0	19.6	13	139	78	**0.003**
All local buses	32.9	13.6	15	104	80	37.6	18.6	12	139	111	**0.048**
Peak	33.3	14.5	20	104	39	32.7	15.3	12	82	37	0.874
Non-peak	32.6	12.6	15	63	41	40.0	19.5	13	139	74	**0.016**
Metro buses	35.6	10.3	18	60	25	40.2	17.9	20	95	28	0.263
Peak	35.8	10.0	23	51	12	36.7	14.8	22	75	10	0.872
Non-peak	35.5	10.6	18	60	13	42.1	19.2	20	95	18	0.242
Other buses	34.0	21.5	9	72	25	20.5	9.6	14	37	4	0.094

Table 3 shows a summary of the registered travel times. The p-values obtained by the t-test show that in there are no significant differences in travel time through this junction in general, when comparing all travel times from the period without traffic signals with the period with traffic signals. The different directions cannot be presented together, as the sections travel time was measured over are not the same length. By dividing the data according to different times of day and different types of buses, some significant differences can be found.

In the analysed non-peak hour, the busses travel significantly slower through the intersection when it is regulated with traffic signals. This goes for both directions. The differences at peak are not significant but they show that the local and metro buses going eastwards on average save time and might have some benefit of the traffic signals in peak hours.

There are more differences between the different types of buses. The main transport routes in Trondheim are serviced by Metro buses – longer buses designed to service for large numbers of passengers, with several wide doors for efficient unloading-/loading. The regional buses and airport buses do not stop to load or unload at the bus stop in the test area. Therefore, their travel time is only affected by speed and whether they are delayed by pedestrians, red lights, or other vehicles. These buses have the most significant increase in travel time after the traffic signals were reinstated, spending more than twice the time through the intersection going eastwards.

Registrations of pedestrian travel times were analysed the same way, by sorting, dividing in groups and calculating average travel time and standard deviation for each group. The Student's t-test was also performed on this data set. The results of the analysis are presented in Table 4.

Table 4: Travel times through the intersection for pedestrians in seconds. P-values lower than 0.05 are marked in bold

TRAVEL TIMES THROUGH THE INTERSECTION											
	Without traffic signals					With traffic signals					t-test
PEDESTRIANS	Avg.	S.D.	Min	Max	N	Avg.	S.D.	Min	Max	N	p-value
ALL	11.1	4.0	5	52	607	24.3	17.5	4	105	980	**0.000**
Peak	10.3	3.2	5	30	173	23.8	18.1	5	105	259	**0.000**
Non-peak	11.4	4.3	5	52	434	24.5	17.3	4	89	721	**0.000**
North - south	11.0	4.6	5	52	292	24.5	17.9	5	86	443	**0.000**
Peak	9.8	2.8	5	29	87	23.2	17.7	5	85	120	**0.000**
Non-peak	11.5	5.1	5	52	205	25.0	18.0	5	86	323	**0.000**
South - north	11.2	3.4	6	30	315	24.2	17.2	4	105	537	**0.000**
Peak	10.8	3.6	6	30	86	24.4	18.4	7	105	139	**0.000**
Non-peak	11.4	3.3	6	27	229	24.1	16.8	4	89	398	**0.000**
EAST	10.6	2.9	5	25	396	23.2	16.5	4	104	647	**0.000**
Peak	9.6	1.8	5	15	129	22.9	16.7	6	104	187	**0.000**
Non-peak	11.1	3.1	5	25	267	23.3	16.5	4	89	460	**0.000**
North - south	10.4	2.8	5	25	213	22.0	15.2	5	72	304	**0.000**
Peak	9.5	1.8	5	15	75	22.7	16.6	6	72	92	**0.000**
Non-peak	10.9	3.2	5	25	138	21.8	14.6	5	70	212	**0.000**
South - north	10.9	2.9	6	24	183	23.0	16.4	4	104	332	**0.000**
Peak	9.7	1.9	6	15	54	22.0	16.0	7	104	92	**0.000**
Non-peak	11.4	3.0	7	24	129	23.4	16.5	4	89	241	**0.000**
WEST	12.0	5.5	6	52	210	26.7	19.2	5	105	333	**0.000**
Peak	12.5	5.0	7	30	44	26.4	21.2	5	105	72	**0.000**
Non-peak	11.9	5.6	6	52	166	26.7	18.6	5	88	261	**0.000**
North - south	12.8	7.3	7	52	78	24.5	17.8	5	86	120	**0.000**
Peak	11.9	5.5	8	29	12	17.3	13.4	5	55	23	0.112
Non-peak	12.9	7.6	7	52	66	26.2	18.3	5	86	97	**0.000**
South - north	11.6	4.0	6	30	132	26.2	18.4	6	105	204	**0.000**
Peak	13.1	4.9	7	30	28	29.2	21.7	7	105	47	**0.000**
Non-peak	11.3	3.7	6	27	100	25.3	17.2	6	88	157	**0.000**

