FAR EAST BRT

BRT & URBAN TRANSPORT PLANNING

Ulaanbaatar BRT Planning and Design

TA-8212 MON: Ulaanbaatar Urban Transport Capacity Development - I4 Public Transport(BRT) Planning and Management

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DRAFT FINAL REPORT, 2 MAY 2017

Contents

1 Introduction and overview

1.1 Study context and authors

The ADB funded a preliminary BRT conceptual design for Ulaanbaatar in 2011. This work was carried out in a short period and with very limited data availability, led by Far East BRT experts at the time working for the Institute for Transportation and Development Policy. At that time the BRT corridor selection was highly uncertain, data availability was poor, and there was only very limited local understanding of or interest in BRT.

The team leader of the 2011 plan has been tasked with providing input to an updated 2016 BRT plan for Ulaanbaatar as part of a wider ADB Technical Assistance (TA) on urban transport capacity development. The new task has several aspects but the main ones are to revise the earlier plan in light of new developments. From Far East BRT this BRT planning work was primarily carried out by **Karl Fjellstrom** but also included inputs by other Far East BRT staff including Wenxuan Ma and Xiaomei Duan. The key local experts providing input to the BRT planning were **Bulgaa Khurelbaatar** (ADB consultant) and **Nurmumukhamyed Bakyt** (ADB consultant). The total budget for the BRT planning, not including the input of the local consultants, was around $110,000, with the work carried out intermittently during February 2016 to April 2017. The report was updated in January 2017 and again in April 2017 to also incorporate inputs by **Ma Wenxuan**, Far East BRT, as part of a related TA input. A final update was carried out in April and early May 2017 to finalize the corridor and phase recommendations.

It is hoped that the project can proceed to detailed design, with a view to possible commencement of construction of the first phase BRT corridor (at minimum preparatory road works) during the construction season in 2017. Many key decisions will be taken during the detailed engineering design stages, and it is essential that the local engineering design firm have international expert support and input. A BRT model should be made in parallel with the early stages of the engineering design, drawing primarily from the excellent smart card data, and using other supplementary surveys and data sources. Utilities are a major source of uncertainty regarding the budget and costs of implementation. This will be clarified during the detailed design stage.

BRT planning has many aspects, and this report is not intended to be a comprehensive coverage of all the issues involved in such a major project. An earlier ADB TA carried out during February to April 2016 focused on bus industry, contracting, institutional and smart card fare collection issues. These issues are therefore not considered in any detail in this this report or TA. While institutional and regulatory issues are very important, the most pressing issue in early BRT planning is to ensure that the BRT infrastructure is correctly designed and that the corridor selection does not preclude a successful project. The infrastructure and corridor selection is closely related to the BRT operational concept and plan, which in turn relates to vehicle, station architecture, station access, traffic circulation and intersection issues.

The report authors thank the Asian Development Bank project manager for continued inputs and guidance throughout the BRT planning process, as well as the excellent local team support under the TA.

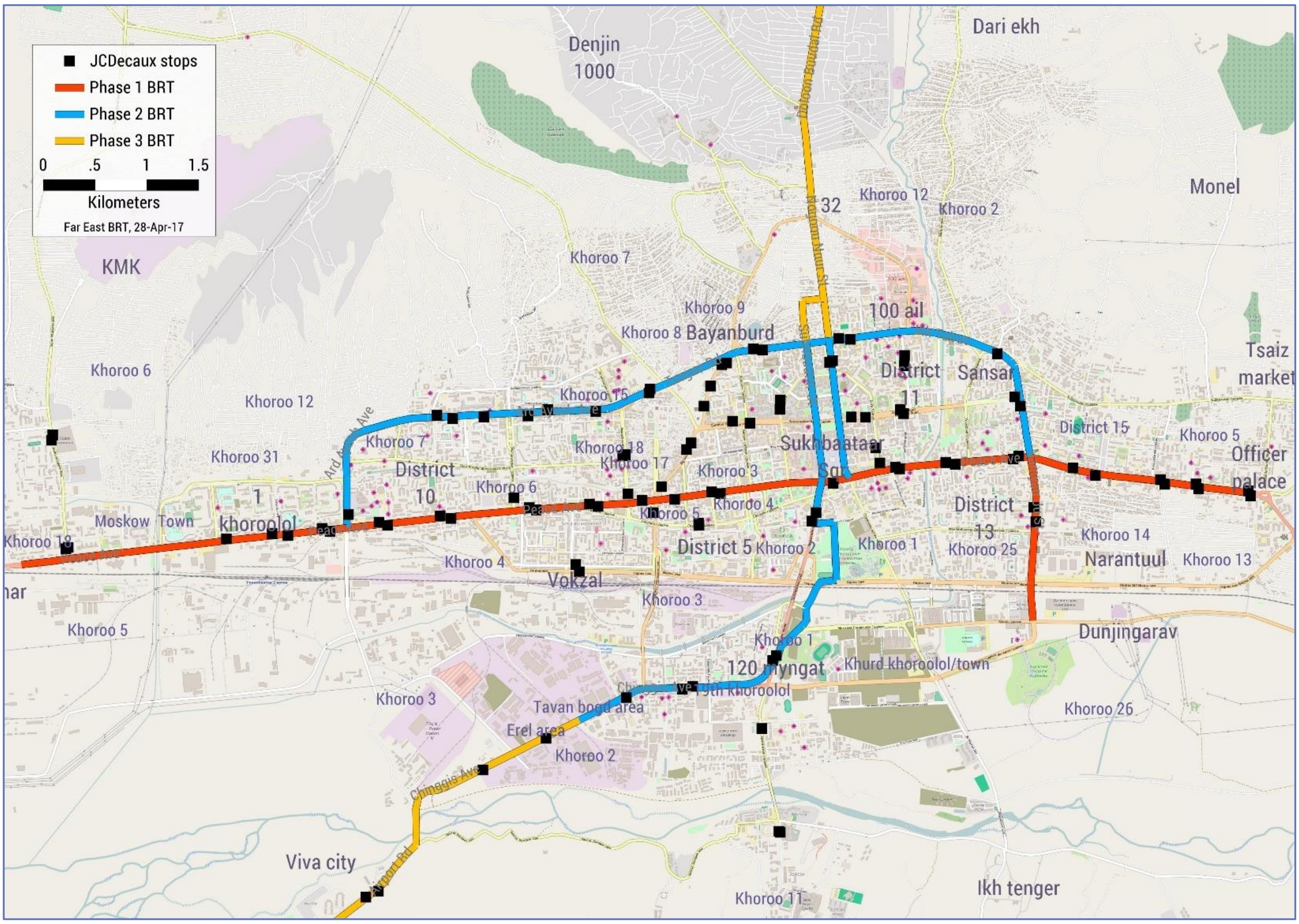
1.2 New developments (since 2011) and observations

The situation regarding BRT in 2016 and 2017 has improved compared to 2011, when the initial BRT conceptual design was carried out, in many ways:

- The ADB has formed a local team with much greater technical and support capability than was available in 2011.
- A Project Implementation Unit is being formed, with positions advertised in November 2016. Key technical appointments to the PIU are expected in early May 2017.
- Many potential procedural obstacles have already been overcome. Parliamentary endorsement for the BRT project was granted in May 2015 and an on-lending agreement allowing the loan to proceed was signed in November 2015.
- A series of major public transport reforms were implemented in 2014 and 2015, including large-scale route changes, implementation of a smart card, and a new payment scheme for operators. The new payment scheme sees operators remunerated based on bus-hours of operation rather than on passengers carried, and in this way breaks the link between operators and particular routes and between revenues and passengers carried which would otherwise be a potential source of friction in the BRT implementation.
- A project technical working group including representatives of key related agencies and headed by the Urban Transport Department of the city, was set up, with the inaugural meeting held on 26 February 2016. Whereas in 2011 BRT was still unknown among many agencies, at the February working group meeting the key agencies all expressed strong support for the project. With the election and change of government in June 2016, the working group composition is different, but the new government has expressed strong support for the project's implementation, including the first phase implementation along Peace Avenue.
- The corridor selection, unlike in 2011, was made subject only to the best technical recommendations, without needing to rule out particular corridors (such as Peace Avenue) for non-technical reasons.
- In 2011 the design capacity that the BRT should be planned for was more uncertain. The city had large development plans, but would they proceed, and in what time frame? In 2016 the situation is clearer, with new developments throughout the central area and along the Airport Road corridor resulting in a proposed significantly higher capacity BRT system than was proposed in 2011.
- Data availability is much better in 2016 than in 2011, due to the new smart card system, the decline in the more informal and harder to monitor minibus services, and the establishment of a dedicated TA office with staffing and other resources. The smart card data in particular is a rich and accurate source of data that can be the basis of a BRT model and/or analysis to develop the operational plan. From 1 April 2017 cash payments were no longer accepted on buses, which further enhances the usefulness of the smart card data.
- The less-regulated minibus and microbus sector has rapidly declined, with larger buses and operators now controlling a larger proportion of the overall public transport market and only

an estimated 200-300 minibuses still in operation in 2016. It is expected that these minibuses will be nearly completely phased out in 2017. The bus system is also better organized than in 2011, making data collection more readily available.

- Information at bus stops is much more comprehensive and accurate in 2016 than in 2011. This is especially the case in the bus stops upgraded under a contract with JCDecaux over the last year (see graphic below). The improved bus stops usually improve route information and the major stops also have route maps displayed and are registered in the smart card system.
- The UB Smart Bus app, developed by the UB Smart Card Company, was not used in this study but provides a good potential source of bus frequency and route information.
- Traffic conditions are significantly worse in 2016 than they were in 2011, with the need for a well-designed, high capacity BRT system readily apparent. Bus speeds are very poor, and despite the economic growth and new development, screenline counts suggest that bus system ridership has not risen significantly since 2011. All stakeholders seem to realize that this is an unsustainable path and that urgent action is needed to prioritize public transport and dramatically improve bus speeds. In stakeholder interactions throughout 2016 there was a strong consensus on the need to dramatically improve the bus system.



Upgraded bus stops as of March 2016, under a JCDecaux advertising contract.

1.3 Key changes from the 2011 BRT plan

This revised study contains many changes to the 2011 BRT conceptual design plan, including the following:

- The corridor selection is based on technical criteria rather than non-technical considerations. Peace Avenue is included in corridor assessment and identified as the preferred priority corridor.
- The station design has been changed to accommodate 18m BRT buses, representing a significant increase in the design capacity. Stop module length is increased from 13m to 20m. Total platform length increases from 41m to around 55m in the directional BRT stations. (The precise platform length depends on various station configurations, as explained below.)
- A larger variety of stations have been proposed in this report, taking into account the right of way and demand conditions in different corridors.
- The corridor recommendations in the 2011 study, even though data at the time was much more limited, were similar to the recommendations in this study, although there have been changes to the corridors based on new developments. Most notably, Namyan Ju St is proposed for inclusion in the phase 1 BRT.
- Station spacing has been adjusted, with major changes. In general, the station spacing is much larger in this report than in the 2011 study, which partly reflects the longer station platforms. **Offsetting the larger station spacing is major improvements to the BRT station access, with many stations having fare collection at both ends of each platform**. This results in significantly shorter average walking distances to access the BRT stations compared to the previous situation where directional platforms had only one access point.
- The minimum gap between platforms in the directional stations has been increased from 30m to 35m, which allows for faster bus speeds.
- Much more reliable basis for operational design and planning in 2016 compared to 2011, with the smart card data.
- A new station concept developed for short term vs long term operation for some stations along Doloon Buudal.
- Inclusion of a 'southwest connection' for accessing the 19th khoroolol area.
- More detailed consideration of intersections and traffic circulation.

1.4 Change in corridor options

The proposed BRT corridor selection criteria were significantly changed in early July 2016, when it was established that the BRT corridor selection should be based on the best technical criteria rather than on non-technical considerations. This meant that Peace Avenue, which had earlier been avoided for non-technical reasons, could now be considered. While this was a very positive development, it also means that the work on the Peace Avenue design, operational plan, and other aspects in this report are less advanced than it would have been had this corridor been open to selection from the beginning of the project.

In addition, in late 2016 a 'southwest connection' was developed to enable the BRT to access the high demand area south of the Peace Bridge potentially as part of the phase 1 BRT. The southwest connection is described in detail later in this report.

2 Current conditions

2.1 Bus routes and frequency

2.1.1 Surveys and data collection

Bus frequency refers to the number of bus trips per hour, in the morning and evening peak, with routes divided into forward and reverse directions. The forward and reverse directions are decided based on GIS mapping of the routes, with west to east being forward and east to west being reverse directions.

The surveys of bus frequency and occupancy where carried out in March and April 2016. These surveys were intended to:

- Determine which routes are actually operating
- Confirm the actual frequency being operated, rather than relying on the scheduled or reported frequency
- Confirm the roads being used by routes, where this was uncertain
- Determine the proportion and routes used by minibuses
- Indicate the frequency and occupancy of buses at particular locations, which is in turn important in determining the BRT station requirements.

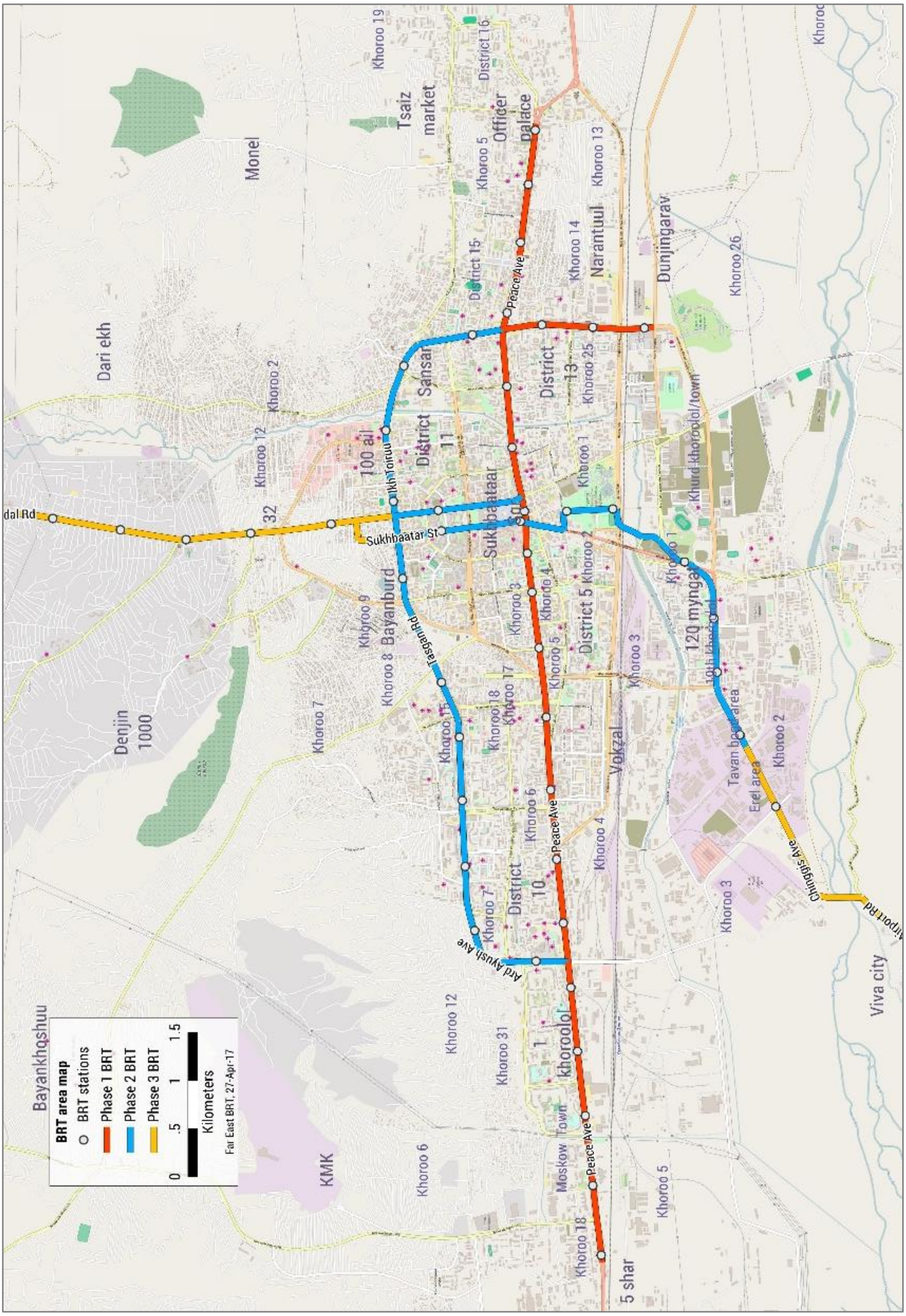
A slightly longer survey was carried out in order to determine the peak hour, which was determined to be 7:30-9:00AM and 5:00-7:00PM. All surveys were carried out in either the morning or evening peak period, because the peak frequency is the key determinant of BRT infrastructure needs.

