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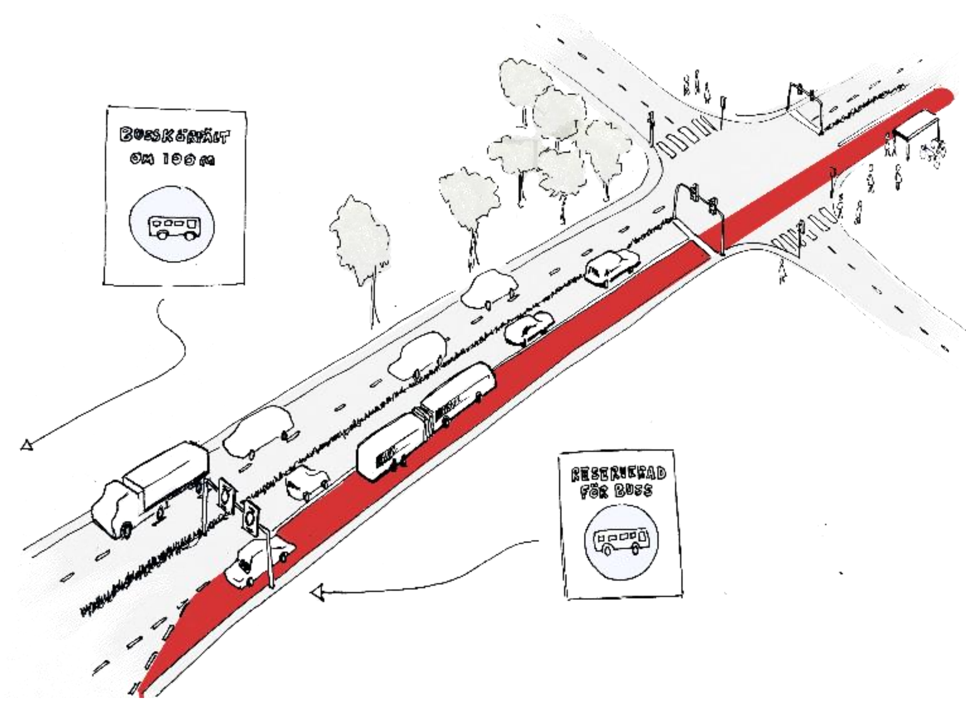
PROVDYK
Dynamic bus lanes in Sweden – A pre study



Project within FIFFI Transport Efficiency

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1. Executive summary

Dedicated bus lanes and bus streets have, in recent years, become common measures for prioritisation of public transport. By ensuring free path along routes, they increase average speed and travel time reliability of buses. However, a major drawback is that the total traffic capacities of the roads decrease. Hence, these measures are only suitable when the total traffic flow is low enough to allow for a reduction of lanes; if it is possible to reroute adjacent traffic; or if it is possible to extend the road with additional lanes. A supplementary priority measure could be to utilize dynamic bus lanes (also called intermittent bus lanes and bus lanes with intermittent priority). Dynamic bus lanes are only dedicated for buses when and where the buses need them, and otherwise open for all vehicles to use. At any given point, adjacent traffic is only permitted from using the dynamic bus lanes at the stretches where buses are in the vicinity. This report presents the results from a pre-study, investigating the potential that dynamic bus lanes could have as a priority measure for public transport in a Swedish context.

Knowledge of situations in which dynamic bus lanes have the highest potential, and their implementation requirements is scarce. It is moreover uncertain how they would affect traffic safety, level of service and user experience. Two real world field tests have been conducted; one in Lisbon and one in Melbourne. The installation in Melbourne is now permanently applied for trams on one street. The field test in Lisbon was on the contrary not made permanent, although the results showed large benefits for buses and limited adverse effects on other vehicles. Dynamic bus lanes have also been investigated by means of traffic analysis and traffic simulation experiments. In general, these studies show that the effects on travel time for buses are in general positive and delays for other vehicles are limited. Results from example calculations in this pre-study show that this also could be true for a Swedish context. It has also been identified that the effects on travel times are highly dependent on factors such as: the total traffic flow; the bus flow, the capacity of roads and junctions; the distance between junctions and bus stops; the type of bus stops and the yielding rules at bus stops. The effects on travel time variations are unclear and need to be further investigated.

