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Innovative Bus-Lane Deployments in Amman: Proposed Field Experiments

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1. Introduction

Described here are field experiments that we propose for the small portion of Amman's road network illustrated in Fig 1. The experiments would test some innovative strategies for deploying bus lanes on the network. The objectives behind these strategies are to eliminate (or nearly eliminate) delays to buses on the network, while minimizing the resulting damage done to car traffic.

The test site shown in Fig 1 was selected as a result of a meeting with Amman officials that took place in early August. The site includes the signalized intersection at the south end (labeled *junction I* in the figure) and the tunnel (labeled *junction II*) to the north. Bus frequencies on this portion of network are projected to be small, at least in the near term, with headways of about 5 min.

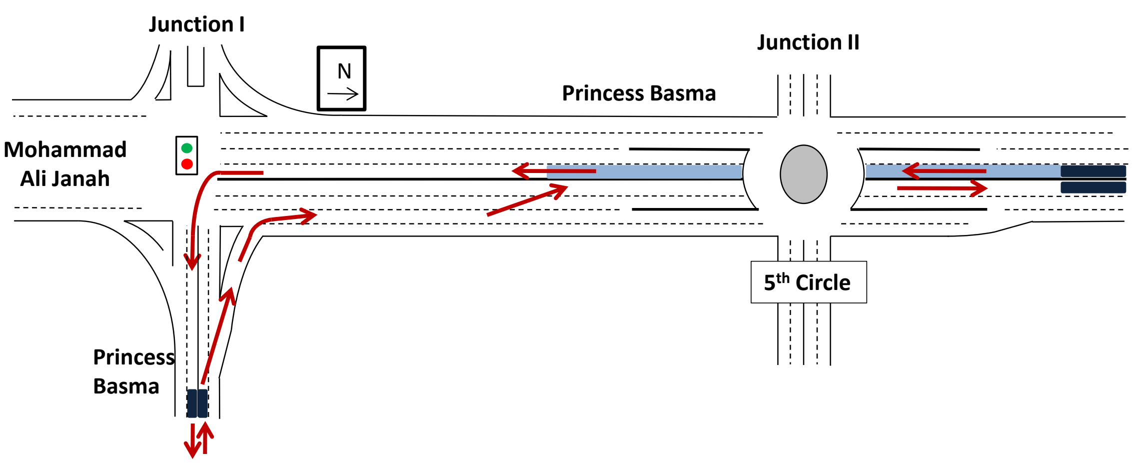

Figure 1. Existing Geometry of Study Location

The proposed experiments would test strategies for buses that travel on Princess Basma: i) westbound to northbound; and ii) southbound to eastbound. These bus paths are depicted by arrows in Fig 1. Also shown in the figure are the approximate locations of what would be: permanent, static bus lanes, which are shown with dark gray shades; and an intermittent bus-lane segment, which is shown with a lighter shade. On portions of the roadway without shading, buses would share lanes with cars without enjoying priority, but would do so in strategic ways that would not delay buses much, if at all.

Details on how all this would work are presented in this brief report. We will begin by describing the proposed strategies in some detail. We will conclude by describing how the experiments could be conducted in simple and safe ways; and without the high cost of investing in permanent infrastructure at this early stage, before the benefits of the proposed strategies have been verified in the field.

We hope that this discussion will serve two purposes. First, to convey that the proposed strategies can be far better options than conventional, static bus lanes, given the test site's large car demand and low bus frequency. Second, we propose to test a variety of innovative strategies on the site. We believe that the outcomes of these field tests will be very successful, and hope that this will pave the way to deploy these ideas on a permanent basis, both at the test site and elsewhere in the Amman network.

2. The Ideas

We will first describe the proposed ideas for the westbound to northbound bus route, and then for the southbound to eastbound route. In each case, we will start by describing the problems that would arise if static bus lanes were used everywhere along these routes. We will then describe the proposed strategies and explain how these would be preferable to the wholesale deployment of static bus lanes.

2.1 Westbound to Northbound Bus Route

The Problems

Deploying a static bus lane over the entire westbound approach to *junction I* would significantly diminish its capacity to serve westbound cars. This would create long car queues and delays. These long queues would now significantly obstruct (and delay) even the right-turning westbound cars by blocking the entrance to their free right-turn lane; see Fig 2.