The aim of the frequency surveys was to have at least 5 peak period samples per route. Many routes had many more samples, with an average of 15 peak period frequency samples per route.

The frequency of all urban routes, with frequencies ranging from 10 to nearly zero, is shown following, along with the bus routes mapped in April and May 2016.

Routes were labelled as ‘forward’ (‘_f’ suffix) or ‘return’ (‘_r’ suffix) depending on the starting and ending points of the route. Routes with a starting point to the west of the ending point were defined as ‘forward’ routes, with routes with starting points to the east of the ending point defined as ‘return’ routes. Routes were further numbered according to bus type, with the main routes subject to analysis being ‘r’ (regular bus routes), ‘t’ (trolleybus routes) and ‘s’ (suburban routes). Other bus routes including microbus route and feeder bus routes were also mapped.

A BRT area map, showing many street and area names used in this report, is provided following.

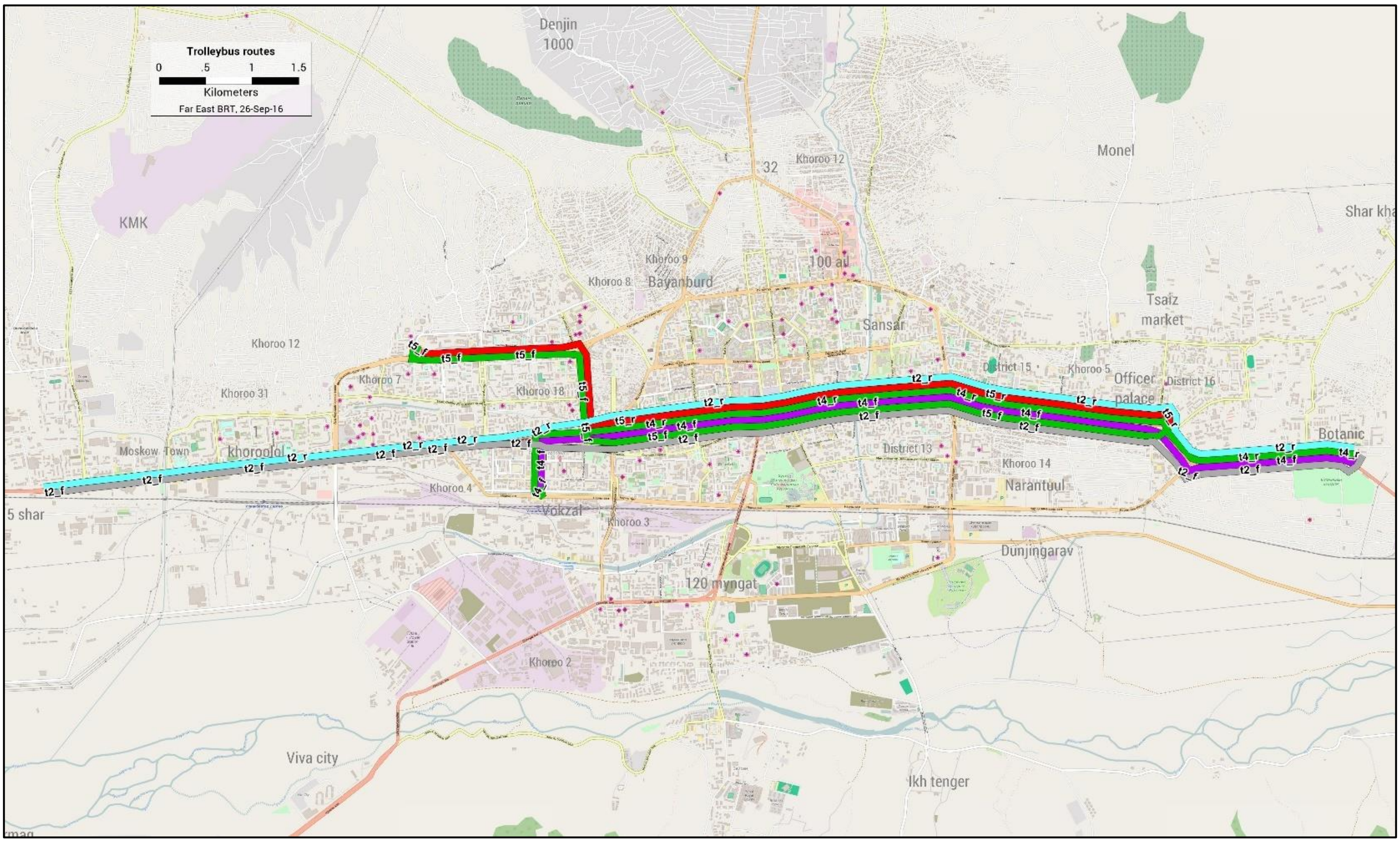


BRT area map showing many street and area names used in this report

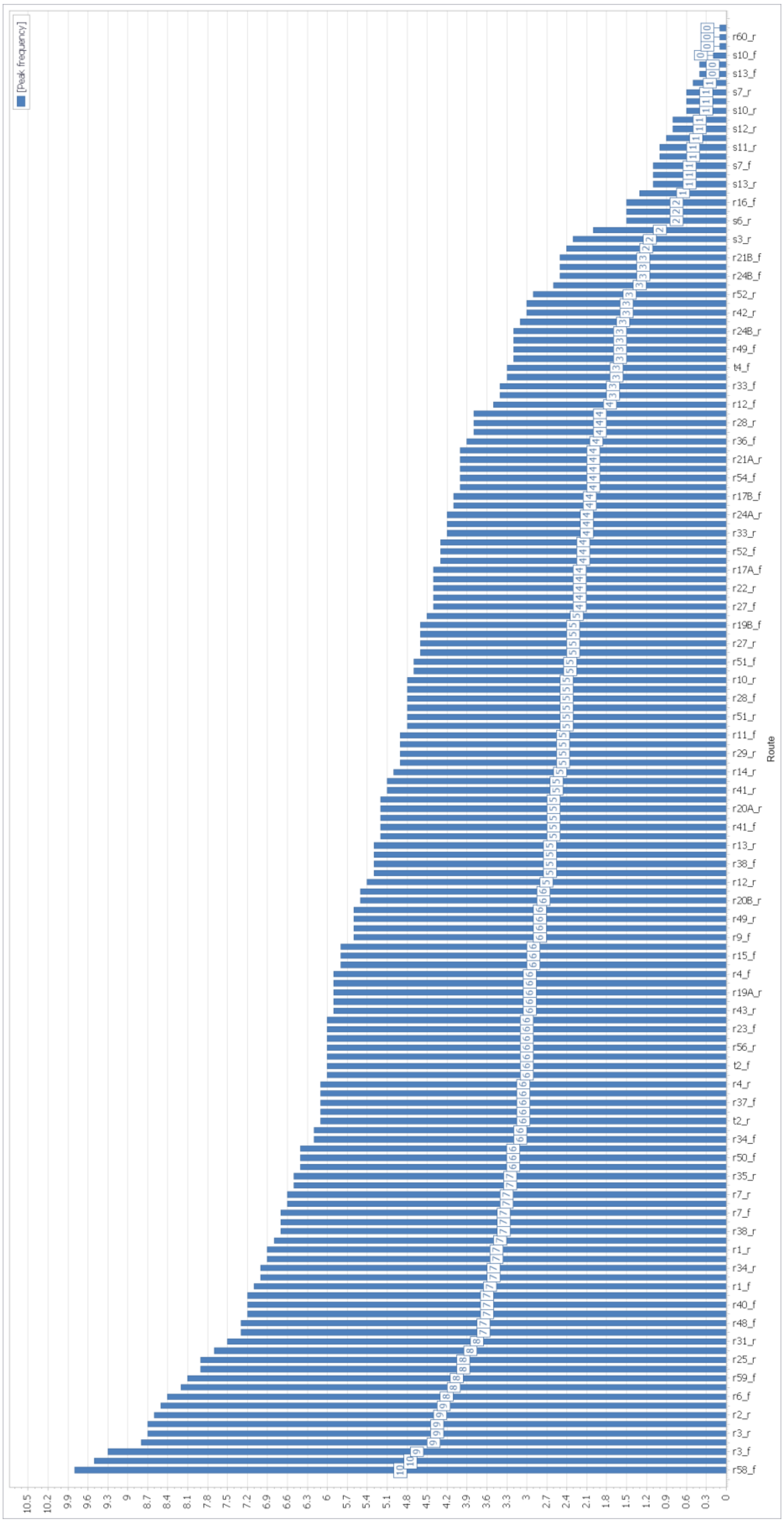
2.1.2 Trolleybus routes

Ulaanbaatar’s three trolleybus routes were mapped and surveyed along with other routes, and smart card data was also obtained for trolleybus routes. The trolleybus routes are shown following.

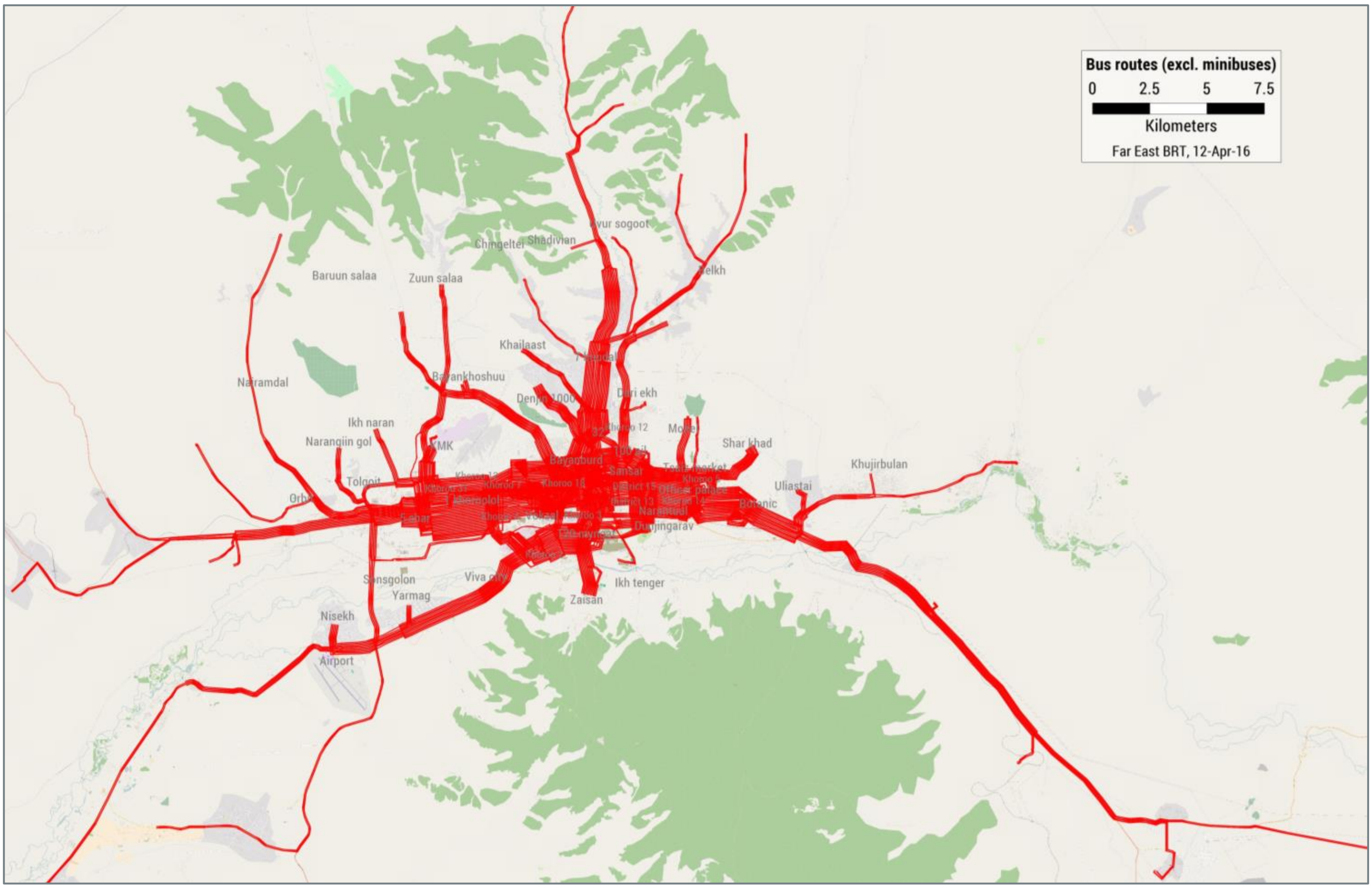
The highest flow of trolleybuses occurs in the central part of Peace Avenue between Ikh Toiruu St and Officer’s Palace, where in peak hours there is an average 15 trolleybuses per hour per direction, which is around 15% of the bus flow in those areas. Thus, while the trolleybus flow is significant, removing the trolleybuses will not have a major impact on overall bus frequencies, and the removed capacity can be easily replaced by other buses.

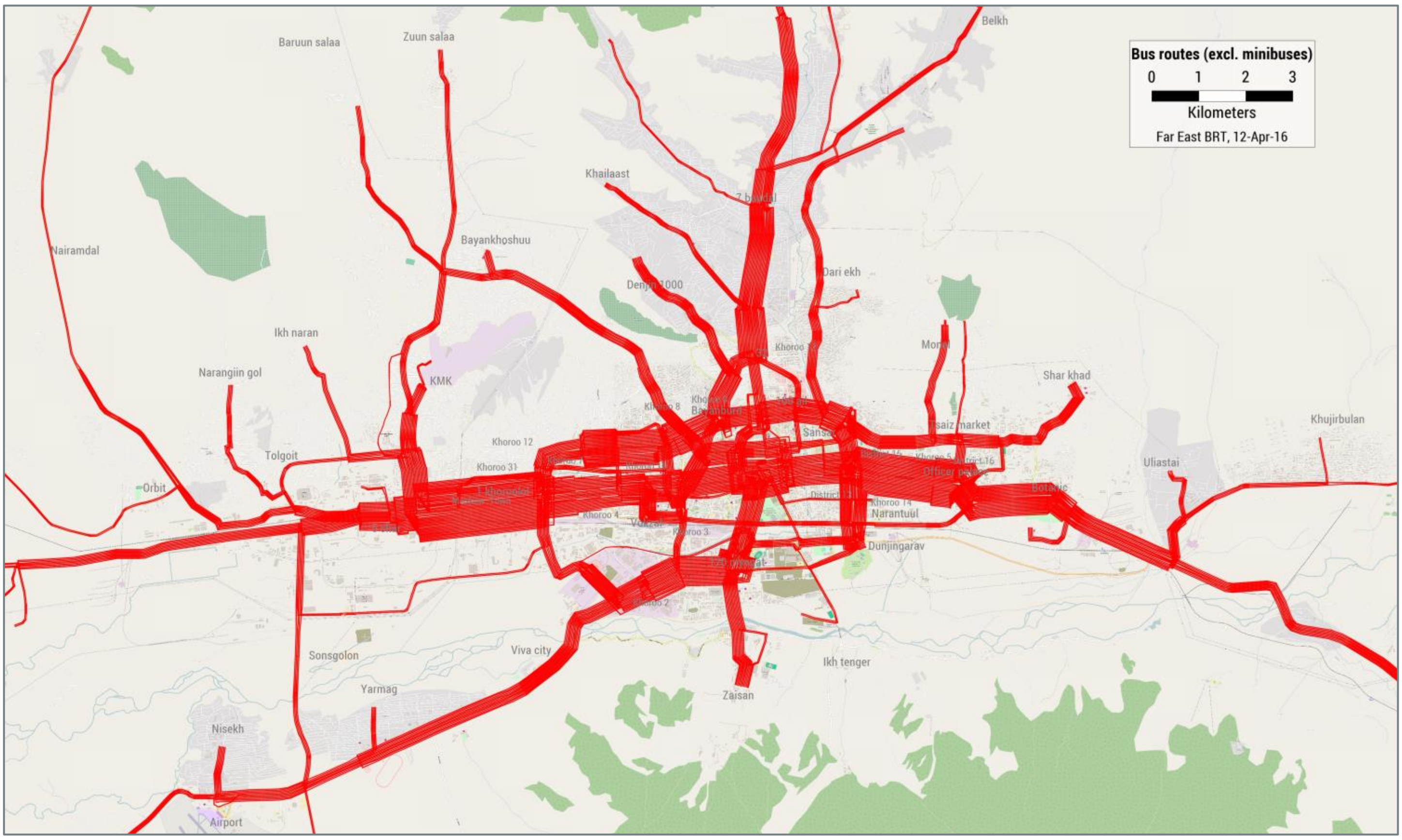


Trolleybus lines in Ulaanbaatar (with forward and reverse directions shown separately).



