Summary

The effect of bus stop design on traffic safety and mobility

Literature review and explorative accident analysis

TØI Report 1703/2019
Authors Ross O. Phillips, Siri Hegna Berge, Oddrun Helen Hagen
Oslo 2019, 59 pages, Norwegian language

Accounting for traffic volume, the number of traffic accidents occurring within 60 meters of the bus stop is somewhat higher for curbside than for layby stops. The data indicates, however, that this is not due to the way the bus stops are designed, but their location in relation to other road characteristics. For curbside bus stops, the number of accidents increases with increasing distance from the bus stop (up to 50 meters away). For layby stops, most accidents happen nearer the bus stop (less than ten meters away). Since more accidents occurring by curbside bus stops are registered in the official accident statistics as "accident at junction", many of the conflict situations occurring near curbside bus stops are probably due to the junction and not the design of the bus stop. The observed difference in accident risk can also be caused by differences in the number of vulnerable road users or bus departures for curbside versus layby stops. We find no support for the hypothesis that there are more head-on collisions by curbside than by layby stops, and no difference in the number of, or types of road user involved in, serious accidents occurring within 60 meters of a curbside and layby stops. Accident risk, mobility, and situational characteristics of the bus stops were studied by literature review and explorative accident analysis. Using data from the national road databank («Vegkart») and Statistics Norway, we studied 5,625 accidents occurring near 63,729 bus stops, on local, county and state roads in Norway. There are few empirical studies on the effects of bus stop design on mobility or traffic safety, and those that exist often conflict with each other. To increase knowledge of the effect of bus stop design on mobility and traffic safety, we conclude that there is a need for empirical observation of conflicts and near-misses occurring near different types of bus stop, accident analyses that control for situational charactersitics of different bus stop types, in-depth studies of accidents near bus stops, and change in accident type and frequency before and after bus stops are changed or introduced.

Background

There are two main types of bus stop: a curbside bus stop, where the bus stops in the road, and a layby stop, where the bus stops to the side of the road (Figure S1). Layby stops can be open to or physically separated from the road beside them.

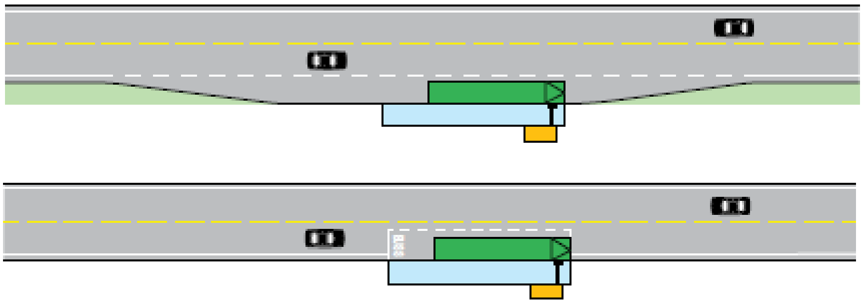

Figure S1. Designs illustrating curbside (lower) and layby (upper) stops. (© 2014 Vegdirektoratet, Trafikksikkerhet-, miljø- og teknologiavdelingen).

When bus stops are reconstructed or upgraded, a case-by-case assessment is made. The criteria used as the basis of stop design account for the form and function of the transport, surroundings, speed limit and traffic volume, and these are assessed against market and capacity needs. All new stops should also be universally designed to help ensure that the public transport service is fully inclusive.

In later years some laybys have been converted to curbside bus stops and in a few cases curbside bus stops have been converted to laybys. This has been a source of debate among authorities and in the media. Important drivers of conversion to curbside bus stops are (i) space saved and (ii) prioritization of public transport over car traffic. Curbside bus stops can also be less expensive that laybys, and give better mobility for vulnerable road users. They also have benefits should several buses need to stop at the same bus stop simultaneously. On the other hand, some argue that curbside bus stops present traffic safety problems, due to the traffic cues formed, the increase in overtaking maneuvers, and the poor visibility of pedestrians crossing the road in front of the bus. There is, however, little scientific literature on the effect of bus stop type on mobility and traffic safety for the different groups of road users, and it is therefore difficult to draw conclusions.