All but one of the obtained p-values for the comparison for pedestrians shown in Table 4 are extremely low. Of that, one can assume it very unlikely that the differences between travel time are random. The pedestrians spend on average 118% more time to travel through the intersection when it is regulated by traffic signals. This goes for all times of the day in both zebra crossings and crossing directions. The exception to the significant differences is for pedestrians crossing the road in peak hours in the western zebra crossing, arriving from north. These pedestrians are particularly difficult to register, as the view may be obstructed by a bay window situated above parts of the waiting area for the zebra crossing. Consequently, there are not that many travel time registrations for this specific group of pedestrians which may have affected the validity of this result.

The most extreme observed travel times through the intersection are all registered when the intersection was signalised. Some of these are above 72 seconds, which is more than what theoretically should be the maximum travel time in the case intersection. This theoretical maximum is considering the intended maximum waiting time of 60 seconds for pedestrians and 12 seconds to cross the road. Possible explanations might be related to user mistakes, such as not pressing the button upon arrival. Some pedestrians are also hesitant to begin crossing the road at the very end of the green phase and would rather wait for the next one.

Traffic signals cause delay to the pedestrians. If one compares Figure 3 and Figure 4, one can see a similar distribution of travel times around the interval 8-12 seconds. The overall mode is 10 seconds, insinuating that it takes around 10 seconds for an unhindered pedestrian to cross this street. Very few pedestrians spend more than 20 seconds crossing the road without traffic signals. As seen in Figure 4, that is a common occurrence in the period with traffic signals.

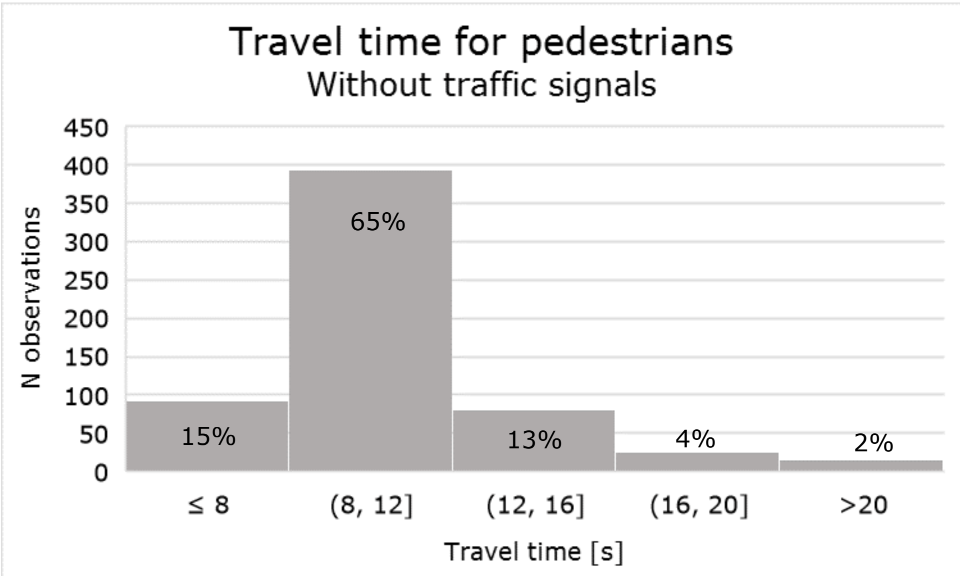

Figure 3: Simple histogram showing distribution of pedestrian crossing times without traffic signals. 607 observations in total.

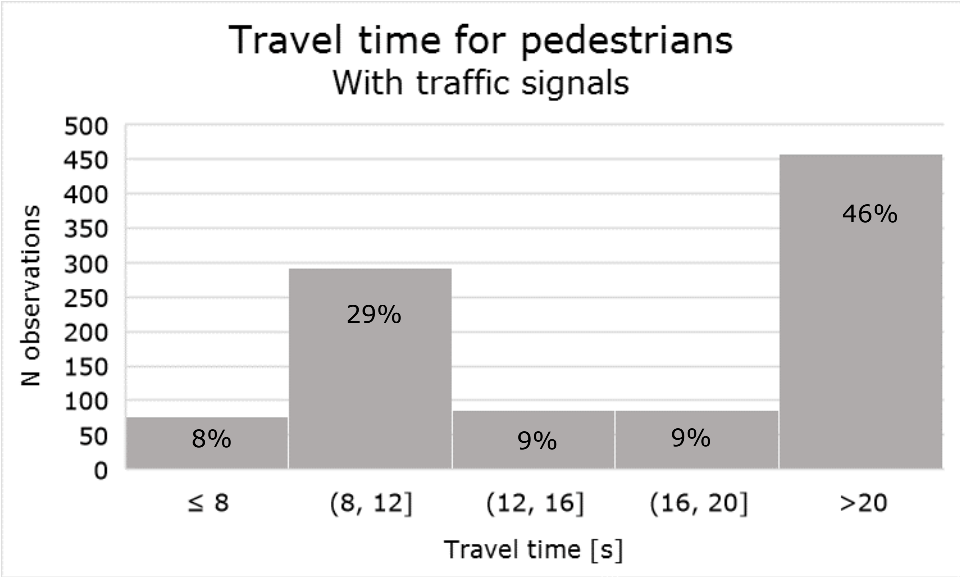

Figure 4: Simple histogram showing distribution of pedestrian crossing times with traffic signals. 996 observations in total.