Peak hour frequency (buses / hour) from surveys in March and April 2016. Not all routes in the right axis are labelled. Frequencies range from less than 1 per hour up to nearly 10 per hour.

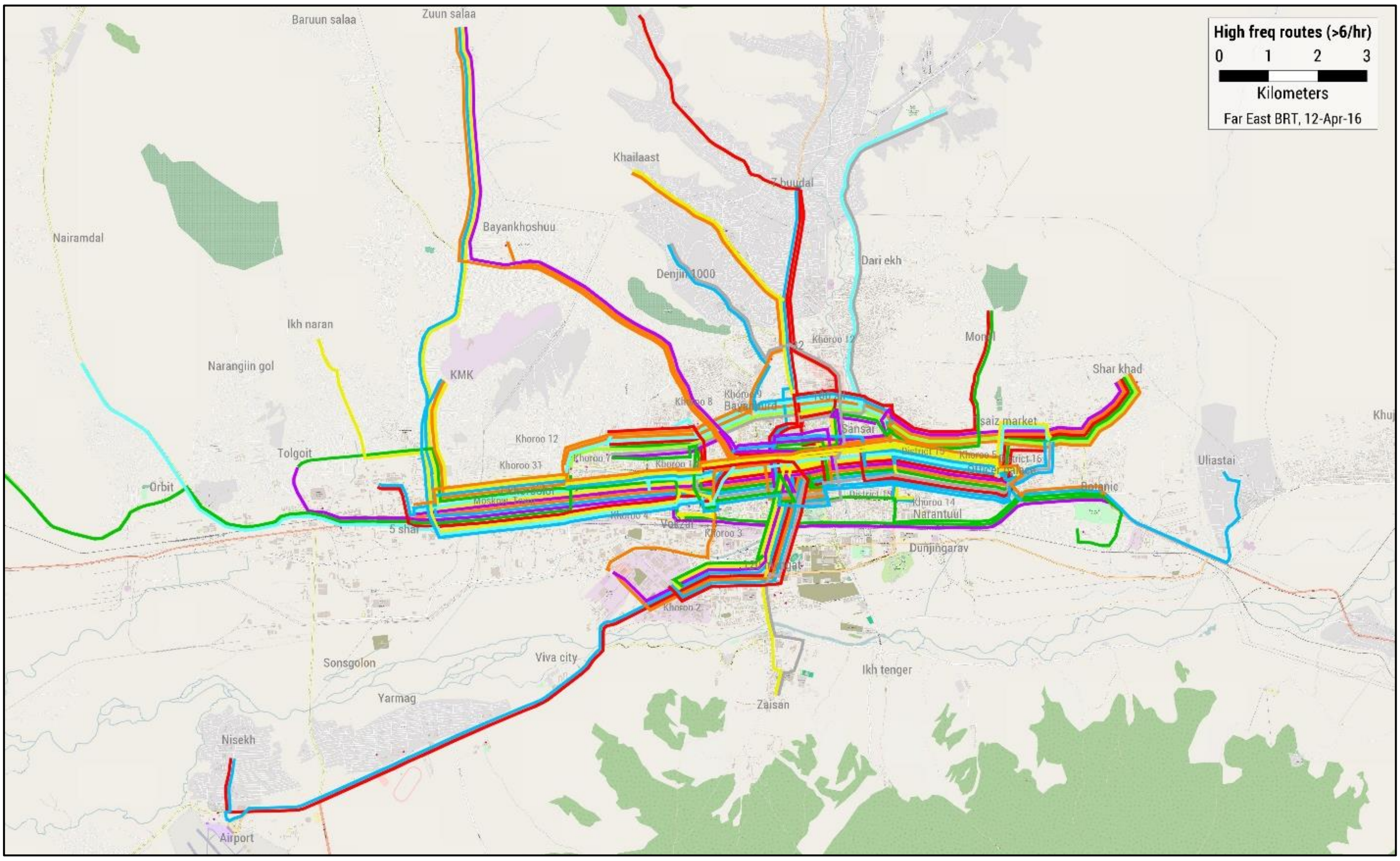




Bus route coverage in Ulaanbaatar, excluding minibuses.

2.2 High frequency bus routes

High frequency routes are defined for present purposes as routes with more than six buses passing per hour in a single direction in the peak time period. Six buses per hour means an average interval between buses of 10 minutes, and waiting time of 5 minutes. For passengers wishing to use these high frequency routes there is no need to consult a schedule. Passengers can simply arrive at a stop and wait for the next bus. The high frequency route network is illustrated below.



High frequency bus routes in Ulaanbaatar, March-April 2016 – 24 in total.

These high frequency routes form the backbone of the transit network and provide a good visual overview impression of the transit demand patterns in the city. The east-west pattern of movement is clear, with demand concentrated along the east-west corridors of Peace Avenue, Ikh Toiruu and Sambuu St and with significant areas of demand to the northwest towards Zuun salaa, to the east at Shar khad and south of Peace Bridge in the 120 myngat area. Other areas with more than one high frequency route include KMK and Doloon Buudal Rd up to 7 buudal.

The following table provides more details of the high frequency routes and shows that around half of these routes are likely to be in the phase 1 BRT system. When both phase 1 and phase 2 are considered, around three-quarters of the high frequency routes are BRT routes. When phase 3 and 4 are included, it is expected that all the high frequency routes will be BRT routes. The high proportion of high frequency routes inside the BRT system, especially in phase 1, is a positive sign for the BRT. Note that all these routes selections are preliminary and are listed before route adjustment that will take place during the follow-up operational design.

High frequency bus routes in Ulaanbaatar (defined as more than 6 buses/hr/direction)

Route Name	AM frequency	PM frequency	Peak freq (all samples)	total samples	length (km)	% in BRT1	BRT1 route	perc in BRT 1 2	BRT1 2 route
r1_f	6.9	7.2	**7.1**	25	12.16	99%	YES	99%	YES
r1_r	6.2	7.7	**6.9**	25	12.17	99%	YES	99%	YES
r2_f	9.5	7.8	**8.7**	32	13.26	46%	YES	58%	YES
r2_r	8.7	8.3	**8.6**	32	13.19	46%	YES	60%	YES
r3_f	9.9	9	**9.3**	26	20.79	48%	YES	48%	YES
r3_r	8.6	8.8	**8.7**	26	20.79	48%	YES	48%	YES
r4_r	6.8	5.1	**6.1**	22	10.78	29%	YES	96%	YES
r5_f	8.6	8.5	**8.5**	35	12.79	0%	no	54%	YES
r5_r	9.4	9.6	**9.5**	35	12.89	0%	no	50%	YES
r6_f	8.2	8.6	**8.4**	20	18.28	29%	YES	29%	YES
r6_r	8.0	8.3	**8.2**	14	18.49	27%	YES	27%	YES
r7_f	7.0	6.4	**6.7**	34	22.37	3%	no	3%	no
r7_r	6.8	6.5	**6.6**	25	22.75	1%	no	1%	no
r8_f	6.6	5.7	**6.2**	23	13.99	4%	no	9%	no
r13_f	6.9	4	**6.4**	6	15.94	20%	no	23%	YES
r23_r	7.2	6	**6.6**	27	12.54	0%	no	6%	no
r25_f	7.5	6.8	**7.2**	15	12.78	0%	no	42%	YES
r25_r	8.8	6.8	**7.9**	13	13.23	0%	no	24%	YES
r30_r	5.3	7.5	**6.9**	7	10.88	8%	no	8%	no
r31_r	7.4	7.7	**7.5**	18	17.87	12%	no	31%	YES
r34_f	6.3	5.9	**6.2**	48	14.36	4%	no	7%	no
r34_r	7.6	6.1	**7**	36	15.19	2%	no	5%	no
r35_f	7.1	5.5	**6.1**	11	7.84	1%	no	16%	YES
r35_r	6.8	6.3	**6.5**	15	7.63	0%	no	22%	YES
r37_f	5.7	6.6	**6.1**	21	9.30	66%	YES	66%	YES
r37_r	7.0	6.4	**6.7**	26	9.47	76%	YES	76%	YES
r38_r	6.8	6.6	**6.7**	10	17.09	16%	no	43%	YES
r39_f	8.7	7	**7.7**	5	6.58	0%	no	49%	YES
r40_f	7.0	8	**7.2**	19	16.06	56%	YES	56%	YES
r40_r	6.9	6.8	**6.8**	10	15.88	56%	YES	56%	YES
r43_f	4.5	7.5	**7**	6	13.35	10%	no	10%	no
r46_f	7.5	7.2	**7.2**	8	12.26	41%	YES	41%	YES
r47_f	7.8	4.3	**6.5**	8	16.27	38%	YES	38%	YES
r48_f	8.0	6.5	**7.3**	8	14.35	6%	no	6%	no
r48_r	8.0	6.5	**7.3**	12	14.27	0%	no	0%	no
r50_f	6.6	5.8	**6.4**	20	10.02	42%	YES	42%	YES
r50_r	6.7	5.8	**6.4**	29	10.11	42%	YES	42%	YES
r55_r	7.5	4.3	**6.1**	7	13.17	4%	no	4%	no
r58_f	10.2	9.5	**9.8**	36	8.65	22%	YES	41%	YES
r58_r	8.1	7.8	**7.9**	32	8.72	22%	YES	42%	YES
r59_f	7.6	8.5	**8.1**	19	14.50	80%	YES	80%	YES
r59_r	8.5	9.1	**8.8**	19	14.53	79%	YES	79%	YES
t2_r	5.5	6.9	**6.1**	33	14.40	83%	YES	83%	YES

Notes: 1. Frequency figures are based on surveys in March and April 2016. The 'samples' column refers to the number of separate frequency counts obtained for the route.

2. BRT route identification includes only a very basic and preliminary adjustment. A more detailed assessment needs to be done as a follow-up study, ideally based on a transit model developed from the smart card data with supplementary surveys.

2.3 Bus speeds

Bus speed was obtained from the smart card transaction data from 21-27 December 2015 and 15-21 February 2016. This bus speed data is extremely useful, as the alternative would be a much more laborious and time consuming on-bus survey which would also be much less accurate due to the large number of samples required to arrive at reliable bus speed data.

Bus speeds show overall operational speed (that is, including stops) and are recorded as stop to stop values. A total of 88,329 peak hour speed samples were retrieved from the smart card data, with peak hour defined as 8-9AM and 5-6PM. This number and coverage of samples is far beyond what could have been achieved through on-bus surveys in the project.

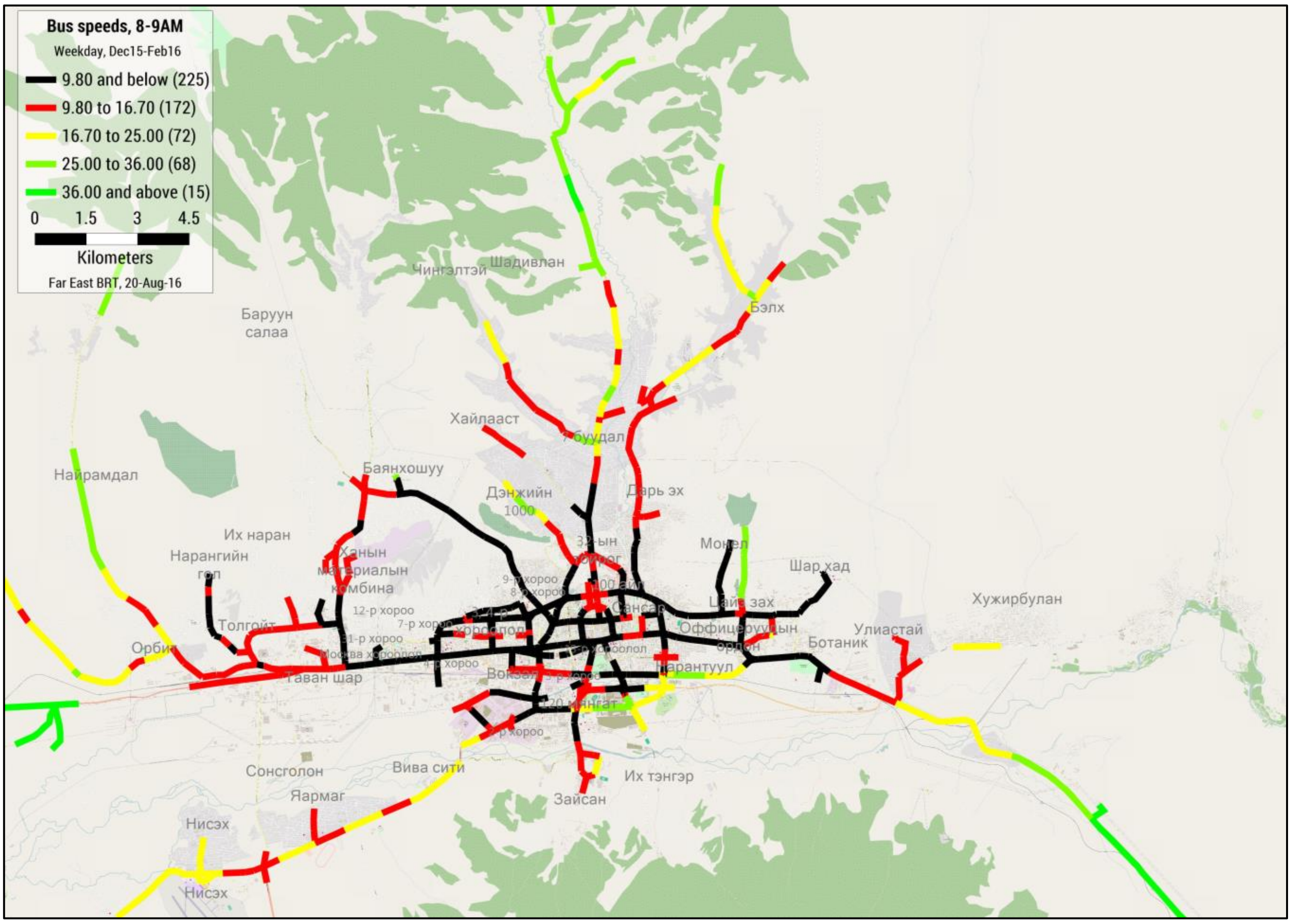
Before the speed data could be used, at least a week of cleaning and processing the data was required by the BRT team, especially to correct errors and omissions in the bus stop locations.

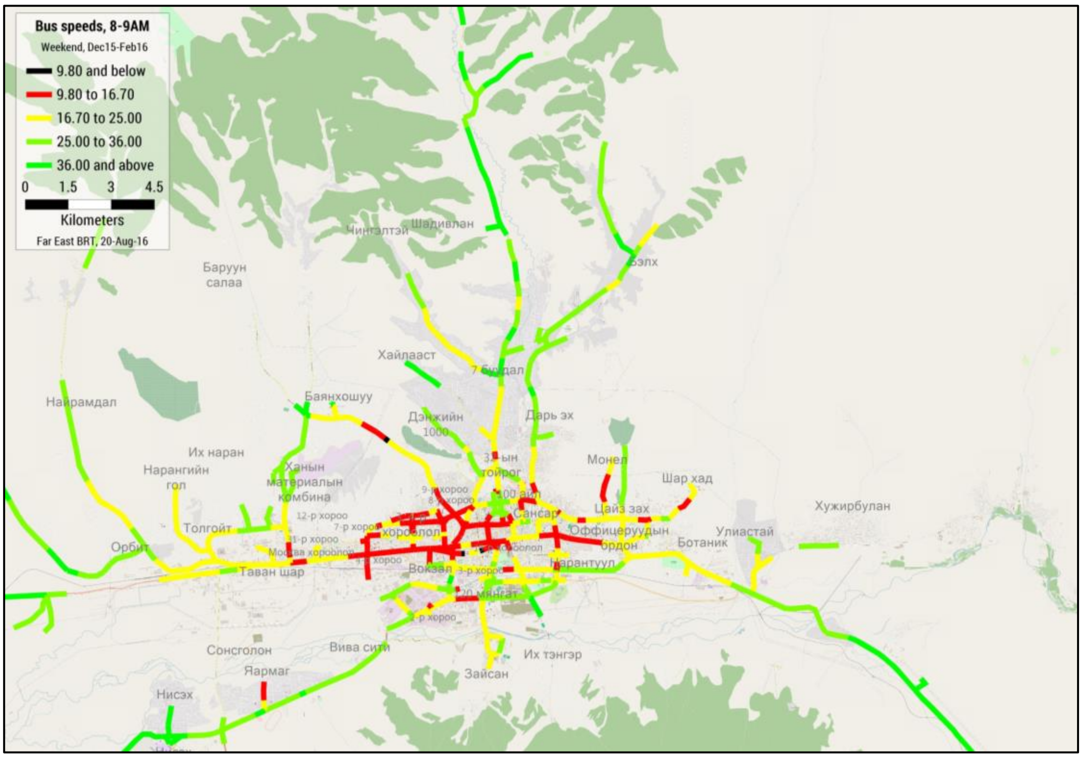
After the bus stop locations were updated and corrected, and linked to the bus speed data in which each bus stop had a unique ID, the 88,329 peak hour speed samples were aggregated to the road network to derive bus speed values for each link.