This study aims to bring new, updated knowledge about the effects of bus stop design on traffic, with a focus on traffic safety and mobility of different road user groups, to enable evidence-based assessments about bus stop design when bus stops are established or converted. We aim to answer the following questions:

- What do empirical studies say about the effects of bus stops, bus stop design and local road characteristics on traffic safety and mobility?
- Is traffic accident risk influenced by how the bus stops are designed, i.e. curbside versus layby stop?
- What characterises traffic accidents occurring near curbside versus layby or other types of stops in built up areas?
- To what degree is it possible to use national databases for traffic accidents to carry out analyses of traffic accidents near bus stops in built-up areas?

Methodological approach

To try and answer these questions, we conducted out a literature review and accident analysis. In the literature review, we assembled and updated international knowledge on the traffic safety, local characteristics and mobility effects of different types of bus stop, focusing on curbside and layby stops. We tried to identify major factors identified by the literature as influencing risk for traffic accidents occurring near the stops. We based our accident analysis on register data from 69,067 stops on local, county and state roads in Norway, and data from 5,625 traffic accidents occurring up to 60 meters from the bus stops in the five years between 2014 and 2018. Our data were collected from the national road database (*Nasjonal vegdatabank,* NVDB) and Statistics Norway (*Statistisk sentralbyrå*, SSB). The data set included variables on whether the bus stop was located in built-up area, and on speed limit and traffic volume for the stretch of road on which the stop was located. The data could not be used to distinguish between traffic accidents involving bus and other types of vehicle. The degree to which the design of the bus stop *caused* the traffic accident was also not known.

Comparisons of risks for traffic accidents near curbside versus layby stops were based on the analysis of accidents by 660 relevant curbside bus stops and 4,588 relevant stops of the type «platform and layby» (which we refer to in the rest of this summary as layby stops).

Many variables influence traffic safety near bus stops

From a review of the literature on accident risks for different types of road user, we identified a number of potential variables that could be relevant to analyse or control for when studying accident risks for different road users near bus stops. Figure S2 illustrates most of these variables.

Figure S2. Illustration of most of the factors that influence the risk of near-bus stop traffic accidents, according to literature review. Graphic made using freepik.com (© vectorpouch).

Figure S2 shows a bus stop. Variables that can potentially be associated with near-stop traffic accident risks, as identified from a review of the literature, are:

- Bus stop type
- Number of bus stops along stretch of road
- Traffic volume
- Number of traffic lanes in the direction of the bus stop
- Speed limit along stretch of road
- Number of road users, passengers, cyclists and pedestrians
- Bus lanes
- Bicycle lanes and whether they are in front of or behind the bus stop
- Pedestrian crossings along the stretch, and at nearby junctions
- Pedestrian crossings with or without traffic signals
- Refuge for pedestrians between driving lanes
- Pavement along stretch
- Lighting conditions along stretch
- Season, weather and driving conditions
- Location of bus stop in relation to nearby junctions, i.e. upstream (come before the junction for buses using the bus stop), downstream (come after the junction for buses using the bus stop) or between junctions
- Location of stop in relation to side roads.

- Road curvature and visibility, i.e. if the stop is on a straight stretch of road, or on, just before or following a bend
- Number of cars parked along the road nearby

To understand differences in accident risk that are due to the way different bus stops with varying local characteristics are designed, one needs to account for a number of confounding variables. To control for the effects of these variables, one must assemble data for stops with and without associated traffic accidents, because one cannot say anything about the risk of traffic accident near a certain type of bus stop without knowing how many similar bus stops have not had traffic accidents nearby. In this study it has not been possible to assemble data on all these variables.

Mobility

Layby bus stops are associated with longer delays for bus passengers than curbside bus stops, especially on roads with speed limits over 60 km/t, where other road traffic does not have to give way to buses pulling out of stops. Layby bus stops, especially with shelters, demand more land than curbside bus stops. If space is limited, it can be a challenge to satisfy universal design criteria for layby bus stops, and this can reduce mobility for vulnerable road users and different user groups. It such cases curbside stops with bus lane, or alternatively «bus bulbs» (where pavement widens and road narrows at the stop) can be considered as preferable solutions for mobility for those using public transport.