Pedestrian crossing behaviour was registered in 2 030 pedestrians, looking at yielding behaviour, choice of crossing location, running and compliance to the traffic signals. The results are presented in Table 5 and Table 6 for both zebra crossings in the intersection.

Jaywalking in terms of crossing on a red light is not illegal in Norway, but bus drivers have expressed concern for traffic safety in the case street because of frequent jaywalking (Lunde, 2019). Pedestrians are allowed to cross the road in their red phase if they don’t disturb the motorised traffic. Crossing the road during a red light is, for obvious reasons, only possible when the intersection is signalised. Therefore, the before/after comparisons on jaywalking will only concern mid-block crossings and a few incidents of crossing the intersection between the zebra crossings. According to the traffic rules, pedestrians must use crossing facilities when they are present nearby, making mid-block crossing a violation.

Table 5: Mid-block crossings

ALL MID-BLOCK CROSSINGS					**MID-BLOCK CROSSINGS - PEAK**				**MID-BLOCK CROSSINGS - NON-PEAK**			
	Without traffic signals		**With traffic signals**		**Without traffic signals**		**With traffic signals**		**Without traffic signals**		**With traffic signals**	
Observed	N	%	N	%	N	%	N	%	N	%	N	%
Mid-block	129	15	137	14	55	17	44	14	72	13	84	10
Intersection	717	85	861	86	261	83	276	86	473	87	766	90
χ^2 p-value	0.354				0.204				0.054			

The results show that approximately 15% of pedestrians do not use the zebra crossings to cross the road. As seen in Table 5, the differences regarding traffic signals are not significant on 5% significance level. The clearest difference is showing outside peak hours. The tendency is that more pedestrians are crossing mid-block when the intersection is not signalised. With the intersection signalised, 25% of pedestrians who crossed within the intersection did so on a red light. 10% of those crossed the road in such a way that motorised traffic was hindered.

Yielding behaviour affects travel time, both for pedestrians and for motorised traffic. Vehicles are required to yield for pedestrians at zebra crossings. Time spent in the intersection will therefore depend on the interaction with pedestrians. Pedestrians rarely yield to vehicles. Out of 388 registered yielding interactions in the time without traffic signals, 35 were situations where pedestrians clearly yielded for motorised traffic, a share of 9%. Pedestrians are significantly more likely to yield to vehicles outside peak hours, as seen in Table 6. It has been observed that the pedestrians often hurry across the road in yielding situations, presumably to accommodate the yielding vehicles. Running or hurrying across was registered in 41 of the 388 yielding situations, a share of almost 11%.

Table 6: Pedestrians yielding for vehicles in period without traffic signals. Note that the p-value is below 0,05

PEDESTRIANS YIELDING FOR VEHICLES				
	Peak		**Non-peak**	
Observed	N	%	N	%
Yielding	6	2 %	29	5 %
Not yielding	261	98 %	516	95 %
χ^2 p-value	**0.043**			

Running or hurrying across the road was registered in about 8% of all crossings, both with and without traffic signals. In the period without traffic signals it was observed that most of the pedestrians that hurried across the road did so to catch the bus or as a courtesy to yielding vehicles. In the period with traffic signals most pedestrians hurried across the road during a red light or at the end of the green phase.

4 Discussion

The aim of this study was to explore how traffic signals affect buses' and pedestrians' travel times through an intersection and to see whether pedestrian behaviour would change. The results indicate that buses' travel times through an intersection are unchanged or increased after reinstatement of traffic signals. The pedestrian travel times are significantly increased, and the pedestrian behaviour is not changed.

The travel time registrations for buses show that traffic signals increase travel time compared to a right-of-way intersection, although they might reduce travel time for prioritised buses in peak hours. The results are not as unequivocally in favour of removing traffic signals as Firths's studies (Firth & Siraut, 2009; Firth, 2011). However, that is as expected due to the different yielding cultures of Norway and the UK. Yielding for pedestrians could increase travel times for buses at varying degrees, depending on pedestrian traffic volume. In the UK study the vehicles did not always yield to pedestrians (Firth & Siraut, 2009), whereas there were only a few observations of failing to yield in this study. The registered effects for bus travel times in this study could be exaggerated, due to fewer pedestrians in the studied periods without traffic signals. The bad weather in the first recording period might imply that the pedestrian volume was lower than usual. Consequently, the registered delays for traffic could be lower than usual as well.