As part of the BRT model development more detailed analysis can be carried out to obtain better directional data and to refine the aggregation process. However, for present purposes and even for detailed modelling, the bus speed which has been obtained is already more comprehensive than the speed data used for BRT modelling in many other cities. It is hoped that the December 2015 data can be updated with data from May 2016 in order to cover both frigid and warm weather conditions, but the UB Smart Card Company has so far been unwilling to provide the hourly speed data from May 2016.

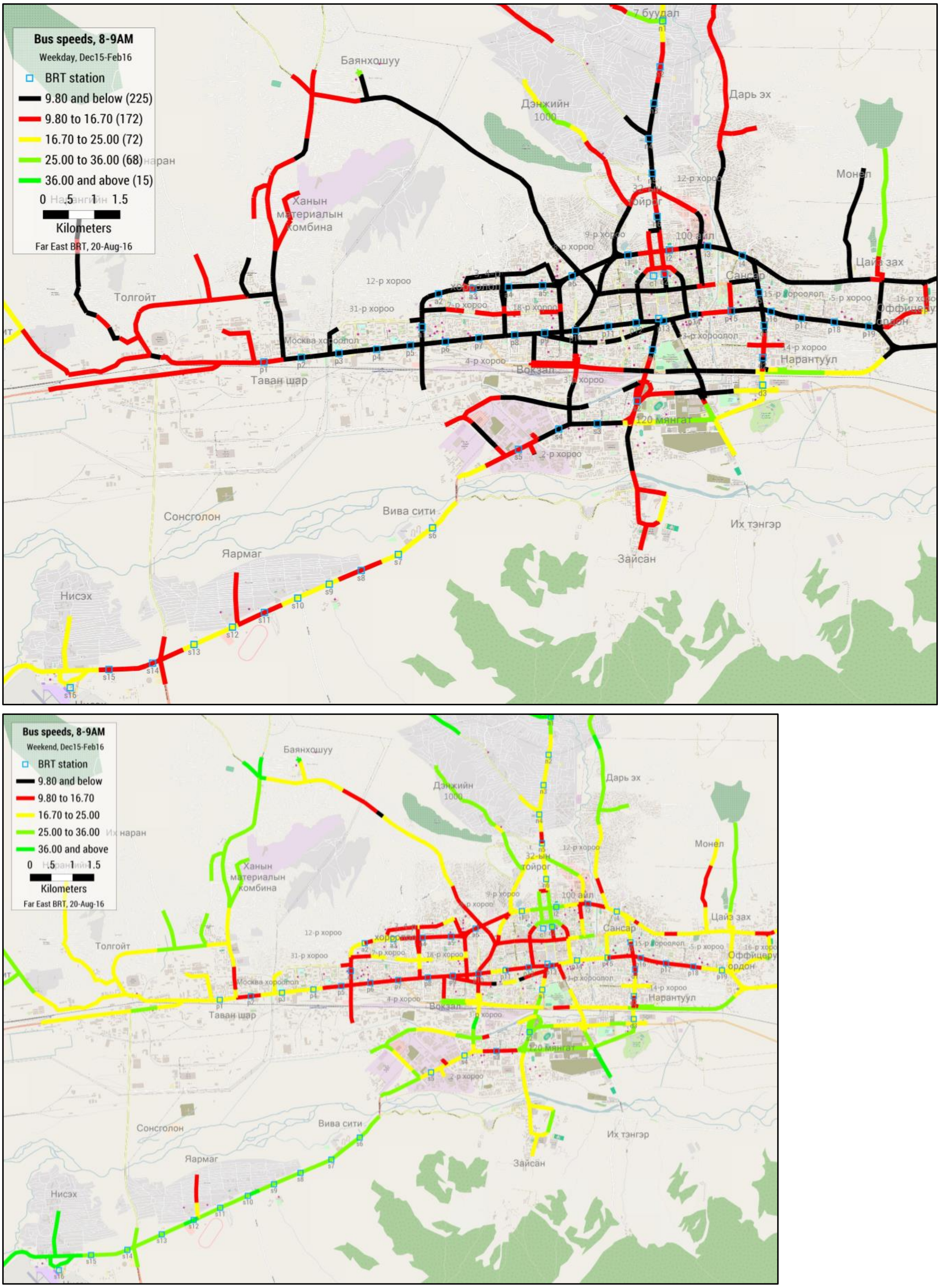
There are various gaps in the smart card data for bus speeds including gaps due to limited coverage of bus stops with smart card data, but these can be fixed by additional analysis and data processing of the smart card data, and if needed by some supplementary field surveys as part of the study follow-up.

The preliminary results of the bus speed analysis are shown following. Though the bus speed data still requires more processing and analysis, the current bus speeds are clearly extremely low. Throughout most of the central area the bus speeds are less than 10km/hr.

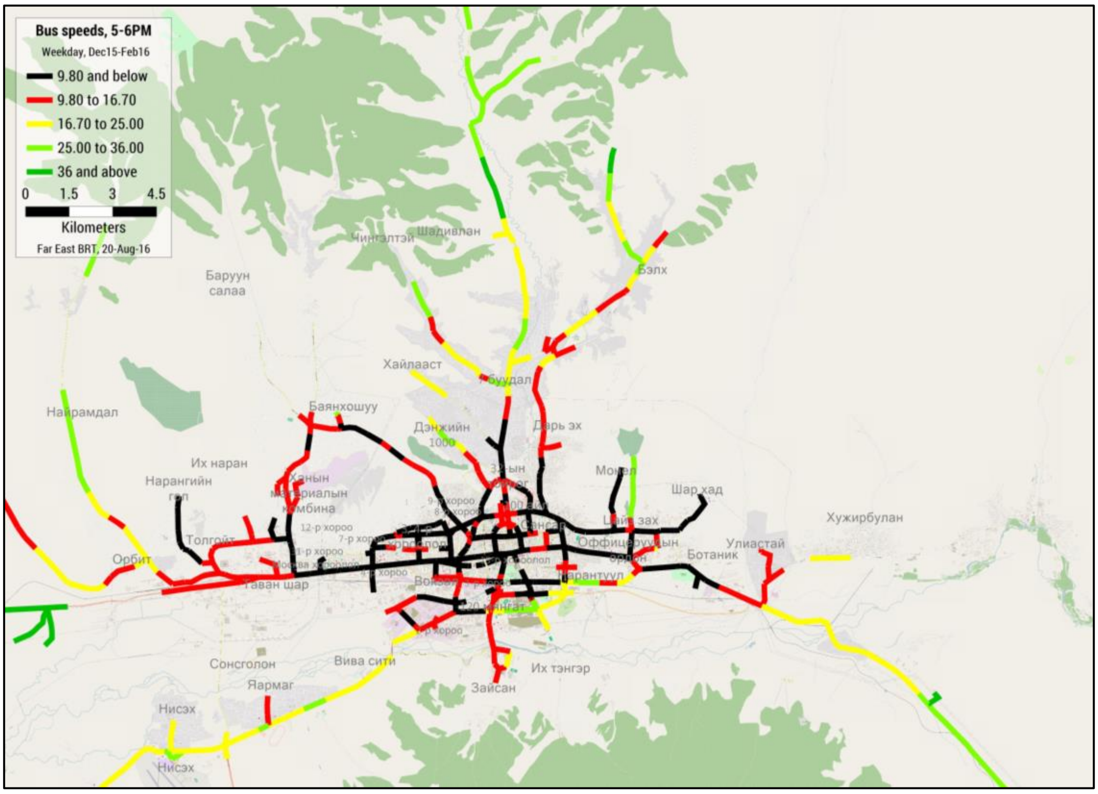


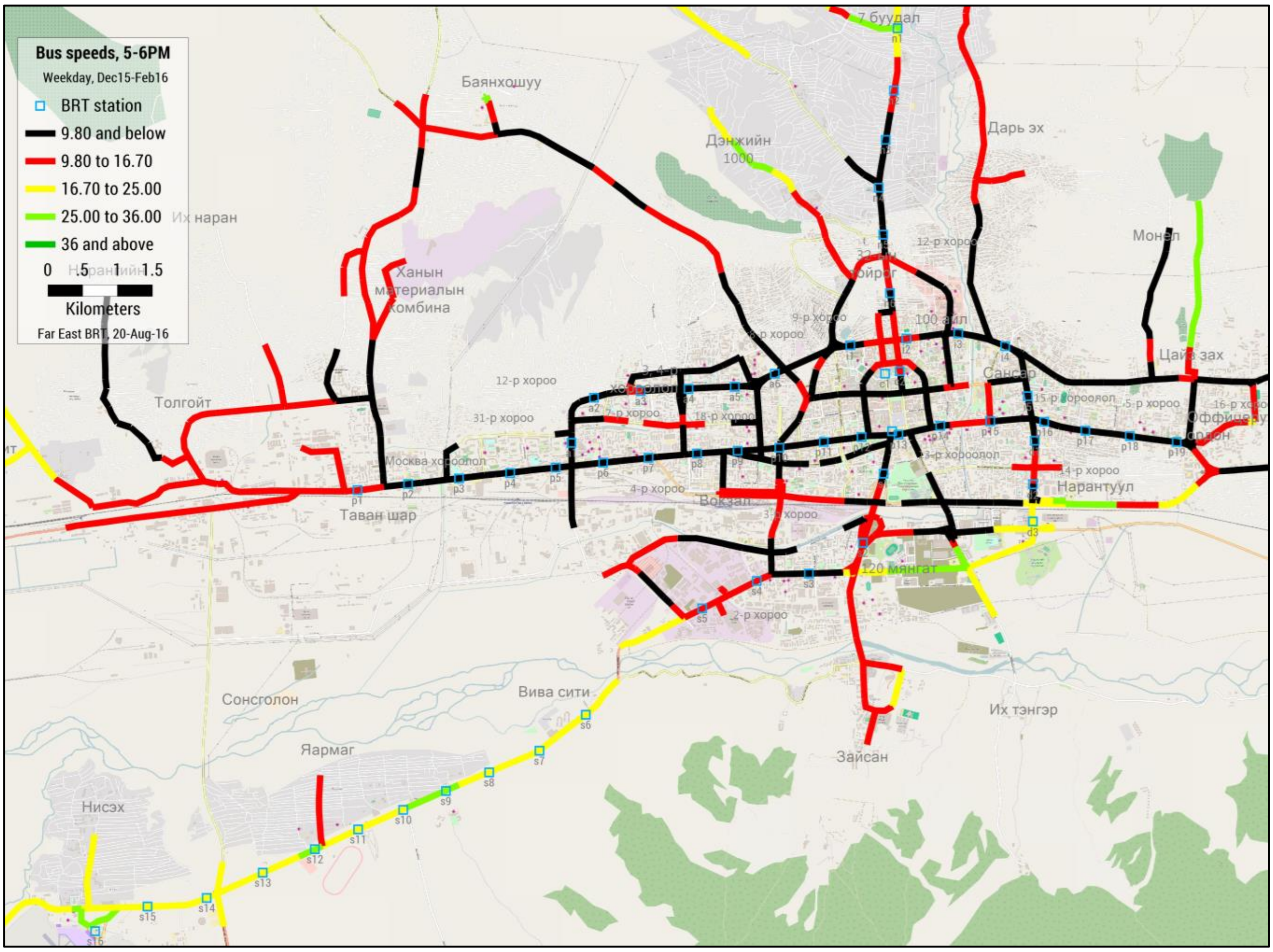


Top: Average weekday bus speeds, AM peak, 21-25 Dec 2015 and 15-19 Feb 2016 – from USCC data (32,579 8-9AM samples, 300m tag). Above: Average weekend bus speeds, AM peak, 27 Dec 2015 (Sun) and 20-21 Feb 2016 (Sat-Sun) – USCC data (10,132 8-9AM samples, 300m tag).

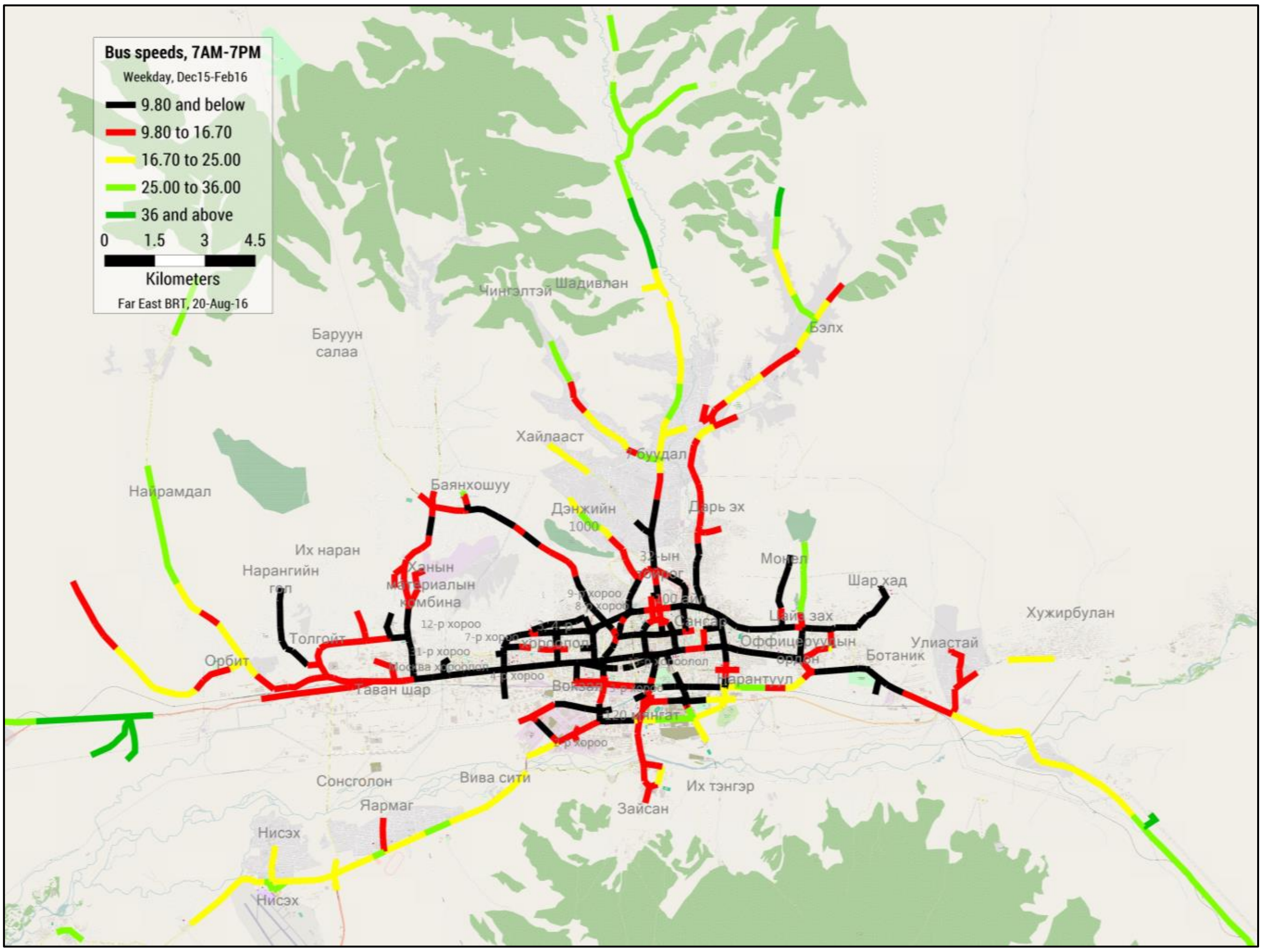


AM peak weekday (top) and weekend (above) bus speeds, with BRT stations superimposed.