Bus stop type and traffic accident risk

The literature review showed that bus stops generally are related to increased risk for accidents involving motorized traffic, cyclists and pedestrians. This is in part due to larger numbers of vulnerable road users, heavy vehicles and more complicated traffic patterns nearer bus stops, especially stops with junctions and crossings nearby. There are not enough studies to enable conclusions about how accident risks are related to different types of bus stop design. One study indicates that pedestrian accidents are more serious near layby than curbside bus stops, but this is probably related to higher traffic speeds near the former. Tram studies show that tram stops placed in the middle of the road have on average more serious pedestrian accidents than curbside tram stops. Several studies highlight the need for traffic measures that ensure that pedestrians can get safely to and from the stop, especially for mid-placed and layby stops.

Of the 69,067 stops on local, county and state roads in Norway, 63,729 were bus stops (based on the assumptions of our analysis). In the period from 2014 up to and including 2018, 5,625 traffic accidents were registered within 60 meters of 3,278 of the bus stops. In this study we calculated the risk of traffic accidents near bus stops for the period 2014-2018, where we use the total number of stops and traffic volume along the stretch of road as exposure variables. Lack of traffic volume registrations on certain stretches limited the data base somewhat. In total there were 47,929 bus stops and 4,703 associated accidents registered on stretches of road for which traffic volume registrations were also available.

In this study we define risk as the number of traffic accidents near a bus stop per 10 mill. vehicles travelling along the stretch of road adjacent to the bus stop per day. For the whole of Norway, the risk for a traffic accident within 60 meters of all types of bus stop, on all types of road in and outside built-up areas, was 0.20. The risk was higher in built-up areas

(0.26) than outside built-up areas (0.15). The risk of an accident occurring within 60 meters of a curbside bus stop in a built-up area was higher than the corresponding risk for layby bus stops (0.32 vs. 0.22). A survey of situational characteristics associated with the traffic accidents shows that a greater share of those accidents near curbside bus stops occur at road junctions, as compared with accidents near layby bus stops. This can be related to two other findings:

- The share of those car and pedestrian accidents occurring within 60 meters from a curbside bus stop, increases with distance from the stop. The share of accidents occurring within 60 meters from a layby stop, is greatest closest to (10 meters or less from) the stop.
- The share of accidents near curbside stops in built-up areas coded as «Driving direction crosses path without turning» – a typical road junction accident – is twice as high for curbside than for layby bus stops.

The reason why accident risk is somewhat higher for curbside than for laybe stops can be that curbside stops often lie closer to junctions, where conflict situations are more common. If we look exclusively at accidents near bus stops (in built up areas) away from road junctions or side roads, we find that the share of pedestrian and car accidents is greater within 0 to 10 meters from both curbside and layby stops.

Differences in exposure (number of bus departures, pedestrians, cyclists etc.) can also help explain the apparently higher risk of traffic accidents occurring near curbside than layby bus stops. We should also note that curbside stops tend more to be located on local roads, where there is less need to meet standard road norms and universal design criteria than there is on county and state roads. The data give no reason to believe, therefore, that there is a difference in traffic accident risk related to stop design.

We found no clear relation between near-stop accident risks and speed limit of the road adjacent to the stop, from 30 to 60 km/h. For curbside stops, the risks appeared to be lower on roads with speed limit 60 km/h than on roads where the speed limit was 30 km/h. The data show a clear and positive relation between traffic volume along the stretch of road adjacent to the stop and average number of accidents within 60 meters of the bus stop, both for curbside and layby bus stops.

Our analysis gives little support to hypotheses about how curbside bus stops increase traffic accident risks compared with layby bus stops, or *vice versa*. Looking at the share of different types of traffic accidents occurring near curbside and layby stops, for example, we find little evidence for many more head-on collisions occurring near curbside than layby bus stops. There are indications that single vehicle accidents tend to occur more near layby stops. This should be studied further, since it may be related to bus stop design.

Comparing curbside and layby bus stops, we found no significant differences in the number of serious road accidents occurring nearby, and no difference in the sort of road user involved in these accidents. The share of traffic accidents involving pedestrians was between 16 and 18 per cent, for both curbside and layby bus stops in built-up areas. The analyses indicate, on the other hand, that more of the accidents near layby than curbside stops occur on roads with a single driving lane in each direction, while there were more relatively more accidents near curbside (than layby) stops on roads with two lanes in each direction. This can be due to the fact that curbside stops tend more to be established on roads with bus lanes; our data do not distinguish which, if any, of the driving lanes are bus lanes.