Few rigorous research studies have been undertaken to measure the user experiences or road safety implications of bus priority schemes, and evidence from those that do exist are mixed. Anyhow, the experiences from Lisbon and Melbourne suggest that drivers in adjacent lanes in general understand and accept that they are deprived of the right to use the lane when the buses need it, and that they will behave appropriately. Neither of the field tests has observed any negative impact on road safety. A workshop was conducted within this pre-study in order to further investigate plausible user experiences. The results indicate that bus drivers' stress levels could be reduced; the relative attractiveness of travelling by bus might rise; and that motorists probably would experience the introduction of dynamic bus lanes as neither good nor bad, as long as the system is fairly intuitive.

Technical solutions for implementing dynamic bus lanes exist. A dynamic bus lane system would require development of a system control unit and integration with bus sensors, sensors for traffic flow measurement, variable message signs (to inform road users of the current status of the dynamic bus lane) and traffic signals. It is moreover, in Sweden, possible to develop a local traffic rule that regulates dynamic bus lanes. However, the rule needs to be properly specified, designed, communicated, signed and marked on the road.

The overall conclusion form the pre-study is that dynamic bus lanes could be a useful complementary priority measure for public transport vehicles in Sweden, especially when dedicated bus lanes are not feasible or desirable. However, a real world installation in Sweden, including pre implementation traffic analysis, is needed, in order to further investigate the potential and consequences. Thus, the next step is to plan for an implementation on a specific road stretch. That would include both estimation of costs, and generate input to further studies of effect on level of service and user experience. Driving simulators and traffic simulation experiments are applicable methods for investigating these issues.

2. Background

Effectiveness and reliability have been identified as two key factors to increase the attractiveness of public transport (Ipsos, 2013, Johansson et al., 2010). Thus, to not be impeded by adjecent traffic along bus routes is critical for bus services' performance. In mixed traffic, buses cannot perform better than what the traffic situation allows them to, and traffic queues frequently delay buses, especially during rush hour. This undermines the bus services' reliability and effectiveness and thereby the attractiveness of the transport mode. Dedicated bus lanes and dedicated bus streets have as a consequence become common measures for separating buses from adjacent traffic. They have proven to be effective in ensuring free path for buses and thus increasing both their average speed (Andersson and Gibrand, 2008) and their reliability (Trafikverket, 2014). A major drawback is however that the total traffic capacity significantly decreases when dedicating one lane for the public transport. Hence, these priority measures can only be used where and when the traffic flow is low enough to allow for a reduction of normal lanes; if it is possible to reroute adjacent traffic; or if it is possible to extend the road with additional lanes. More often than not, none of these alternatives are economically viable.

A supplementary priority measure is to utilize dynamic bus lanes (also called Intermittent Bus Lanes (IBL) and Bus Lanes with Intermittent Priority (BLIP)). Dynamic bus lanes are only dedicated for buses when and where the buses need it, and otherwise open for all vehicles to use. At any given point, only the sections of the dynamic bus lane where buses are in the vicinity are dedicated for buses. Therefore, dynamic bus lanes can, in appropriate settings (e.g. suitable traffic flow), ensure bus accessibility without deteriorating the total traffic capacity. The measure moreover utilise existing infrastructure and is thus a comparatively inexpensive priority scheme.