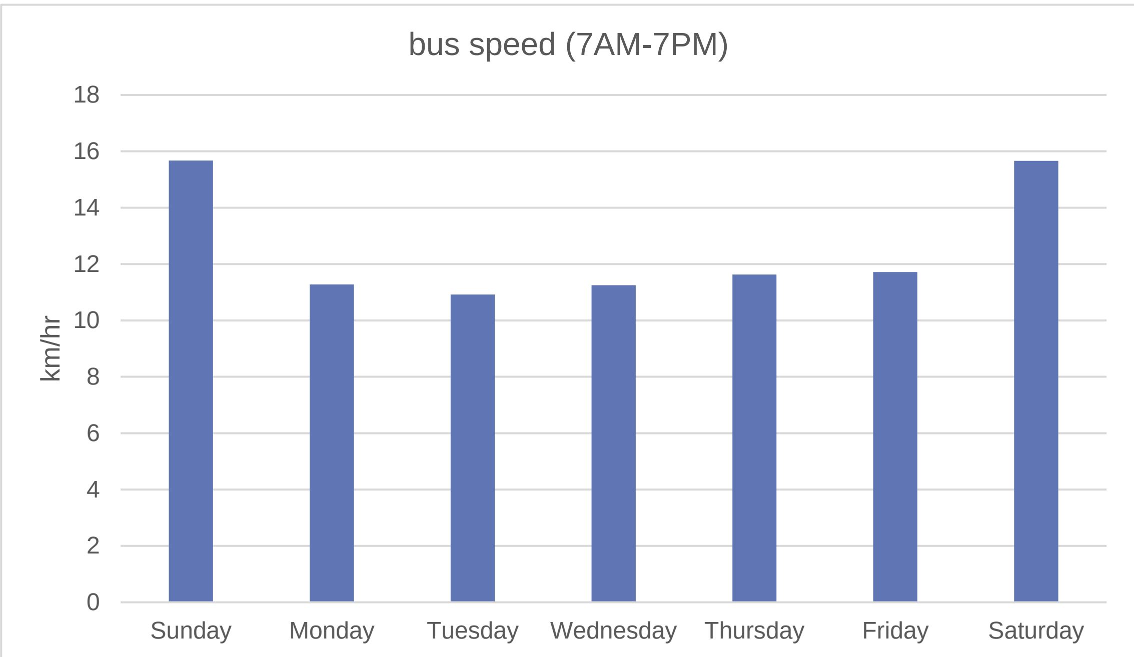




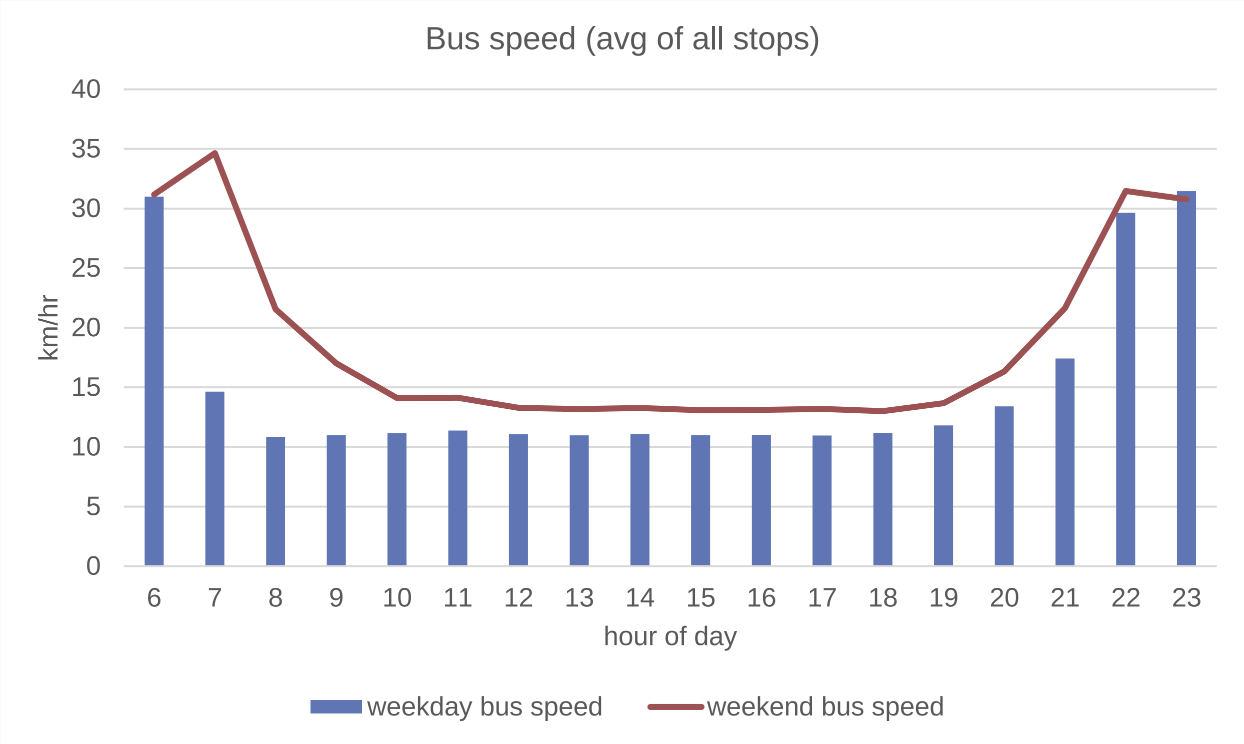
PM peak average bus speeds, weekdays.



Weekday bus speeds, 7AM to 7PM.

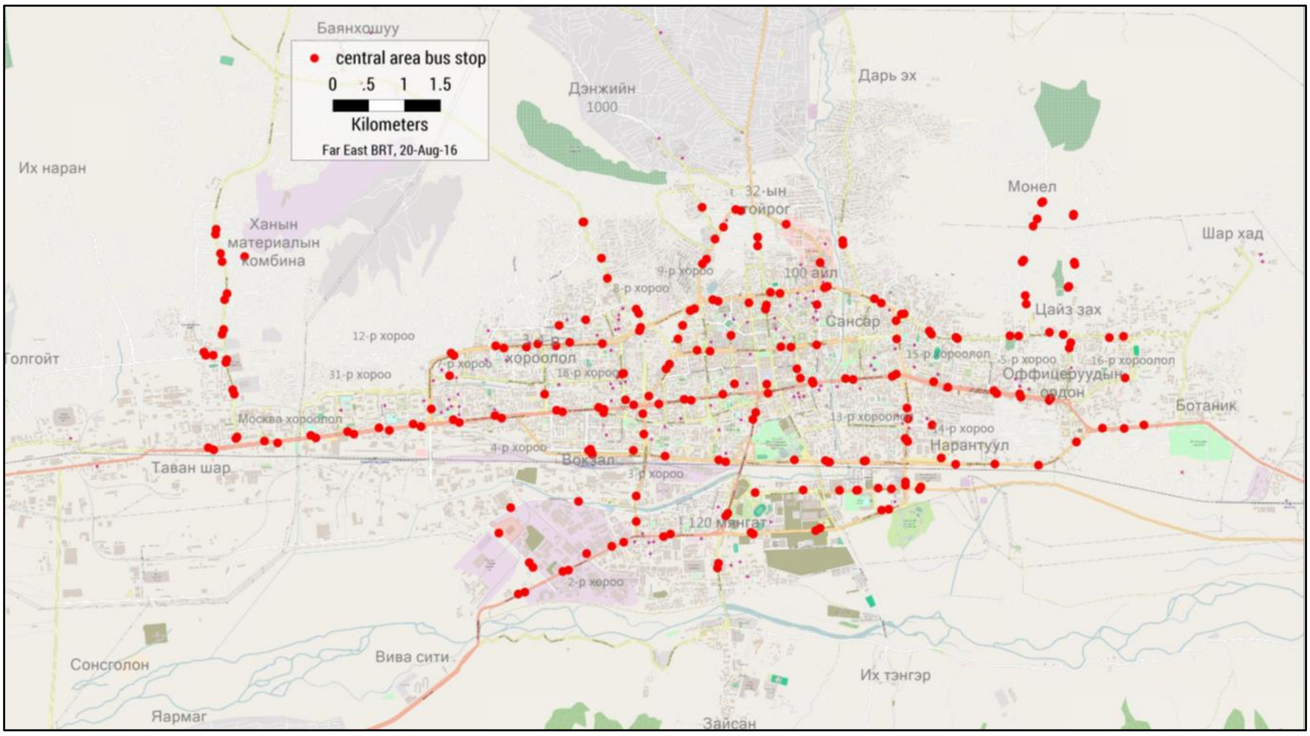


Bus speeds by day of the week. Figures are the average of all bus stops with smart card speed data, during 7AM-7PM, from 21-27 December 2015 and 15-21 February 2016.

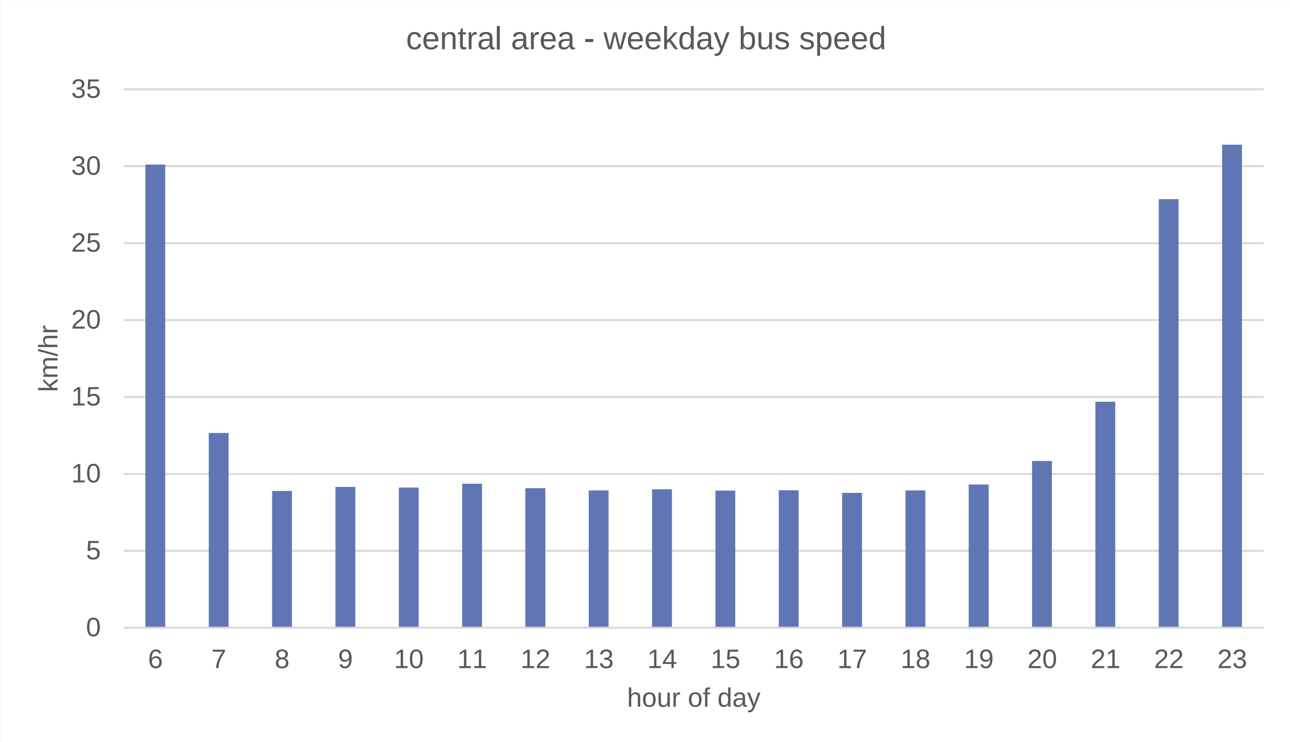


Weekday and weekend bus speed from 6AM to midnight. (From Smart Card data.)

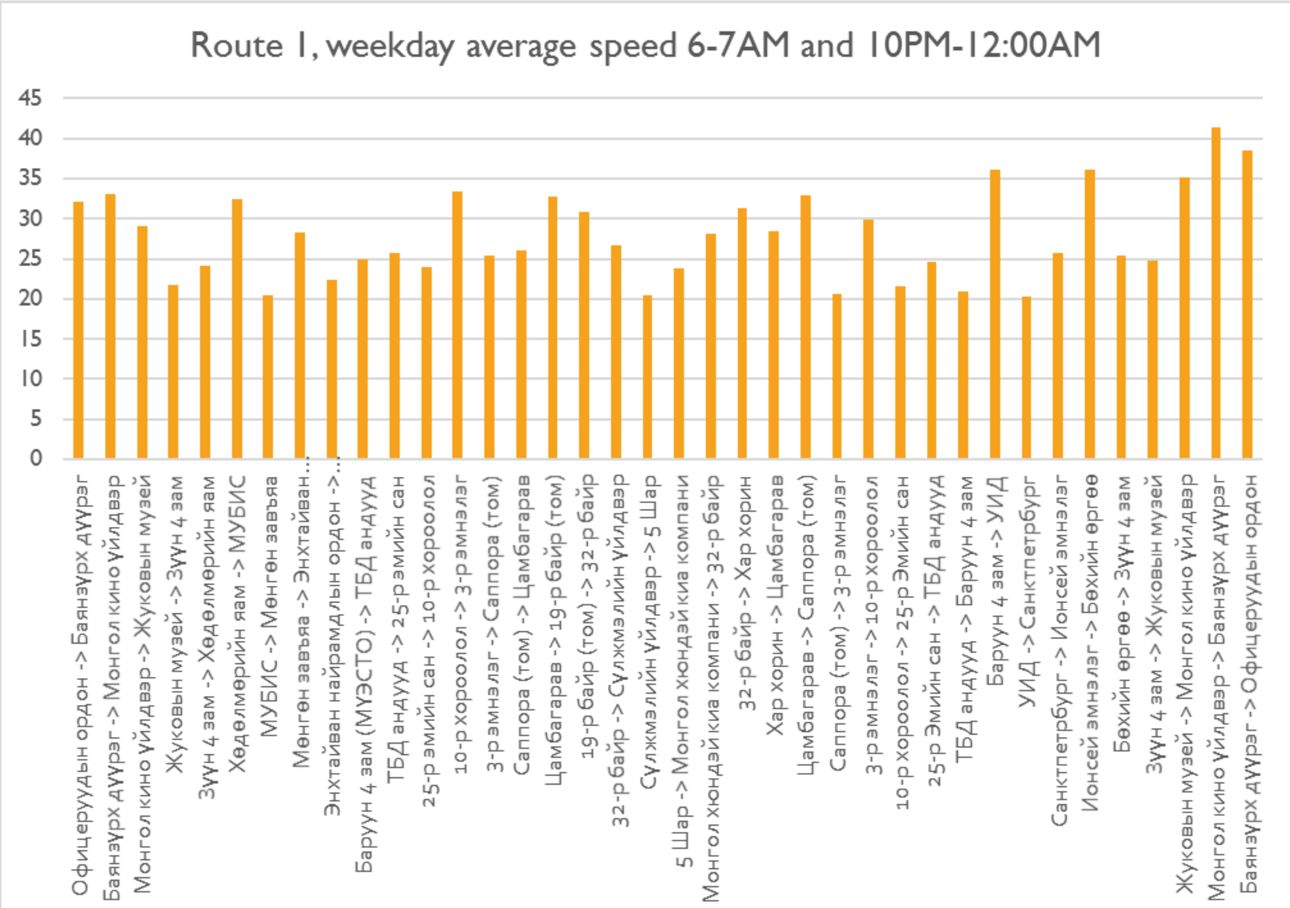
In the central area, defined arbitrarily as the stations shown below, the weekday speeds are even lower than indicated by the citywide figures. **Weekday bus speeds in the central area are on average less than 10km/hr during the entire 8AM to 8PM 12 hour period**.