The most prominent difference in bus travel time shown in Table 3 is the statistically significant large increase in travel time for long distance and airport buses traveling eastwards. They experienced more than a doubling of travel time through this intersection. These buses were, however, not prioritised in the traffic signal system, hence illustrating the importance of bus prioritisation.

The local bus company has data showing that the travel time for buses through the city centre increased during the trial period, after traffic signals were first removed (Lunde, 2019). It is not obvious where those delays happened since their travel time registrations are done between bus stops. Because the whole street was remodelled it is not certain that the observed differences in travel time were due to the removal of traffic signals either. If one compares the results of this study with data provided by the local bus company from the same time as the analysed periods, they also show that there is no statistically significant benefit of the traffic signals, see Appendix 1. The bus company's data cover larger parts of the town centre, with travel time measured between bus stops. That could allude that the results for this intersection might be extrapolated to the entire street. Richardsons (1980), however, showed that it is possible that longer stretches of bus prioritisation signals work, even though the intersections might be deemed unsuccessful on their own.

Traffic signals are clearly slowing down pedestrians. This is as expected since pedestrians have right of way when crossing in unsignalized zebra crossings. Firth (2011) found that most pedestrians spent the same time whether waiting for acceptable gaps or for green light, but that the maximum waiting times were shorter without traffic signals. The latter can also be seen in the results of this study. There are several extreme waiting times for the signalised period, where 8% of the pedestrians would spend more than 52 seconds crossing the street - the maximum registered travel time without traffic signals. All the most extreme waiting times in the case of no traffic signals seemed to be due to pedestrians deliberately yielding to the motorised traffic or misunderstanding that the intersection was not signalised, since the installations were still present.

The differences in pedestrian crossing behaviour are not as clear. Regarding jaywalking, there is just a slight difference in behaviour with and without traffic signals. The tendency is that pedestrians are more likely to cross mid-block in peak traffic. That is presumably because pedestrians are hurrying more in the morning and afternoon. The difference between traffic signals and no traffic signals is most prevalent outside peak hour traffic. In both peak and non-peak hours, pedestrians are more likely to cross mid-block when there are no traffic signals. This is unexpected, since the benefits of crossing at an unsignalized zebra crossing should be bigger than the benefits of crossing at a signalised intersection. A possible explanation is that the vehicles might drive slower and more attentively in the period without traffic signals, making it seem safer to cross the road mid-block (Hamilton-Baillie, 2008). It might also feel like one is breaking the rules to a larger extent by crossing mid-block when the intersections are signalised.

Crossing the road on a red light is done by 25% of the pedestrians choosing to cross the street in the intersection. Compared to what others have found, this is within expectations. Studies from Asian cities have found red light violation shares of 18% and 26% (Koh, et al., 2014; Ren, et al., 2011). Results from metropolitan Asian cities might not be comparative for this case study, though. A few studies done in the case city of Trondheim have found shares of crossing on a red light as high as 32% and 35% (Øvstedal & Ryeng, 1999; Holsdal, 2009). The observations made in the case study are therefore not unexpected, as it is not illegal for Norwegian pedestrians to cross the street during a red light.

Concerning hurrying across the road there is no difference between the periods with and without traffic signals. Although running and hurrying is equally frequent in both situations, it is likely due to different reasons. Without traffic signals, running seems to be done as a courtesy to the vehicles so they do not have to wait so long while yielding. When the intersection has traffic signals, running is more likely done to be able to cross the road during the green time or to avoid being in the way when crossing on a red light. One can also assume that some running is done to catch the bus in both cases, as the bus stop is situated so close to the intersection. This is often done in combination with jaywalking, which is not unexpected. Koh, et al. (2011) found that jaywalking was more common towards transit stations.

Yielding behaviour in pedestrians is only relevant when the intersection is not signalised. Norwegian pedestrians do not have to yield for vehicles in zebra crossings, but 9% of pedestrians did so anyway. The yielding was commonly done by expressive body language, such as turning away from the street until the vehicle had passed. There has also been registered a significant difference between peak- and non-peak hours. In non-peak hours, pedestrians are far more likely to choose to yield to vehicles. A reason for that could be that pedestrians walk with less urgency during the day. Another cause of this difference could be under-reporting in peak hour recordings due to darkness and video quality issues. This is because observing yielding behaviour in pedestrians requires that one can see body language well.

In the period with traffic signals there were several observations of pedestrians stopping up by the zebra crossing and then continuing to walk at the same side of the street after waiting only a few seconds by the traffic signal. This was presumably done in hope that the next intersection would have a green period upon arrival. According to Middleton (2009) it is not unusual to wish for an optimal trip and to take pride in walking between signalised intersections in such a way that the waiting time is minimised. The observations support the claim that pedestrians will seek to eliminate waiting time when walking.