The main goal with dynamic bus lanes is to utilise the existing infrastructure in order to create the same benefits for bus service as with dedicated bus lanes but with less impact on adjacent traffic. In other words, the goal is that the travel time and travel time variability of buses should decrease without the travel time and travel time variability for adjacent traffic deteriorating significantly. The method to achieve this is to only dedicate the bus lane for buses when they need it. Figure 1 and Figure 2 illustrates the basic principles of the dynamic bus lane concept, which was originally introduced in Viegas and Lu (1996) and can be described as:

> *"When a bus is approaching such a section, the status of the lane is changed to BUS lane, and after the bus moves out of the section, it becomes a normal lane again" (Viegas and Lu, 1999).*

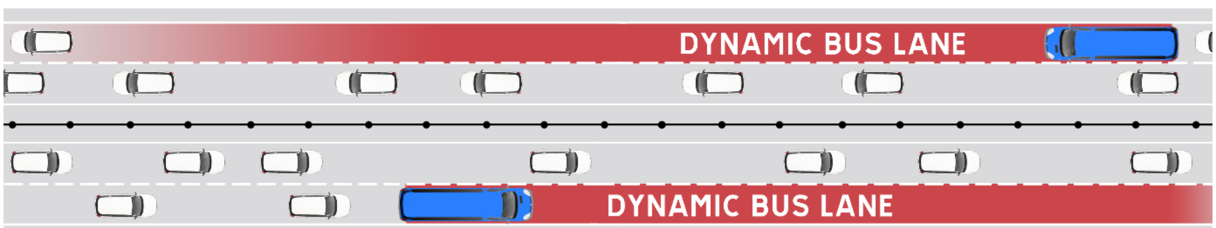

Figure 1 Illustration of the dynamic bus lane concept. (Illustrator: Göran Smith)

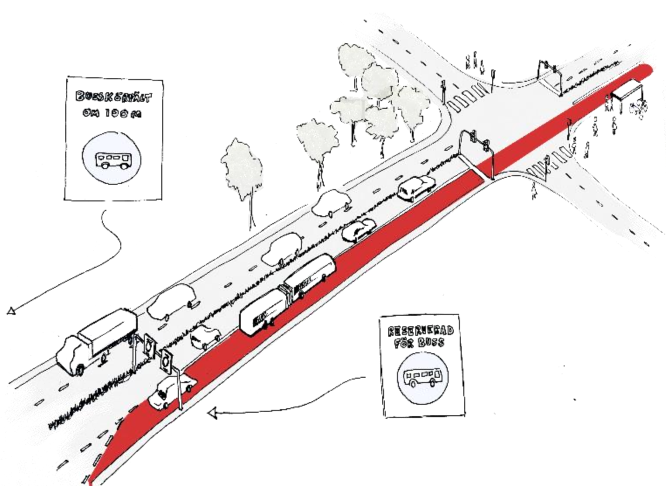

Figure 2 Illustration of the dynamic bus lane concept. (Illustrator: Göran Smith)

The concept of dynamic bus lanes was initially proposed by Viegas and Lu (1996). Since then analytical evaluations, simulation studies and a field test has been performed. A version of the measure has moreover been permanently applied for trams on one street in Melbourne since 2001 (Currie and Lai, 2008). The results of these studies indicate reduced travel time and travel time variability, usually without any significant impact on adjacent traffic. However, knowledge of the requirements for implementing dynamic bus lanes, in which traffic situations they have the highest potential, and how they would affect traffic safety, level of service and user experience remains scarce. Further investigations are also needed for assessing which design that can be used in a Swedish traffic context.

3. Objective

The aim of this pre-study was to investigate which potential dynamic bus lanes has as a measure to prioritise public transport in a Swedish context. The following research questions were therefore investigated:

- What is the state-of-art of dynamic bus lanes?
- Are there any legal constraints on their implementation in Sweden?
- What technology is available and what technical solutions still need to be developed?
- How would level of service for buses and for adjacent traffic be affected?
- How would road users view and experience the introduction of dynamic bus lanes in Sweden; how would they react and what consequences would the introduction thereby have, especially on road safety?

4. Project realization

Reviewing the state of art and how it applies for a Swedish context has been the core of the pre-study project. The pre-study was divided into four work packages, each package dealing with a specific aspect of dynamic bus lanes. The packages were:

- legal aspects
- system architecture
- level of service
- user experience and safety

The methods and approaches utilised differ to some extent between the different work packages.