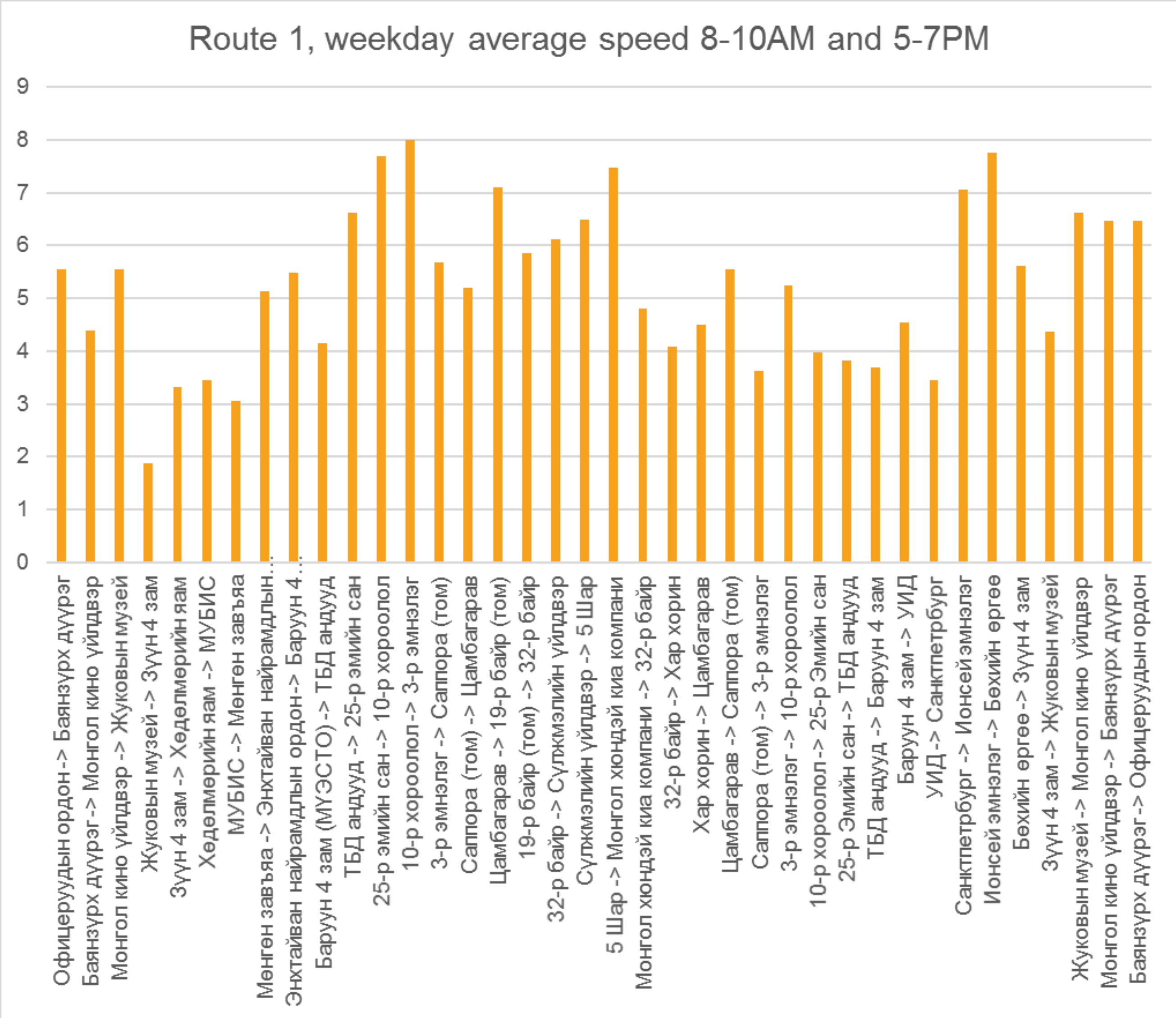
Central area bus stops



Central area bus speed, average of all central area stops, USCC data from Dec-2015 & Feb-2016.



Route 1 weekday average speed from Dec 2015 and Feb 2016. Speed to stop, from USCC data.



Route 1 weekday average speed from Dec 2015 and Feb 2016. Speed to stop, from USCC data.

The bus speed data shows that:

- Bus speeds are extremely low from 8AM to 9PM every day.
- The weekend bus speeds average around 2km/hr more than the weekday speeds throughout the day.
- Before 7AM and after 10PM bus speeds are much higher, averaging around 30km/hr.
- Central area bus speeds are extremely low, averaging less than 10km/hr across all central area bus stops during the entire 8AM to 8PM period.
- Daily bus speeds are around 11.3km/hr averaged across all bus stops from 7AM to 7PM for each weekday, and around 15.7km/hr on both Saturday and Sunday from 7AM to 7PM.
- Bus speed is low throughout the day. In the central area, bus speeds average around 9km/hr during the entire 8AM to 8PM period. Speeds during apparently off-peak hours, such as 10AM or 3PM, are the same as during apparently peak hours such as 8AM and 5PM. (In fact, as the bus boarding data by time of day shows, there is only a slightly

noticeable peak period for bus ridership in Ulaanbaatar, with relatively constant demand throughout the day.)

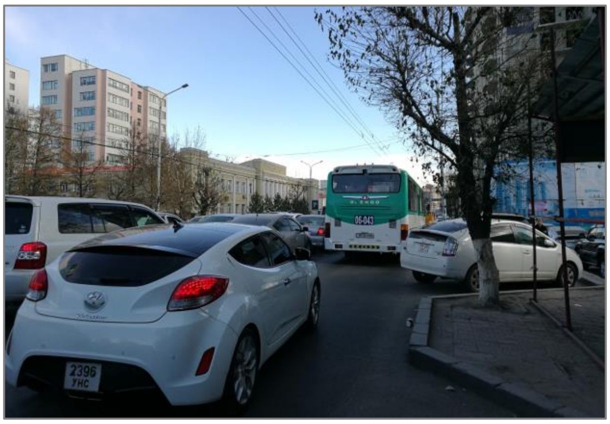
Overall, the bus speed data reveals what is arguably the most important urban transport policy challenge in Ulaanbaatar: extremely slow bus speeds.

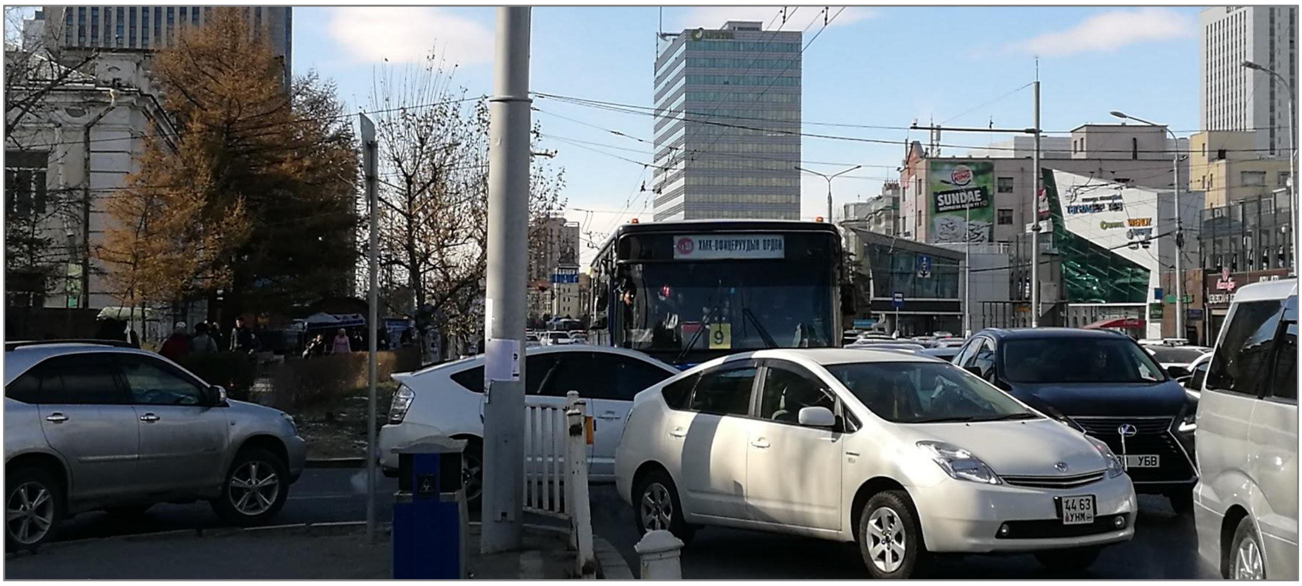
The bus speed data shows that BRT, which if well-designed will increase bus speeds to more than 20km/hr in the BRT corridor, can provide huge benefits. With BRT, **bus speeds will be more than doubled in the BRT corridors**, providing major time saving and operational saving benefits.

Moreover, the benefits from BRT will accrue throughout the day; not only during the peak hours. Based on current bus speeds and ridership figures, the time saving and operational saving benefits will be similar for each hour of the day between 8AM and 8PM. BRT will also provide significant benefits during 7-8AM and 9-10PM.

2.4 Bus lanes along Peace Avenue

The proposed BRT corridor in Peace Avenue has bus lanes, but these do little to improve bus speeds and may even reduce speeds due to queuing problems at bus stops. Bus lane enforcement is at best sporadic, and is generally ineffective. The photos below show turning, stopping and even parked vehicles blocking or entering the bus lanes, and through traffic also often enters the bus lanes.




SUNDAE


Kempinski Hotel Khan Palace
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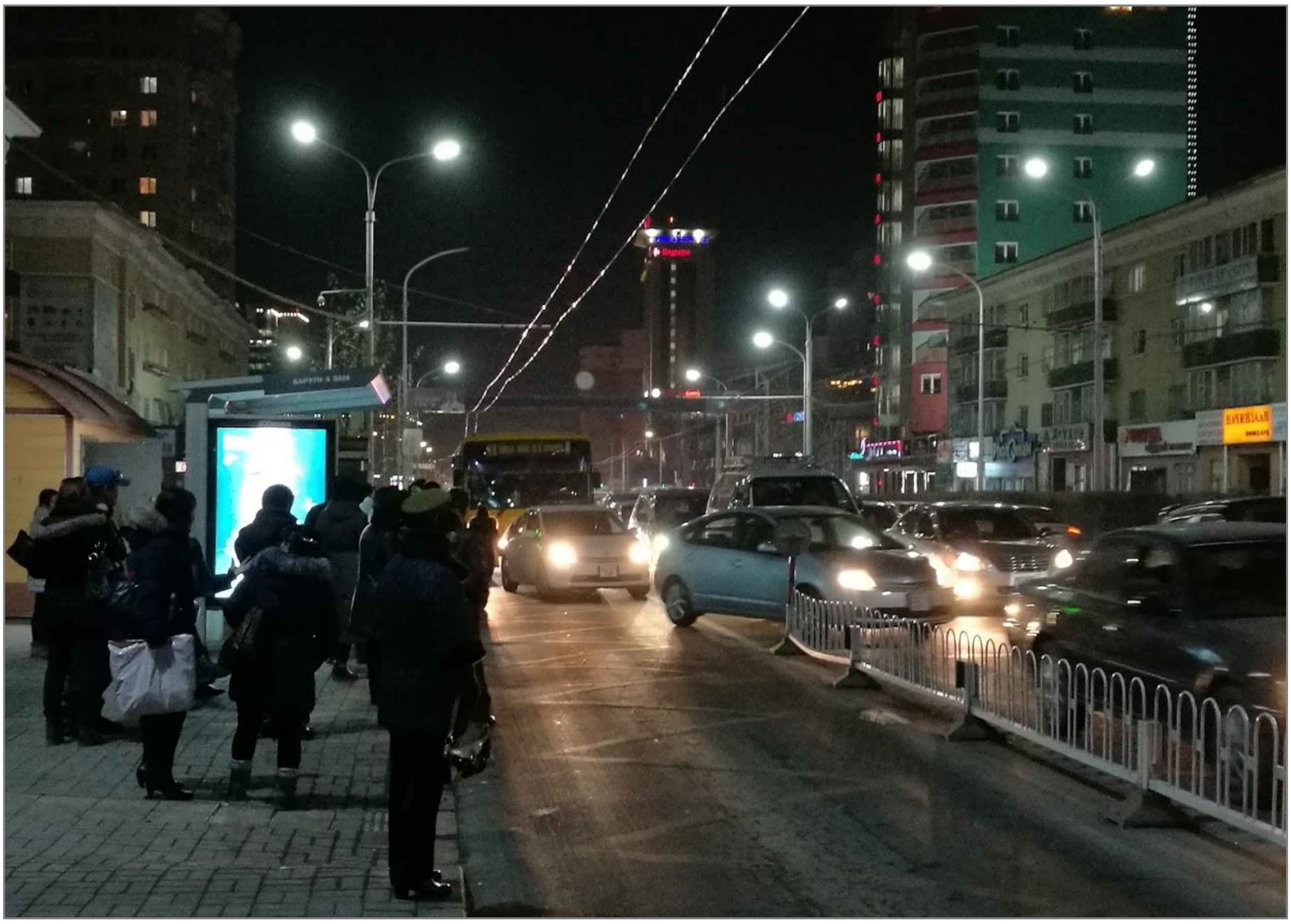


Bus lanes in Peace Avenue in October and November 2016. As the bus speed data and site visit observations show, kerbside bus lanes along Peace Avenue are ineffective.

2.5 Bus stops

Although there have been recent improvements to bus stops, the bus stops still fail to meet the needs of transit passengers. In higher demand locations, the bus stop facilities are clearly inadequate, with passengers fanning out along the street.

Passengers fan out along the street at high demand bus stops in Ulaanbaatar, including this one in Peace Avenue near the State Department Store. The long travel times due to low bus speeds are compounded by the unreliable and potentially long waiting times for buses, and further compounded by the cold weather conditions at bus stops in Winter.

3 BRT operations

3.1 BRT corridors and phases

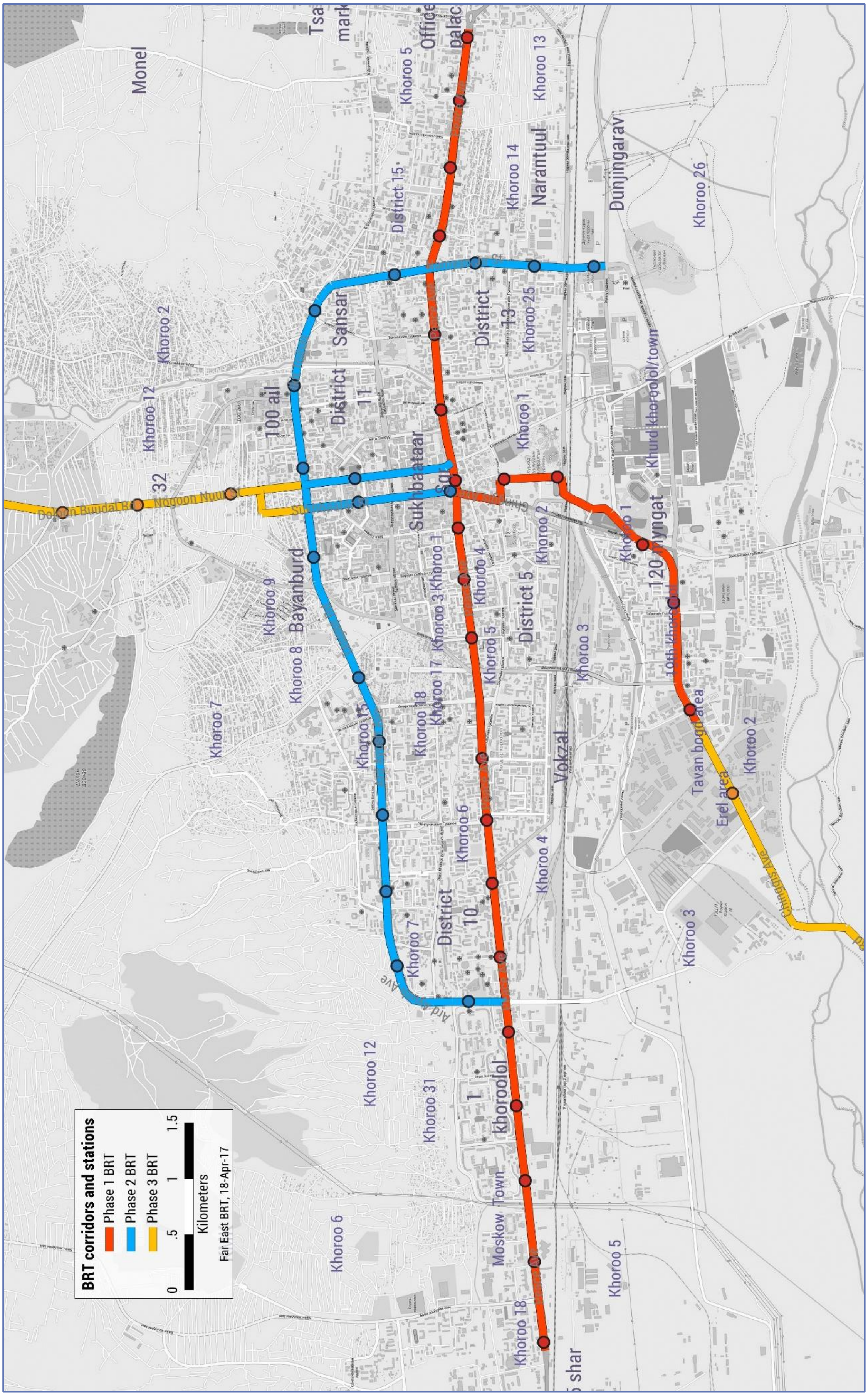
The following BRT corridors options were compared, with the east-west Peace Avenue, 3/4 khoroolol, Ikh Toiruu, southwest connection and Namyan Ju St corridors proposed for phase 1 and phase 2, and the north-south corridors proposed for phase 3. All corridors can potentially be implemented within the ADB loan funding amount of around US$219 million.