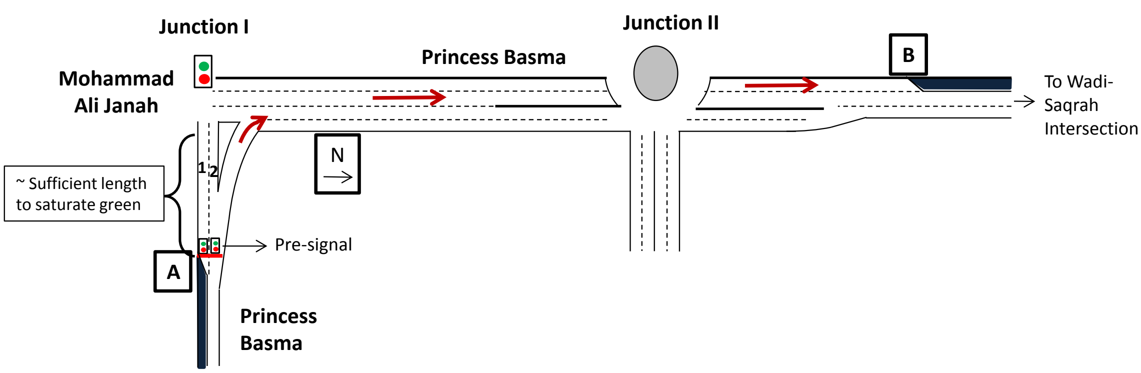

Figure 2. Proposed Strategy for Westbound to Northbound Route

Proposed Solutions

A static bus lane could be deployed on the westbound approach to allow westbound buses to bypass car queues. However, we propose that this static bus lane be discontinued about 75 m upstream of *junction I*, at the location labeled A in Fig 2. Cars would be permitted to use the 75 m segment of the median lane immediately upstream of *junction I*. In this way, the traffic signal's green time for westbound cars could be very nearly saturated (i.e. fully used) in every cycle during the rush. Little or no car-carrying capacity would be lost.

Westbound buses would be managed by means of a pre-signal at location A. When a bus arrives at that location, the pre-signal would typically display a red signal to that bus, thereby causing it to stop and wait for an opportune time to proceed to *junction I*. That time would come when the indication for the intersection's traffic signal for westbound cars next changed from red to green. The pre-signal would then display a green indication for the westbound bus, while displaying a red indication for the cars. (Note that these cars would have already been stopped by the intersection queue, so the pre-signal would only delay their start-up). The bus would now have right-of-way to proceed undisturbed to *junction I*; the bus would follow behind the fast moving queue of discharging cars and turn right via the junction's free right-turn lane. The delay incurred by the bus as a result of this control measure would be small; i.e. typically no more than the duration of the intersection's signal cycle.

Westbound cars, on the other hand, would encounter almost no additional delay from the proposed control measures. The cars temporarily detained by the pre-signal at location A would receive a green indication from that pre-signal shortly after the westbound bus began its motion toward *junction I*. These cars would enter junction I during the following green, just as they would have done had there been no priority treatment for buses (i.e. no upstream bus lane and no pre-signal).

The data indicate that car queues do not presently form on the northbound road link between *junctions I* and *II*; i.e., traffic travels at free-flow speeds on this segment. Reserving a lane for buses on that link would therefore not diminish bus trip times, but could create northbound car queues at the tunnel formed by *junction II* where none exist at present. We therefore propose that westbound buses travel with cars until reaching the location labeled B in Fig 2. At that point, a static bus lane could be resumed to enable westbound buses to bypass the car queues created by the Wadi Saqrah intersection located further downstream.

2.2 Southbound to Eastbound Bus Route

<u>The Problems</u>

Installing a static bus lane over the entire southbound link would sharply diminish the rates that southbound cars could enter *junction I*; see Fig 3. An even bigger problem would occur by having diminished the number of lanes available to southbound cars inside the tunnel formed by *junction II*. The tunnel would become a very restrictive bottleneck for southbound cars. The resulting car delays could be extensive. The resulting queues of southbound cars would often extend far upstream to the Wadi Saqrah intersection, and create large delays there as well.

Proposed Solutions

We propose that the static bus lane for southbound buses be discontinued about 585 m upstream of *junction II*, at the location labeled C in Fig 3. The segment of southbound median lane that passes through the tunnel would operate as an intermittent bus lane, as described below.