5. Results and deliverables

5.1 Delivery to FFI-goals

The project have contributed to the overall FFI goals in the following ways

- The project have contributed to enhance the research and innovation capacity in Sweden by investigating new and innovative ways to increase the capacity utilisation of the Swedish road infrastructure.
- The project have contributed to the development of strong research and innovations environment, especially the public transport research centre K2.
- The project have been conducted by a consortium consisting of institutes, universities, industry, authorities and municipalities. This together with the wide variety of scientific competences in the project group have contributed to the goals of cross-industry collaboration and industry-academy collaboration.

The project have contributed to the FIFFI goal

- “Driveways and vehicles for specific usage and applications – Qualifying Transport Systems, e.g. Buss Rapid Transit (BRT), High Capacity Transports (HCT) and urban goods transports. ” (Vinnova, 2013)

and the identified need of analysis, model development and design of such systems.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The knowledge and results from the project have been presented and discussed at a final project seminar at K2 in Lund. The project have also been presented at the Vinnova FFI project days.

6.2 Publications

Olstam, J., Häll, C-H, Smith, G. Habibovic, A. and A. Anund. PROVDYK – Final report: Dynamic bus lanes in Sweden – A pre study, K2 Research 2015:5, Lund, Sweden. http://www.k2centrum.se/sites/default/files/fields/field_uppladdad_rapport/dynamic_bus_lanes_in_sweden.pdf

7. Conclusions and future research

This report presents the results of a pre-study on dynamic bus lanes as a concept for the prioritization of public transport vehicles.

7.1 Conclusions

What is the state of art of dynamic bus lanes?

- Two real world tests have been conducted, one in Lisbon and one in Melbourne.
- The installation in Melbourne is permanently applied for trams on one street and planned to be applied for more streets, but is unclear if this has been done.
- The field test in Lisbon was not made permanent although the results show large benefits for the buses and limited effect on other vehicles. The main reason seems to be that the public transport provider and the municipality preferred dedicated bus lanes and that dynamic bus lanes were seen as a second best alternative.

Are there any legal constraints for an implementation in Sweden?

- It is possible to develop a local traffic rule that regulates dynamic bus lanes. However, the rule needs to be properly specified, designed, communicated and signed and marked on the road.
- Assessing culpability in the case of non-compliance with the bus lane by other drivers might be difficult since the police need to be able to show that the dynamic bus lane sign was showing when the driver passed it.

Which technical solutions are available and what technical solutions need to be developed?

- There are technical solutions that can be utilized to implement dynamic bus lanes. Such a system would require the development of a system control unit and integration with other traffic controllers, sensors for traffic flow measurement (e.g. traffic signals, inductive loops, cameras), communication systems and variable message signs (to inform road users of the current status of the dynamic bus lane).
- Since surveillance of compliance is an issue from a legal aspect the system might need to be extended with a compliance control unit (e.g., plate recognition).
- Future traffic system including connected and autonomous vehicles might give possibilities for enhanced dynamic bus lane systems, e.g. by informing drivers via the vehicles internal displays making it possible to start and end a dynamic bus lane in any location and not only at those fixed locations with a VMS.

How would level of service for buses and for adjacent traffic be affected?

- The effects on travel time for buses are in general positive and the delays for other vehicles are in general limited.

- The effects on travel time depends highly on the traffic flow and the bus flow in relation to the traffic flow, the capacity of the road and the junctions, distance between junctions and bus stops, type of bus stops and yielding rules at bus stops. This makes it difficult to make general recommendations on when dynamic bus lanes are applicable.
- The effects on travel time variation and travel time reliability are unclear and need to be further investigated.

How would road users experience and react upon dynamic bus lanes in Sweden and what would the consequences be?