Study limitations

There are a number challenges to be faced when linking and analysing data describing objects and events located in time and space. Our knowledge about potential sources of error or weaknesses in the data available from NVDB and SSB are limited. Another problem is that the extent to which registrations are made systematically varies according to region and according to whether objects and events associated with local, county and state roads. This matters because stops may have varying design standards, according to varying practice associated with local, county and state roads. Better differentiation between bus stops on state, regional and local roads would have, for example, allowed us to compare bus stops administered by National Public Roads Administration (NPRA)'s versus those administered by those responsible for local roads.

Our literature review identified 18 variables that could influence risks for traffic accidents near bus stops, but we could only control for bus stop type, traffic volume, and to some extent speed limit. Even though we accounted for total traffic volume, our analyses do not account for the number of buses, pedestrians or cyclists passing the bus stop. The risk numbers we present are directly comparable only if there are no systematic differences in the number of buses, pedestrians and cyclists passing or using different types of bus stop.

Conclusions and recommendations

According to the literature, layby bus stops and stops placed in the middle of the road can present challenges to mobility for bus passengers, pedestrians, cyclists and other vulnerable road users. Even though they may also present mobility challenges to passing pedestrians and cyclists, curbside bus stops prioritise public transport over car traffic. Analyses of this prioritisation shows that the socioeconomic benefit tends to outweigh the disadvantages for car users. Layby bus stops will often demand the use of more land for universal design than curbside bus stops.

Literature on accident risk at different types of bus stops is both limited and conflicting. There is little empirical support for or against curbside stops being more dangerous than layby stops or *vice versa*. Our analyses indicate that the risk of traffic accidents near bus stops in built-up areas are somewhat higher for curbside than layby stops, but that can be due to more departures, pedestrians, cyclists and other vulnerable road users using or passing curbside stops. It can also be due to more curbside stops being placed near junctions or crossings. We see an increase in traffic accidents with increasing distance from the bus stop for curbside stops, and relatively more of those accidents occurring by curbside stops are junction accidents than those occurring near laybys. Traffic accidents occurring at junctions within 60 meters of a curbside stop will in some cases have nothing to do with the bus stop. Since bus stops increase the amount of pedestrians using nearby junctions, and that the design of the bus stop can feasibly lead to conflicts at junctions, the effect of bus stop on accident risk at junctions should be looked at in detail. Indications of higher risks for traffic accidents near curbside stops on roads with traffic volumes over 5,000 vehicles per day should also be studied more closely.

Our accident analysis does not support a hypothesis that more accidents occur near curbside than near layby stops, due to an increase risk for dangerous overtaking maneuvers. The data do not support a difference between the share of pedestrian accidents occurring near curbside and layby stops. We see indications that more traffic accidents occurring nearer layby bus stops are single vehicle accidents, which can suggest that there are several road-exits at these types of stop.

To further develop an empirical knowledge base for reconstruction or establishment of bus stops in built-up areas in Norway, we recommend the following:

1. Carry out conflict studies i.e. direct observation of mobility challenges and dangerous situations occurring due to the way the bus stop is designed in interaction with local road characteristics. The results will give a basis for the optimisation of bus stop design for mobility and traffic safety according to local road characteristics.
2. Build further on the analyses in this study, by better controlling for local road characteristics and road type (local, county, state), and study the higher risk of accidents in the vicinity of curbside stops, with a focus on road characteristics such as nearby junctions and crossings, in addition to higher traffic volumes. It is also possible using *Vegkart* to look at different types of vehicles involved in accidents near bus stops – not least bus. We have not looked vehicle type in this study. Coupling of *Entur's* data on bus stop use with data from NVDB would give information on bus and passenger volumes using a bus stop. These variables, together with variables for number of pedestrians and cyclists on a stretch of road, are needed for a multivariate model with all relevant exposure variables. Such a model could not be built with the resources of the present study.
3. Carry out in-depth studies by looking in detail at accidents associated with a limited number of bus stops. This would generate increased knowledge about the role of bus stop design in traffic accidents, e.g. by comparing accidents at different types of stops located on a straight stretch of road, i.e. uncomplicated by nearby road objects.
4. Before-and-after studies of bus stops that have been reconstructed. Collection and evaluation of data from traffic accidents along a stretch of road before and after reconstruction could also contribute to knowledge on the relation between bus stops and accidents, but limited numbers of relevant accidents may be a problem.