This study was done with limited time and scope and the results are valid for the case intersection in the recorded periods. Ideally, the entire street could have been included in the study. That would have given a more complete answer to the research questions, and one could have further investigated the mechanisms of the changes in the street network. Additionally, one could have recorded the intersection(s) in different weather conditions both before and after the reintroduction of the traffic signals. Weather influences both traffic volume, mode choice, and how pedestrians behave. Thus, these differences in weather might have affected the results. Lastly, more hours could have been analysed, including weekends, to get a broader picture of the traffic situation. All these measures would improve the reliability of the results.

It was not possible to thoroughly investigate the spillback occurring east of the intersection. The real impact of the bus queuing is likely more prevalent than shown in the results of this research. The spillback is due to queue that occurs when buses must wait to enter the bus stop because it is occupied by other buses. The buses have not been registered until they enter the bus stop, meaning that several buses clearly have longer travel times from the end of the block through the intersection than what is registered. The measuring distance would have to stretch back to the next intersection to the east to properly address the problem of spillback. Unfortunately, it was not possible to see that far in all the studied videos.

Intersections normally require a minimum vehicle flow of 500-600 in peak hour for traffic signals to be deemed effective (Webster & Cobbe, 1966; Vegdirektoratet, 2012). The case intersection no longer has that high traffic volumes in peak hour after the remodelling. Traffic signals may therefore be unnecessary to guide the vehicles, as shown in this study.

5 Conclusion

Prioritising public transport and active modes in urban areas will continue to become more important as the shift towards a more sustainable transport system is implemented. The interests of public transport and pedestrians might conflict since buses can benefit from traffic signal schemes while pedestrians lose valuable time waiting. A case study was done on travel times for buses and pedestrians through an intersection in Trondheim, Norway as well as studying pedestrian crossing behaviour. The results showed that buses did not have significant benefits from the installation of traffic signals, although they have priority in the signalling scheme. The pedestrians had significant increase in travel time, which more than doubled in average. Pedestrian behaviour was not altered from change of traffic regulation in terms of running and mid-block crossing. Peak traffic is the only period when it can be suggested that the signals might work as intended to prioritise buses. Presumably, peak hour is also when the buses are operating to the fullest, serving most passengers. This means that one would have to consider the traffic signal benefits for peak hour bus passengers up against the overall disadvantages for pedestrians.

As more and more urban areas wish to increase sustainable modes' prioritisation in traffic, downgrading traffic regulation could be a way to increase walkability and efficiency for public transport. More extensive studies on street remodelling and traffic deregulating in urban areas are needed to be able to plan for future transport needs. Urban planners will need to find an optimal balance of prioritisation between different transport modes to encourage more transport users to choose walking, cycling, and public transport over private cars.

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Appendix 1

Another data set was introduced to the research after the case study was finished. This data set was provided by the local bus company, AtB, and includes the travel times between bus stops for relevant buses driving through the centre of Trondheim in the same periods that are registered in the case study. The data describes travel times between bus stops, thus covering longer sections of the street network, including two other trial intersections that had traffic signals reinstated. Investigating this second data set could shed some light on the effects of signalisation at town centre level.

The data is collected by the local bus company using GPS registrations. The data set contained information on routes, lines and how late the buses were according to schedule, but the analysis was made solely on the data for arrival and departure at bus stops. Similarly to the case study data set, the data provided by the local bus company was tested with the Student's t-test. Table A1 shows the results in travel times. The buses traveling eastwards and westwards past the case intersection are further divided because they take different routes onwards from the case street. In Table A1 one can also see that although more bus groups seem to benefit from traffic signals than in the case study results, there are no significant differences at a 5% level.

Table A1: Travel time for buses through town centre within same periods as the case study. Note that no p-values are significant at 5% level