Southbound cars would be allowed to use both lanes in the tunnel prior to the actual arrivals of every southbound bus. Shortly before each southbound bus arrives, cars would be prohibited from entering the median lane. This prohibition would be enacted at location C by means of a red signal, mast-arm, etc.; and a barrier, such as retractable cones, which would physically separate the two tunnel lanes, as annotated in Fig 3.

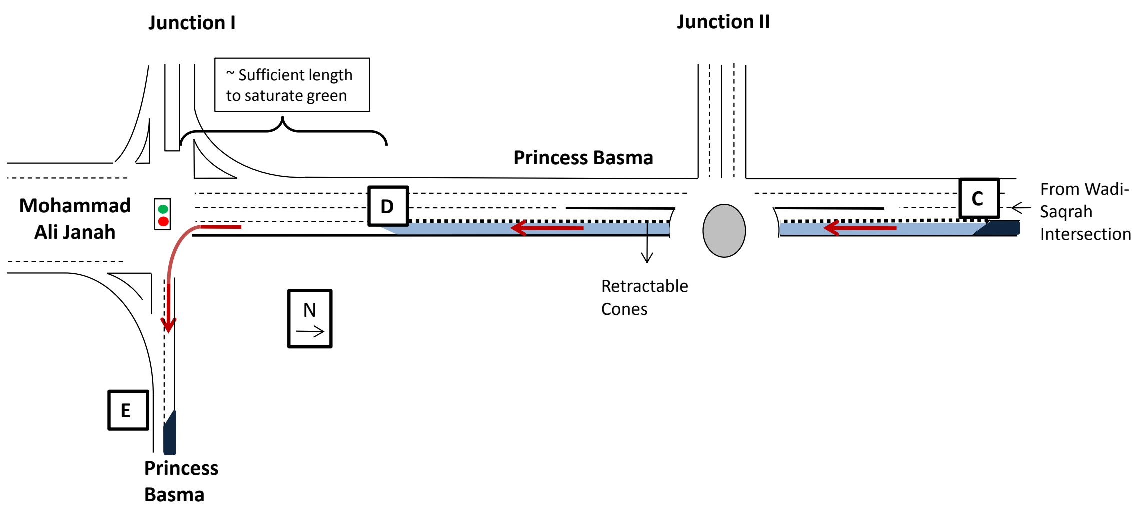

Figure 3. Southbound to Eastbound route

This periodic prohibition for cars would be enacted at such times that an arriving southbound bus would enter the intermittent lane after it was nearly emptied of cars. The bus would thus pass through the tunnel without delay. The prohibition against car use would be lifted at location C each time buses pass that spot. Cars turning left at *junction I* would therefore proceed into the tunnel while following behind buses. Advanced signage would designate that only left turning cars are to use the intermittent lane.

This intermittent lane would be terminated about 190 m upstream of *junction I,* at location D in Fig 3. Cars and buses would therefore always share that 190-m long segment. The intersection green for southbound traffic could therefore be fully saturated during rush hours for each cycle. This would mean that the bus treatment would not add delay to cars beyond what they already incur at present.

The 190-m shared lane segment would impart very little added delay to southbound buses: most of these buses would wait no longer than one signal cycle at the intersection. This is similar to the delay that they would incur even if a static bus lane spanned the entire southbound road link.

A static bus lane could be resumed at around location E of Fig 3. In this way, eastbound buses could bypass the car queues on that link. By resuming the bus lane sufficiently far downstream of *junction I*, two lanes could be used for serving southbound cars that turn left at that junction.

3. Experimental Designs

We now describe how the ideas of the previous section can be field tested in simple and relatively inexpensive ways without posing risks to travelers. These experiments would enable us to quantify the effectiveness of the proposed strategies in real settings. This knowledge could then guide decision-makers in their ultimate choices of bus lane design.

We describe first how the experiments could be carried out for the westbound to northbound bus route. The experimental design for the southbound to eastbound route is described thereafter. The experiments could be conducted for both routes simultaneously. Or, the tests could be separately conducted for each route on separate days. In either case, experiments for each route would ideally be performed over multiple days during the peak hours. A single bus (or similarly large vehicle) would be needed for these experiments. This vehicle would cycle through the test site at 5-minute headways.