Station codes are also shown. The station codes are generally referenced in place of station names in the planning process and in this report.

The following very preliminary BRT operational plan concepts are based on these corridors.

BRT stations and corridors divided into implementation phases (45km and 60 stations).

Codes used for BRT stations. The codes, station names and station locations are also available at http://www.ubbrt.net.



BRT corridor and stations, showing the full phase 1 and phase 2.

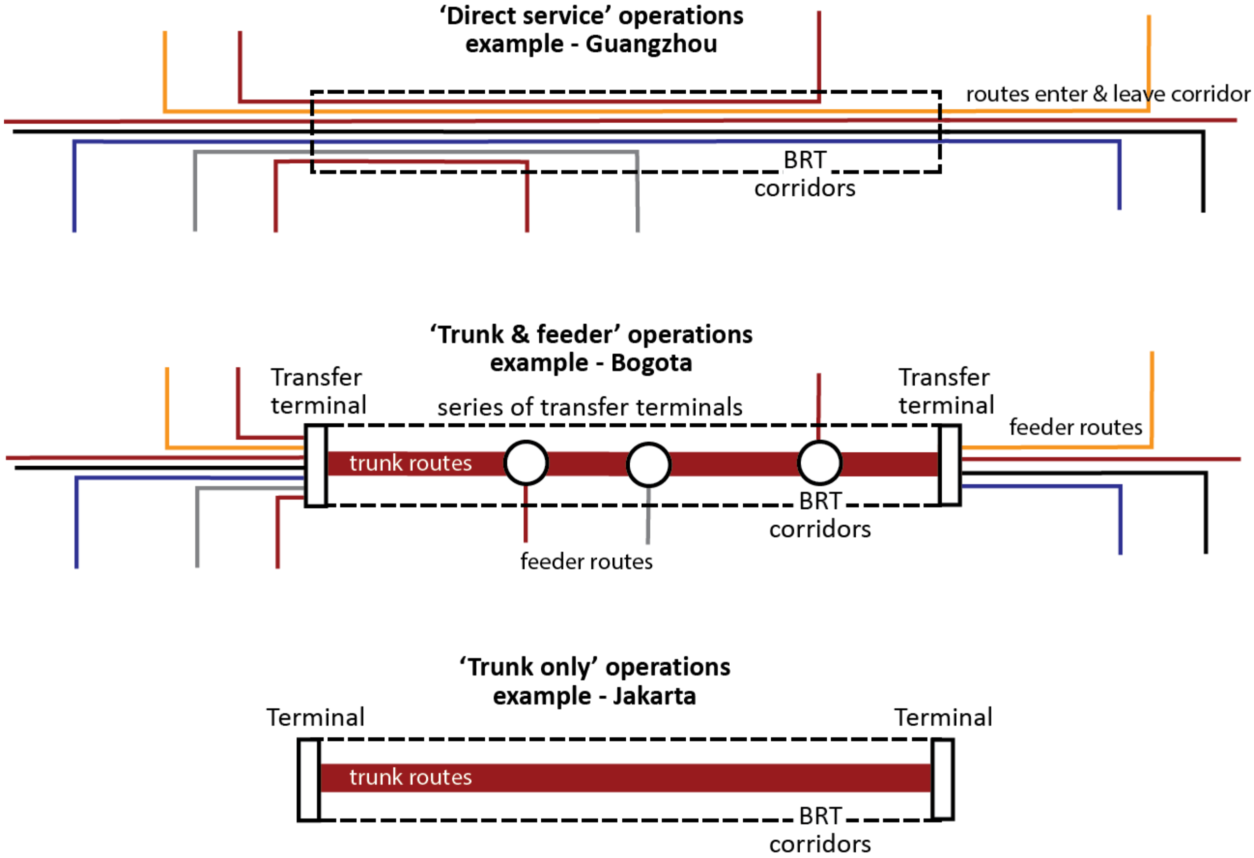
The following table shows basic BRT corridor parameters.

BRT phases and corridors: length and number of stations

Corridor	Length	Stations
Phase 1 – Peace Avenue & Namyan Ju	13.6 km	22
Phase 2 – Ikh Toiruu & 3/7 khoroolol & southwest connection	15.4 km	20
Phase 3 – Doloon Buudal & Airport Rd	15.9 km	18
Total	**44.9 km**	**60**

3.2 'Direct service' BRT operations

The Ulaanbaatar BRT will be based on a direct service operational model as illustrated below. The direct service approach has many advantages for efficiency of fleet allocation and hence reduced fleet requirements, matching of bus frequency to demand, minimizing passenger transfers, and removing the need for transfer terminals and interchanges.



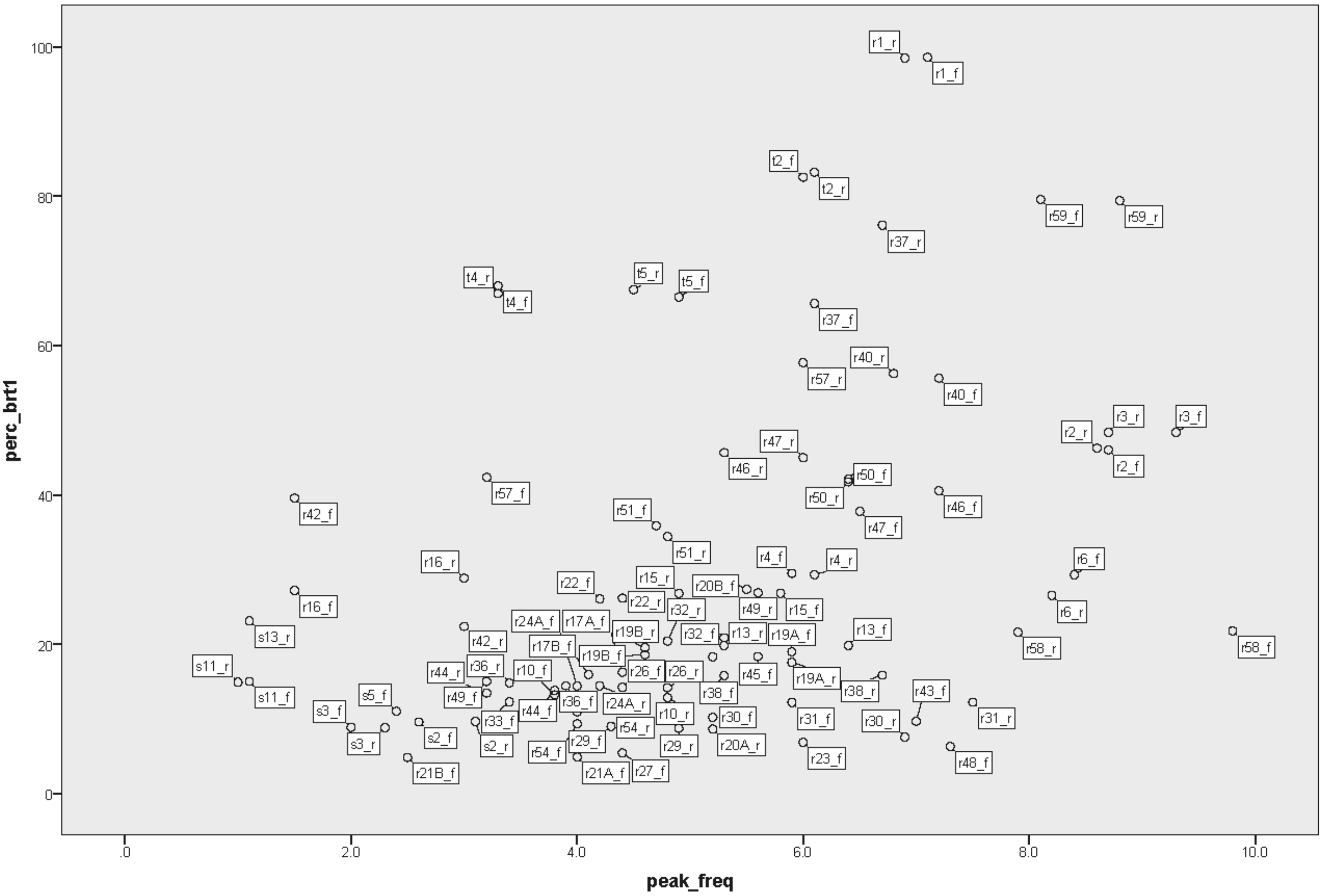
A direct service approach contrasted with trunk-feeder and trunk-only operations.

In broad terms, in cities where the bus route structure is already reasonably well adapted to the demand patterns, which appears to be the case in Ulaanbaatar (though this will be verified during the BRT modeling process), BRT routes are selected based on a consideration of peak frequency and percentage of the route length inside the BRT corridor. Routes with a higher peak frequency and higher percentage inside the BRT are preferred for inclusion in the BRT.

After this initial selection, routes are adjusted and optimized in an iterative process where changes to one route leads to changes required in other routes, and so on. Ideally this detailed operational planning is done based on a BRT demand model which also considers the impact of route changes on transfers.

A key goal of the route design process in Ulaanbaatar will be to reduce transfers. For example, it is likely that extending the current route 1 beyond Officers Palace to Botanik would significantly reduce passenger transfer volumes at Officers Palace.

The proportion of passengers who start and end their trip at BRT stations is likely to be relatively high in Ulaanbaatar, given the way the BRT corridors align with overall demand patterns. This proportion of ‘station to station’ trips in the Guangzhou BRT is less than 10%. In Yichang it is higher, at around 20% of trips. The proportion of ‘station to station’ trips in Ulaanbaatar will be determined during the modeling and operational design stage, and this will in turn influence the operational design, especially on the issue of whether to have a BRT route running only inside the BRT corridor along Peace Avenue (the current route 1 alignment).

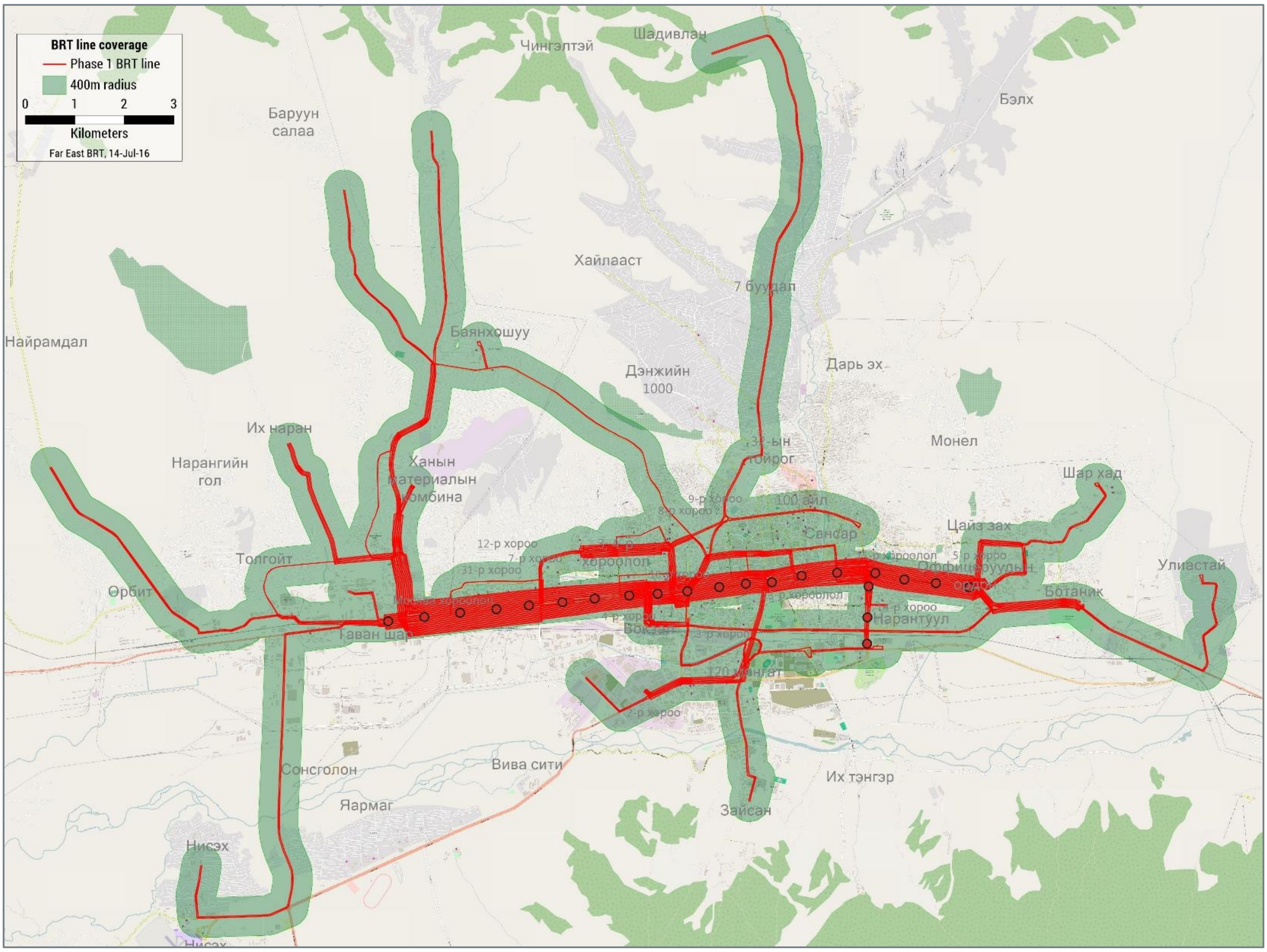


Preliminary route selection for inclusion in the BRT

For the purposes of proving preliminary input to the BRT infrastructure design, comparing the corridor options, and showing the demand patterns, a route selection was carried out based on peak frequency and percentage in the BRT corridor with only minor adjustments. For fleet requirements and a preliminary operational plan a more detailed analysis will be required.