BUS TRAVEL TIMES THROUGH TOWN CENTRE WITHIN SAME PERIODS AS CASE STUDY											
	Without traffic signals					With traffic signals					t-test
BUSES	Avg.	S.D.	Min	Max	N	Avg.	S.D.	Min	Max	N	p-value
ALL BUSSES TRAVELING EASTWARDS											
All local buses	00:04:48	00:00:49	00:03:14	00:06:44	63	00:04:55	00:00:53	00:03:20	00:07:32	62	0.489
Peak	00:04:49	00:00:50	00:03:15	00:06:25	31	00:05:08	00:01:00	00:03:20	00:07:32	32	0.182
Non-peak	00:04:48	00:00:48	00:03:14	00:06:44	32	00:04:40	00:00:41	00:03:24	00:06:18	30	0.536
Metro buses	00:05:05	00:00:51	00:03:35	00:06:33	24	00:05:00	00:00:42	00:03:39	00:06:18	26	0.743
Peak	00:04:31	00:00:19	00:04:05	00:05:11	13	00:05:16	00:00:32	00:04:13	00:06:14	15	0.535
Non-peak	00:05:03	00:00:53	00:03:55	00:06:33	11	00:04:38	00:00:44	00:03:39	00:06:18	11	0.271
BUSES TRAVELING EASTWARDS - BAKKEGATA TO PRINSENS GATE 1 BUS STOPS											
All local buses	00:05:17	00:00:52	00:03:34	00:06:44	29	00:05:18	00:00:54	00:03:47	00:07:32	28	0.904
Peak	00:05:17	00:00:52	00:03:34	00:06:25	14	00:05:45	00:00:52	00:04:10	00:07:32	15	0.176
Non-peak	00:05:16	00:00:53	00:03:55	00:06:44	15	00:04:48	00:00:38	00:03:47	00:06:18	13	0.130
Metro buses	00:05:31	00:00:48	00:03:55	00:06:33	14	00:05:10	00:00:45	00:03:47	00:06:18	15	0.266
Peak	00:05:30	00:00:40	00:04:18	00:06:25	8	00:05:33	00:00:22	00:04:59	00:06:14	9	0.866
Non-peak	00:05:32	00:00:57	00:03:55	00:06:33	6	00:04:37	00:00:49	00:03:47	00:06:18	6	0.134
BUSES TRAVELING EASTWARDS - TRONDHEIM S TO PRINSENS GATE 1 BUS STOPS											
All local buses	00:04:25	00:00:35	00:03:15	00:05:38	17	00:04:35	00:00:42	00:03:24	00:06:05	17	0.315
Peak	00:04:25	00:00:35	00:03:15	00:05:38	17	00:04:35	00:00:46	00:03:20	00:06:10	17	0.497
Non-peak	00:04:23	00:00:24	00:03:14	00:04:51	17	00:04:35	00:00:42	00:03:24	00:06:05	17	0.315
Metro buses	00:04:28	00:00:26	00:03:35	00:05:11	10	00:04:46	00:00:33	00:03:39	00:05:31	11	0.191
Peak	00:04:28	00:00:34	00:03:35	00:05:11	5	00:04:52	00:00:28	00:04:13	00:05:31	6	0.297
Non-peak	00:04:28	00:00:13	00:04:05	00:04:41	5	00:04:40	00:00:36	00:03:39	00:05:12	5	0.569
ALL BUSES TRAVELING WESTWARDS											
All local buses	00:02:52	00:00:39	00:01:47	00:04:44	74	00:02:59	00:00:39	00:00:35	00:04:33	71	0.301
Peak	00:02:59	00:00:32	00:01:47	00:04:18	41	00:03:04	00:00:42	00:00:35	00:04:33	39	0.548
Non-peak	00:02:43	00:00:44	00:01:50	00:04:44	33	00:02:52	00:00:35	00:01:29	00:03:51	32	0.372
Metro buses	00:02:52	00:00:35	00:01:47	00:04:16	22	00:03:04	00:00:33	00:02:01	00:04:33	23	0.268
Peak	00:02:58	00:00:29	00:01:47	00:03:37	12	00:03:14	00:00:31	00:02:36	00:04:33	13	0.416
Non-peak	00:02:45	00:00:40	00:01:55	00:04:16	10	00:02:51	00:00:32	00:02:01	00:03:41	10	0.730
BUSES TRAVELING WESTWARDS - PRINSENS GATE 2 TO OLAV TRYGGVASONS GATE 2 BUS STOPS											
All local buses	00:02:46	00:00:34	00:01:47	00:04:10	30	00:02:50	00:00:43	00:00:35	00:03:48	27	0.691
Peak	00:02:49	00:00:31	00:01:47	00:04:06	17	00:02:58	00:00:44	00:00:35	00:03:48	14	0.565
Non-peak	00:02:41	00:00:38	00:01:50	00:04:10	13	00:02:41	00:00:39	00:01:29	00:03:45	13	0.977
Metro buses	00:02:47	00:00:27	00:01:47	00:03:21	12	00:03:02	00:00:25	00:02:27	00:03:48	12	0.192
Peak	00:02:44	00:00:29	00:01:47	00:03:16	7	00:03:11	00:00:22	00:02:36	00:03:48	7	0.099
Non-peak	00:02:52	00:00:23	00:02:17	00:03:21	5	00:02:50	00:00:23	00:02:27	00:03:21	5	0.915
BUSES TRAVELING WESTWARDS - PRINSENS GATE 2 TO OLAV TRYGGVASONS GATE 3 BUS STOPS											
All local buses	00:02:56	00:00:41	00:01:55	00:04:44	44	00:03:04	00:00:36	00:01:51	00:04:33	44	0.344
Peak	00:03:06	00:00:32	00:02:12	00:04:18	24	00:03:08	00:00:40	00:01:51	00:04:33	25	0.863
Non-peak	00:02:49	00:00:50	00:01:55	00:04:44	17	00:02:57	00:00:28	00:02:01	00:03:51	16	0.571
Metro buses	00:02:58	00:00:42	00:01:55	00:04:16	10	00:03:06	00:00:41	00:02:01	00:04:33	11	0.688
Peak	00:03:17	00:00:15	00:03:01	00:03:37	5	00:03:17	00:00:38	00:02:37	00:04:33	6	0.979
Non-peak	00:02:39	00:00:50	00:01:55	00:04:16	5	00:02:53	00:00:40	00:02:01	00:03:41	5	0.679