3.1 Westbound to Northbound Bus Route

The car demand is highest for this route during the morning rush from 7:30 to 8:30 am. Thus, experiments for this route would occur during these times (and possibly others). Traffic cones could be used at the locations shown in Fig 4 to emulate the presence of a static bus lane on the westbound approach to *junction I*. The physical length of this faux bus lane could be relatively small; 100 m or so would suffice. Only the bus would be permitted entry into this faux lane (at its upstream end). Entry could be controlled by means of a mast arm, perhaps operated by the bus driver via an on-board remote.

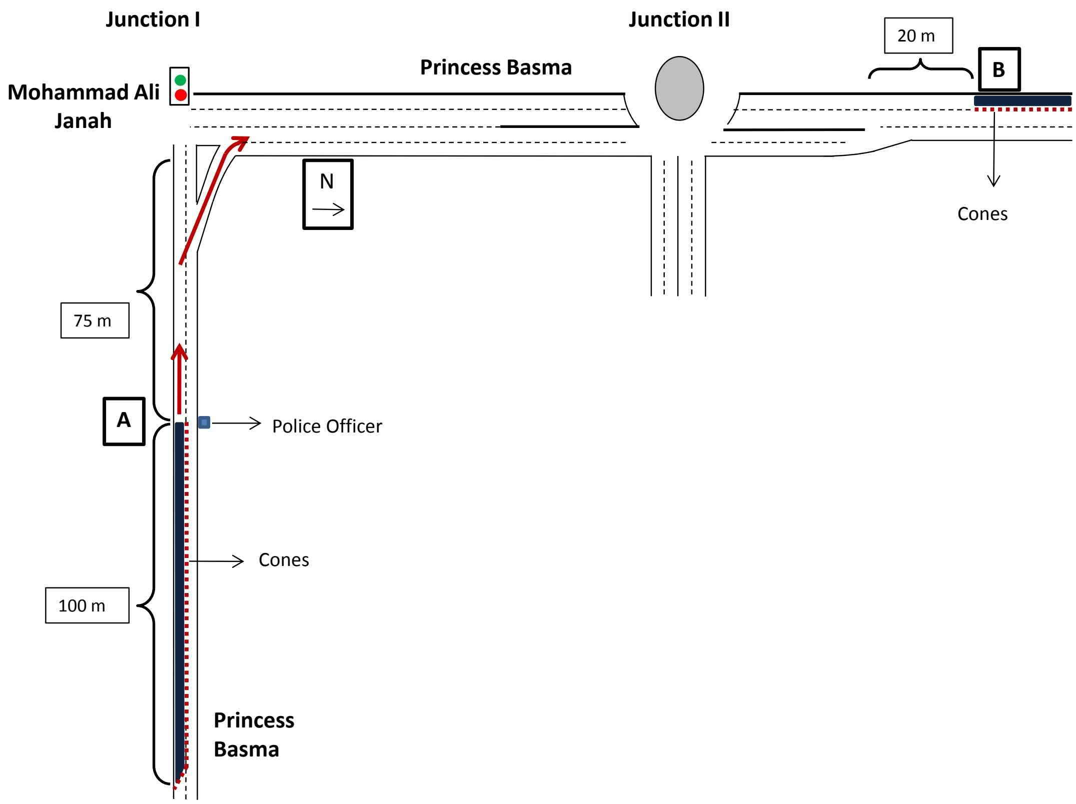

Figure 4. Westbound to Northbound Route Experiment Design

The pre-signal at location A in Fig 4 could be emulated with the aid of a police officer. The bus driver would voluntarily halt upon arriving to that location (via the faux bus lane). In the presence of the stopped bus, the police office would wait for the traffic signal at *junction I* to turn green for westbound traffic. The officer would then instruct the cars stuck in the upstream portion of the queue to remain stopped – but just long enough to allow the bus to move forward undisturbed.

The resumption of a static bus lane in the northbound direction (location B in Fig 4), could be a part of the field test as well. However, it would be sufficient to test this idea for the eastbound travel direction, as will be described in section 3.2.

Data to be Collected During the Experiment

The queue discharge flows of westbound cars at *junction I* would be collected using video cameras. (Car delays for any demand levels can be assessed once these discharge rates are field-estimated). The sampled discharge rates would be compared against those that presently occur at *junction I* in the absence of any bus priority strategies. We expect that these comparisons will unveil only small differences. It would also be useful to measure the westbound discharge rates – at least for a few cycles – that occur when the median lane is closed at *junction I*. This would verify the extreme damage that would be done to cars by extending the bus lane over the entire westbound approach.