- Bus drivers' stress levels could decline, which may be reflected in their driving behaviour. Fewer interactions with adjacent traffic and lower stress levels moreover lead to fewer bus incidents and accidents. The working conditions for bus drivers might therefore become better.
- The relative attractiveness of travelling by bus might rise due to smoother flow and higher reliability. Thus, some degree of modal shift in favour for public transport can be expected.
- Most private motorists would probably experience the introduction of dynamic bus lanes as neither good nor bad as long as the system is fairly intuitive, it is stress-free to change lanes at the entrance point of the lane and the system doesn't create a significant worsening of the situation for adjacent traffic. A malfunctioning system could however cause anxiety and annoyance. If the lane-changing manoeuvre causes stress and irritation, there is a risk of intentional or/and unintentional misuse and thereby less safe road behaviour. Some motorists will moreover probably change lane earlier, pick a different route or choose when to pass the section more carefully, if the system causes severe congestion. This will likely redistribute traffic across the network and over the day.
- Professional drivers will probably have similar experiences as private motorists. The lane-changing manoeuvre at the entrance point might however be particularly difficult for truck drivers and professional drivers might in general have a greater tendency than private motorists to adapt their behaviour. Furthermore, taxi drivers may feel marginalized since they consider themselves as a part of the public transport sector.

The conclusions can be summarized as follows. Dynamic bus lanes have the potential to be complementary concept to prioritize public transport vehicles where dedicated bus lanes are not feasible or desirable. However it is, based on the current state of art, not possible to draw conclusions as to whether this is true in the Swedish context or not. More real world installations, including pre implementation traffic analysis, are needed.

7.2 Potential cases for dynamic bus lanes based on lessons learnt

Based on the literature review, workshops and discussions, the project group have come to the conclusion that the potential locations and traffic situations for dynamic bus lanes in Sweden might differ to some extent compared to the ones commonly investigated in the literature. Our view is that dynamic bus lanes can be an alternative measure when the arguments for a dedicated bus lane are not strong enough. This could, for example, be if the bus frequency is low (e.g., more than 5-10 minutes between buses) or when the road space is limited (for example at bridges or under bridge passages). Dynamic bus lanes mainly aims to solve the problem of buses being delayed due to queuing. Therefore, the traffic demand is an important factor to consider when deciding where to implement dynamic bus lanes. If the traffic demand is low, a dedicated bus lane is probably more appropriate than a dynamic bus lane (even on streets with low bus frequencies). If the traffic demand is larger than the capacity, the impact on adjacent traffic will probably be too high and neither a dedicated nor a dynamic bus lane is appropriate. To summarize, our view is that dynamic bus lanes can be a suitable bus priority measure in traffic situations fulfilling the following conditions:

- buses are delayed and would benefit from prioritisation, e.g. due to queues (also delays due to shorter queues of 5-10 vehicles) in connection with junctions or roundabouts
- dedicated bus lanes are not feasible, e.g. due to too large delays for other traffic or limited available space
- the bus frequency is low (e.g. more than 5-10 minutes between buses)
- the traffic demand is below the reduced capacity.

7.3 Further research needs and suggestions for next step

There are several topics that need further investigation, including effects of dynamic bus lanes on travel time reliability, merging behaviour, installation costs, etc. We propose that the next step should be to plan for an implementation on a specific road stretch, partly to enable estimation of installation and maintenance costs, and partly as an input to driving simulator and traffic simulation experiments. The driving simulator experiment could be used to investigate driver interaction with a dynamic bus lane system interface, merging behaviour at the start of a dynamic bus lane, etc. Also, such experiments could provide information for the traffic simulation experiments. The traffic simulation experiment could be used to investigate performance of dynamic bus lanes in terms of travel time savings and travel time variability for different bus frequencies and traffic flows. The analysis should not only include dynamic bus lanes as the only bus prioritization measures, but should compare alternative bus priority measures such as traffic signal priority, pre-signals, and bus queue jump lanes. The traffic simulation experiments could also be utilized to evaluate the impacts of different merging behaviours and percentage of non-compliant drivers.

8. Participating parties and contact person

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Lunds kommun: Samuel Yngve
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