Vedlegg 1 - Om arbeidet med oppgaven

Dette vedlegget beskriver kort deler av arbeidet med masteroppgaven som ikke fikk plass i artikkelen.

Høsten 2019 begynte arbeidet med prosjektoppgaven, som hadde utgangspunkt i universell utforming i shared space-områder, gater og kryss med lite eller ingen trafikkregulering eller separering mellom trafikantgrupper. I løpet av høsten ble det jobba med et utdypende litteratursøk om emnet. Det viste seg raskt at det er få egnede studieområder i Norge med shared space, noe som ville gjøre det utfordrende å finne en god og gjennomførbar masteroppgave om det. Etter hvert som bildet av temaet ble klarere kom det også fram at et av de viktigste motargumentene for å benytte shared space er at de påståtte positive effektene for trafikksikkerhet og framkommelighet i liten grad er vitenskapelig bevist. Kritikere peker på at det finnes få studier på shared space generelt, og enda færre som ser på effekten av redusert regulering av trafikken uavhengig av store ombyggingsprosjekter.

Mot slutten av arbeidet med prosjektoppgaven ble det funnet en studie fra Bristol i England som ble gjennomført på grunn av en teknisk feil i et lyskryss. Denne studien viste at trafikkavviklingen ble forbedra av at lyskrysset ble ødelagt, og ble brukt som inspirasjon til å utarbeide forskningsspørsmål til masteroppgaven. Dette er en av få studier som omhandler effekter av å redusere trafikkregulering, og den refereres til i kilder som omhandler shared space. I et norsk perspektiv er det viktig å påpeke at engelske sjåfører ikke må vike for fotgjengere som krysser vegen, og derfor ble det utforma forskningsspørsmål for å finne ut om man kunne fått de samme positive effektene av å fjerne lyskryss med norske trafikkregler.

Det ble bestemt at det skulle gås videre med ideen om hvilke effekter signalregulering kan få på framkommelighet og fotgjengeratferd. Etter samtaler med Miljøpakken ble det klart at det var flere aktuelle kryss i Trondheim sentrum som kunne egne seg til å se på effekten av signalregulering. Noen av de aktuelle kryssene var signalregulert, med en mulighet for å søke om å få gjennomført en testperiode uten trafikklys. De tre kryssene i Olav Tryggvasons gate skilte seg ut fra disse fordi det var kjent at de kom til å få trafikklysene skrudd på i løpet av våren, noe som ville forenkle prosessen betraktelig. Krysset med Nordre gate ble valgt på grunn av god strøm av fotgjengere og et relativt ukomplisert svingemønster der alle bussene kjører rett igjennom krysset.

Av praktiske årsaker ble det valgt å filme krysset. På det viset kan man se situasjoner flere ganger for å få med seg detaljer og hendelser som skjer samtidig. Det var lenge uvisst når trafikklysene i krysset skulle skrus på. Derfor ble det tatt kontakt med Vegvesenet og Trondheim kommune i desember for å finne ut når krysset måtte filmes, og om det måtte gjøres før jul. Det tentative svaret var at det ikke skulle skje før tidligst uke 4, og mest sannsynlig etter det. Det ble derfor antatt at det kom til å ta litt tid før alt var klart, og at jeg ville få forvarsel noen uker før. Da neste oppdatering kom om når trafikklysene skulle skrus på var det bare ei uke til. Det medførte at opptakene måtte tas i all hast, og at forholdene ikke var ideelle. Om trafikklysene hadde blitt skrudd på noen uker seinere hadde man kunne dratt nytte av lysere dager og bedre vær i tillegg til at man kunne ha filma helgetrafikk.

Senterleder og driftssjef ved Byhaven kjøpesenter var veldig behjelpelige med å sette opp kameraene. Testfilming med kameraene hadde bare blitt utført på dagtid, og etter at det ble klart at kvaliteten på filmene fra morgen og ettermiddag var relativt dårlig ble det tatt ei vurdering med veileder om å justere opp oppløsninga litt. Det ble også funnet en kamerafunksjon som automatisk justerte lysstyrken. Dette gjorde at de seinere opptakene ble av mye bedre kvalitet. Kameraene ble satt opp med loop-funksjon. Det vil si at kameraet filmer kontinuerlig, men sletter film underveis sånn at det bare er de siste timene som ligger på minnekortet til enhver tid. Dette gjorde at det bare var nødvendig å komme innom en gang om dagen for å avslutte filmene, laste dem over fra minnekort til ekstern harddisk og sette i gang kameraet på nytt. Datamengden gjorde likevel dette til en stor oppgave som tok lang tid og krevde mye lagringsplass. Ett av minnekortene ble ødelagt i prosessen med å overføre data, og en dag med film fra det ene kameraet gikk tapt.