Finally, an observer on-board the bus (possibly the driver) would measure the time required for the bus to travel from the pre-signal to *junction I* during each trip. We expect that these data will confirm that the proposed strategy will impart only modest delays to buses.

3.2 Southbound to Eastbound Bus Route

The car demand is highest for this route during the afternoon rush from 5:00 to 6:00 pm, meaning that experiments should be conducted during these times. Traffic cones could be used at the locations shown in Fig 5 to emulate the presence of a static bus lane on the southbound approach to *junction II*. The physical length of this faux bus lane and its other features could be as described in Section 3.1.

Traffic cones starting a short distance (30 m or so) downstream of location C would be used along the length of the intermittent bus lane to separate it from adjacent car lanes. The cones would continue until location D, for a distance of approximately 365 meters. The periodic prohibition for cars at location C could be emulated with the aid of a police officer. Whenever the officer sees an approaching southbound bus, the officer would stop cars from entering the median lane until the end of the next green for southbound left turning cars. Once the bus enters the intermittent bus lane, the police officer would allow left turning cars (only) to follow behind the bus. Signage designating the intermittent lane for left turning cars only would be required; and the control enacted by the police officer could easily be automated if the strategy were to be adopted permanently.

The resumption of the static bus lane downstream of junction I in the eastbound direction would again be emulated with the use of traffic cones. This faux bus lane would be started a short distance downstream of the *junction I*, at a distance of approximately 50 meters, and continue for a nominal distance of 100 m or so. Once again, only the bus would be permitted entry into this faux lane (at its upstream end), perhaps via a mast arm and an on-board remote.

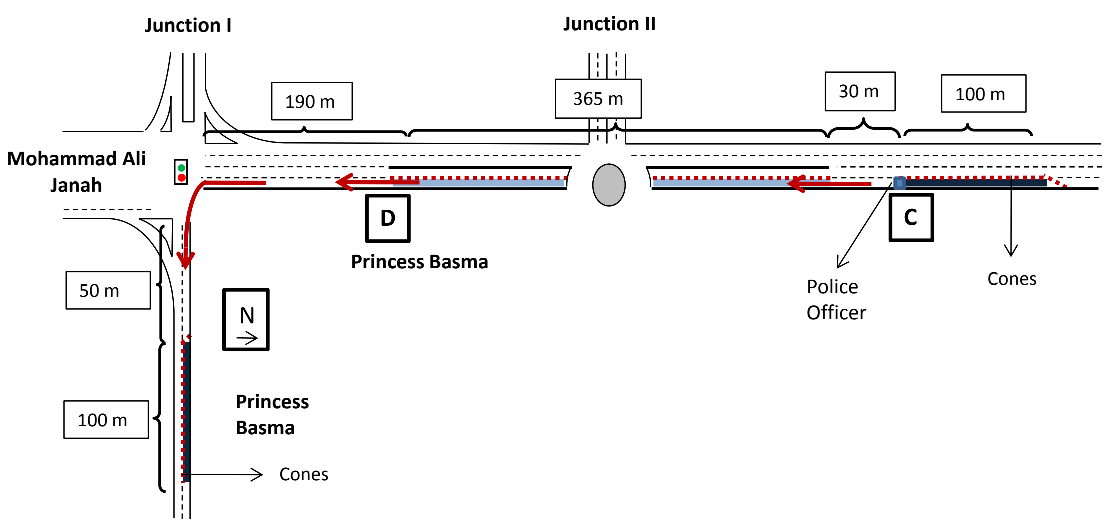

Figure 5. Southbound to Eastbound Route Experiment Design

Data to be Collected During the Experiment

The queue discharge flows of southbound cars at both *junction I* and *junction II* would be collected using video cameras. The sampled discharge rates would be compared against those that presently occur at the junctions in the absence of any bus priority strategies. We again expect that these comparisons will unveil only small differences. It would also be useful to measure the discharge rates at both locations– at least for a few cycles – that occur when the median lane is completely closed; again to verify the damage that would be done to cars by extending the bus lane over the entire westbound approach.

Videos would also be taken of queued cars to estimate both: i) the speed of kinematic waves that travel through car queues; and ii) the jam density of stopped cars. These estimates would further assist us in predicting the physical extents of car queues once some lanes have been given over to buses.

An observer on-board the bus will measure the time it takes to travel from the downstream end of the faux bus lane to *junction I* during each trip to verify the modest bus delays that would arise from these strategies.