Til analysen var det først planlagt å bruke programvare til å registrere reisetider og analysere framkommeligheten i krysset. Derfor ble det gjort iherdige forsøk på å benytte et svensk analyseprogram for trafikk, T-Analyst, fra Lunds Universitet. Dessverre ble det problemer med å installere programvaren på privat datamaskin, selv etter korrespondanse med utviklerne fra Lunds Universitet. Det ble også sendt en forespørsel om å få programmet installert på en av NTNUs datasaler, men dette ble ikke godkjent. Da alle forsøk på å få T-Analyst til å fungere ble avslutta ble det konkludert med at det enkleste var å gjøre registreringene manuelt. Hva som skulle registreres og hvilke sammenhenger som skulle utforskes var ikke helt klart på det tidspunktet, så det ble registrert flere ting som ikke endte opp i oppgaven. For eksempel ble både tilsynelatende årsak til bussforsinkelse, hvorvidt fotgjengerne krysset innenfor markeringene og gangbane gjennom krysset registrert. Det var tidkrevende å gå igjennom filmene, og den manuelle registreringa tok mye lenger tid enn venta. Det ble gjort manuelle registreringer til langt uti april, og det ble ikke tid til å registrere mer enn seks timer film til sammen (halvannen time på to kamera i to opptaksperioder).

De statistiske analysene ble til i mai, ved hjelp av de statistiske verktøyene i Microsoft Excel. Reisetidsanalysene ble gjennomført som planlagt med veileder. For analysene av fotgjengeratferd måtte det mer prøving og feiling til for å finne ut hvilken informasjon som kunne brukes. Det ble blant annet sett på fotgjengeres gangbane og om fotgjengere velger å gå innenfor gangfeltsmarkeringene når de krysser gata. Seinere ble det innsett at disse analysene ikke vil gi mening, siden det ble vrimlefase i krysset da det ble innført signalregulering, noe som oppmuntrer til å krysse diagonalt og til dels til å bruke hele krysset til å komme over.

Fordi det ikke var så stor overlapp mellom prosjektoppgaven og masteroppgaven måtte det meste av litteratur til artikkelen finnes i arbeidet med masteroppgaven. I arbeidet med masteroppgaven ble det mer tydelig hva studien skulle handle om. Derfor ble litteraturen funnet mer ad hoc enn i prosjektoppgaven, med mer spesifikk leting etter relevante publikasjoner. NTNUs søketjeneste Oria ble brukt som søkemotor for å finne egna litteratur, og det ble lagt vekt på å forsøke å finne publiserte artikler fra fagfellevurderte tidsskrifter der det var mulig. Det ble brukt varierte søkeord som «traffic signals», «effects», «pedestrians», «pedestrian behaviour», «bus», «prioritisation» og «red light» i ulike kombinasjoner. Dette er ikke ei fullstendig liste over søkeord, siden det ble benyttet utallige varianter. I tillegg ble enkelte av kildene funnet i referanselista til relevante artikler.

Koronautbruddet våren 2020 påvirka ikke oppgaven direkte med tanke på datainnsamling og gjennomførelse, men det gikk definitivt utover kontorfasiliteter, arbeidsmoral og livsgnist. Det var tungt å gå fra å ha en rutineprega hverdag, fast arbeidsplass på et kontor og gode studievenner i nærheten til å måtte bo og jobbe aleine på studenthybelen. Mye som vanligvis hadde blitt gjort fort og greit ble langvarig og seigt arbeid. Likevel ble det en oppgave av det til slutt, og det er nok ikke til å stikke under en stol at alle som har skrevet masteroppgave antakeligvis har kjent på frustrasjon rundt arbeidet, uavhengig av hvilke tider den ble skrevet i.

NTNU

Faculty of Engineering
Department of Civil and Environmental Engineering

Date	Our reference
3 June 2020	
Your date	Your ref

To Whom it Might Concern

Master thesis spring 2020 - consequences of the Covid 19 pandemic

The pandemic situation in spring 2020 made it necessary to change or adjust the topic for master theses at NTNU. The university closed including laboratories and did not allow any type of field work, thus made it impossible to continue planned work for many students.

Sincerely yours

Inge Hoff
Professor

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This letter was sent to all students with specialisation in Transport, Road or Railways in the Civil and Environmental study program to be included as an attachment in their thesis.

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