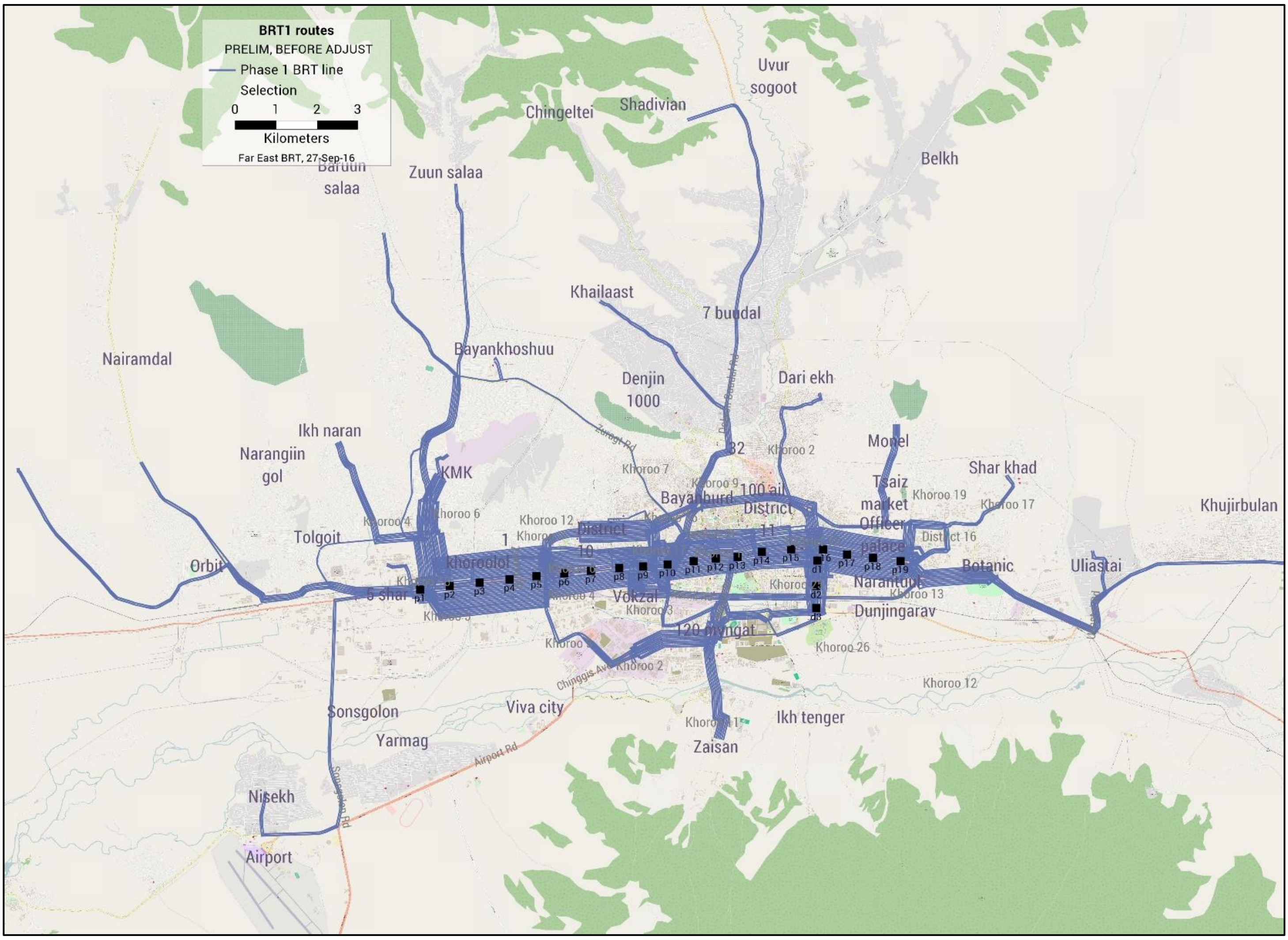
route	length (km)	peak frequency	perc in BRT 1
r1_f	12.16	7.1	99
r1_r	12.17	6.9	99
r2_f	13.26	8.7	46
r2_r	13.19	8.6	46
r3_f	20.79	9.3	48
r3_r	20.79	8.7	48
r4_f	10.72	5.9	29
r4_r	10.78	6.1	29
r6_f	18.28	8.4	29
r6_r	18.49	8.2	27
r15_f	14.43	5.8	27
r15_r	14.43	4.9	27
r16_f	14.50	1.5	27
r16_r	13.67	3	29
r20B_f	9.90	5.5	27
r20B_r	10.27	5.5	0
r22_f	21.86	4.2	26
r22_r	21.79	4.4	26
r32_f	18.07	5.3	21
r32_r	18.46	4.8	20
r37_f	9.30	6.1	66
r37_r	9.47	6.7	76
r40_f	16.06	7.2	56
r40_r	15.88	6.8	56
r42_f	12.39	1.5	40
r42_r	13.84	3	22
r46_f	12.26	7.2	41
r46_r	10.74	5.3	46
r47_f	16.27	6.5	38
r47_r	16.55	6	45
r50_f	10.02	6.4	42
r50_r	10.11	6.4	42
r51_f	8.46	4.7	36
r51_r	8.82	4.8	34
r57_f	13.47	3.2	42
r57_r	13.69	6	58
r58_f	8.65	9.8	22
r58_r	8.72	7.9	22
r59_f	14.50	8.1	80
r59_r	14.53	8.8	79
t2_f	14.52	6	83
t2_r	14.40	6.1	83
t4_f	9.76	3.3	68
t4_r	9.90	3.3	67
t5_f	9.18	4.9	66
t5_r	9.04	4.5	67

Preliminary, before adjustment. 23 phase 1 BRT routes. Routes are selected based on peak frequency and percentage in BRT corridor. Note that this is before route adjustment and for preliminary concept purposes only.



Phase 1 BRT routes, with 400 bands from the routes and phase 1 BRT stations indicated. Large parts of the city are covered by BRT services after just the first phase BRT implementation.

An expanded phase 1 BRT route selection was also carried out, in which the selected routes were increased from 23 to 32. The additional routes were 'borderline' routes which had a percentage in the BRT corridor of 15-20%, and routes along the Namyan Ju corridor. If these additional routes are included in the phase 1 BRT corridor, BRT routes cover 178km of roadways in Ulaanbaatar. The coverage of the expanded phase 1 BRT route selection is shown below.



Expanded route selection of 32 phase 1 BRT routes – before adjustment. The route selection needs to be done as part of the preliminary operational design which ideally involves developing a BRT model with the smart card data as the basis and starting point.

4 BRT demand

The current bus demand is the best available indicator for future BRT demand. The BRT routes will be broadly based on the current routes, taking current routes as a starting point and making various adjustments to optimize the BRT and regular bus system operation. This operational planning process has not yet been carried out, so this study includes a preliminary operational design based on a selection of existing bus routes for inclusion in the BRT.

While this is fairly rough, the accuracy of the smart card data means that the figures provided provide a good overall view of the future BRT demand patterns.

4.1 Bus demand data

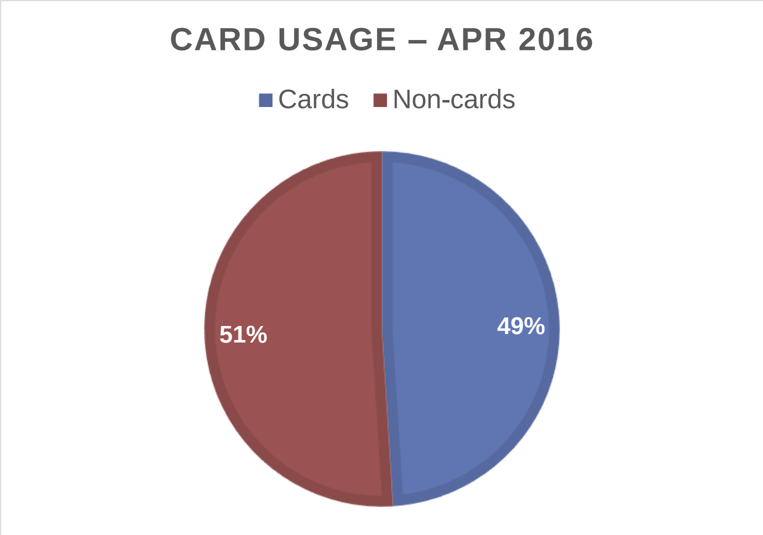
The smart card data from the Ulaanbaatar Smart Card Co (USCC) is an excellent resource which can be used throughout the BRT planning process, but has some anomalies which need to be corrected/addressed:

- Some bus stops are in the wrong location in the smart card database, and many are missing in outer areas. USCC is currently correcting this, though this work has been ongoing for a month with no results yet.
- The route 1 data is incorrect, showing excessive boardings at the first or last station. This is a major issue because it noticeably skews the overall data. The problem was pointed out to the USCC on 12 April 2016 and a response is requested. Counts are being done at the first and last stops to correct the route 1 data, if there is no response/resolution from USCC.
- Some newer buses do not have card readers. The route 56 minibus data is missing, as it does not have smart card readers, and surveys are being done for this route this week.

Surveys were done in early April 2016 to check the proportion of boarding passengers which are using cards, so that the card data can be converted to estimated total boardings. From 3,740 samples at several different bus stops, 49% of passengers used cards, with 51% not using cards. From 1 April 2017 only smart card payment is permitted on buses, which will further and greatly enhance the usefulness of the smart card data.

Bus frequency and occupancy counts were done throughout March 2016 so that demand estimates can be based on actual rather than scheduled or reported frequency.

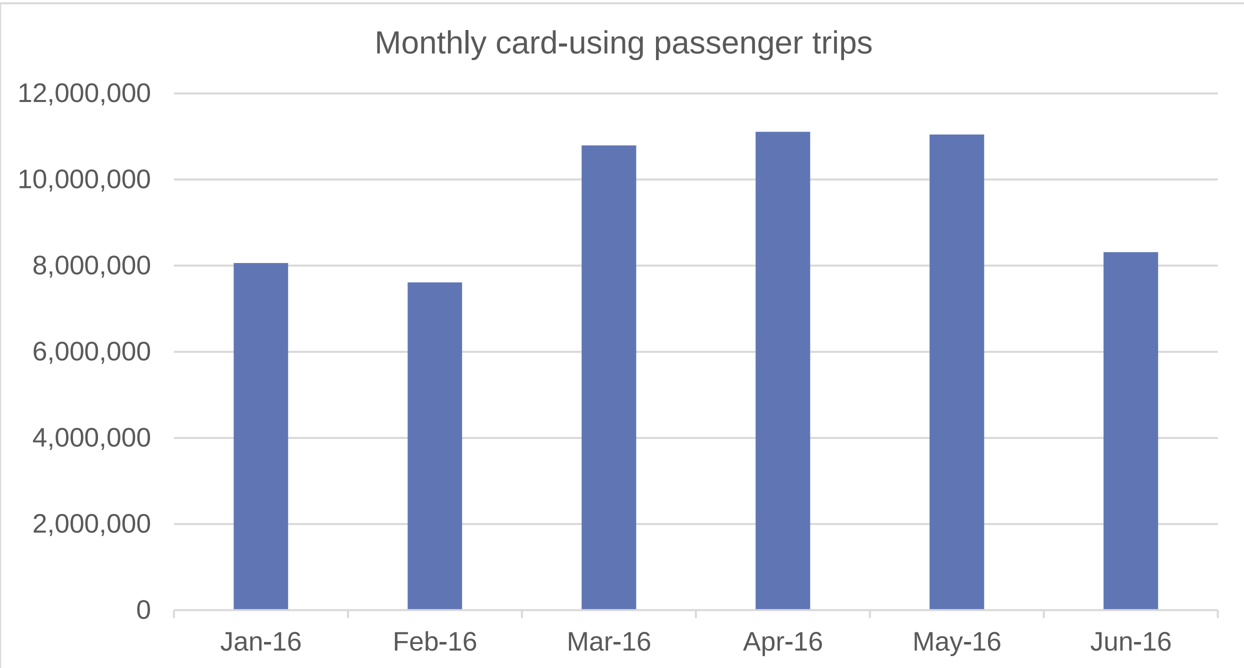
Transfer surveys are needed at major transfer locations as part of the BRT demand model preparation. This can be done later in 2017.



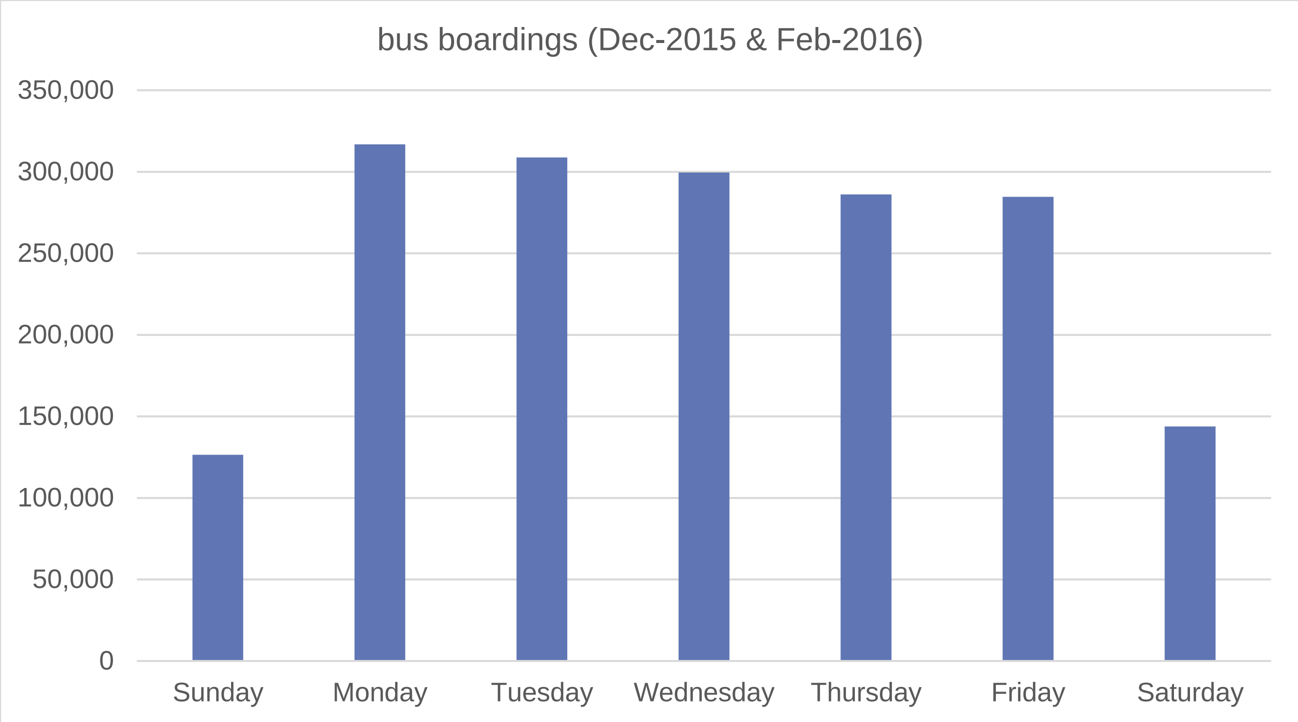
Card and non-card usage from 3,740 samples of peak hour boarding passengers at several different bus stops (surveys early April 2016). (From 1 April 2017, all boardings are with smart card as cash payment on buses is no longer accepted.)

4.2 Current bus demand based on smart card data

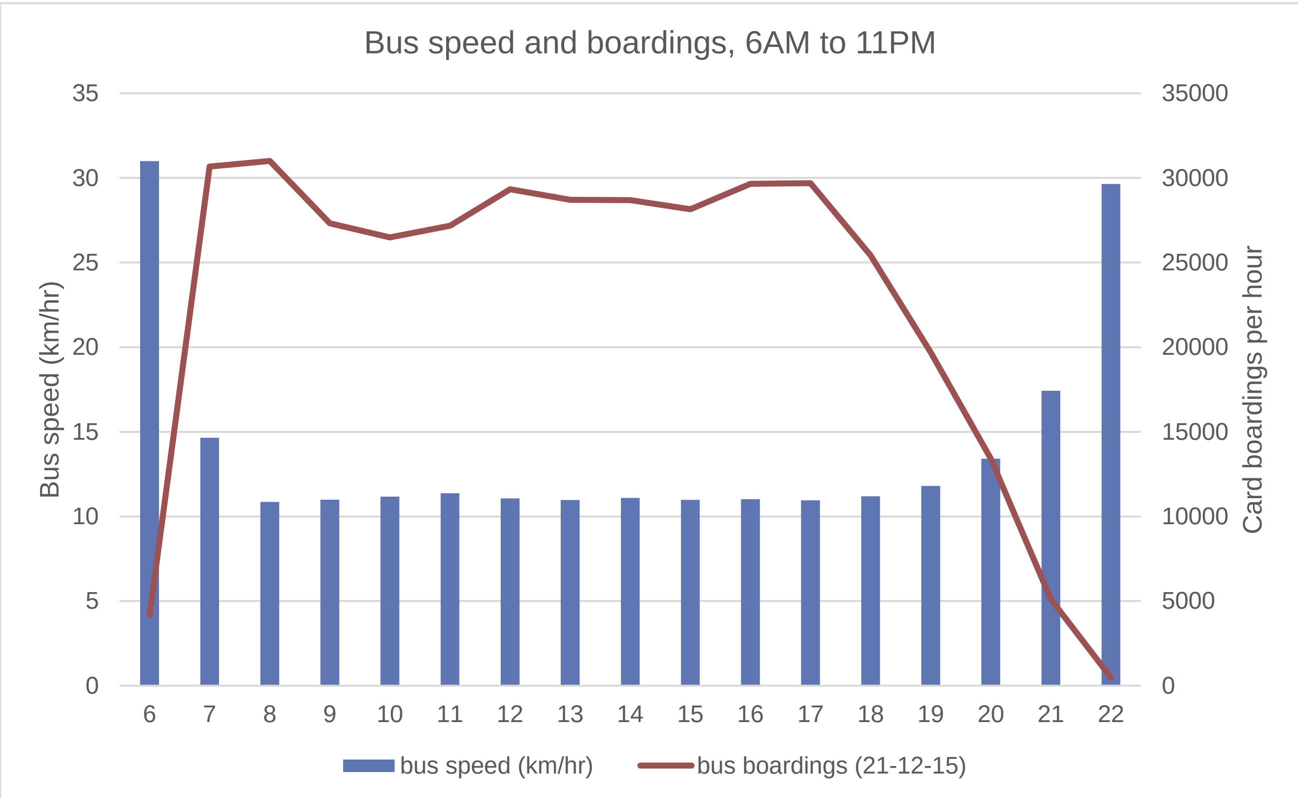
Smart card data was analysed in April 2016 based on March 2016 data, and further assessed in early July 2016. The smart card data has a wealth of route and stop based data that can be used throughout the BRT planning process. For present purposes of illustrating the current bus demand and the likely future BRT demand patterns, the monthly ridership data from January to June 2016 was compared, with the peak month selected for further analysis. The month with the highest ridership based on smart card usage was April.



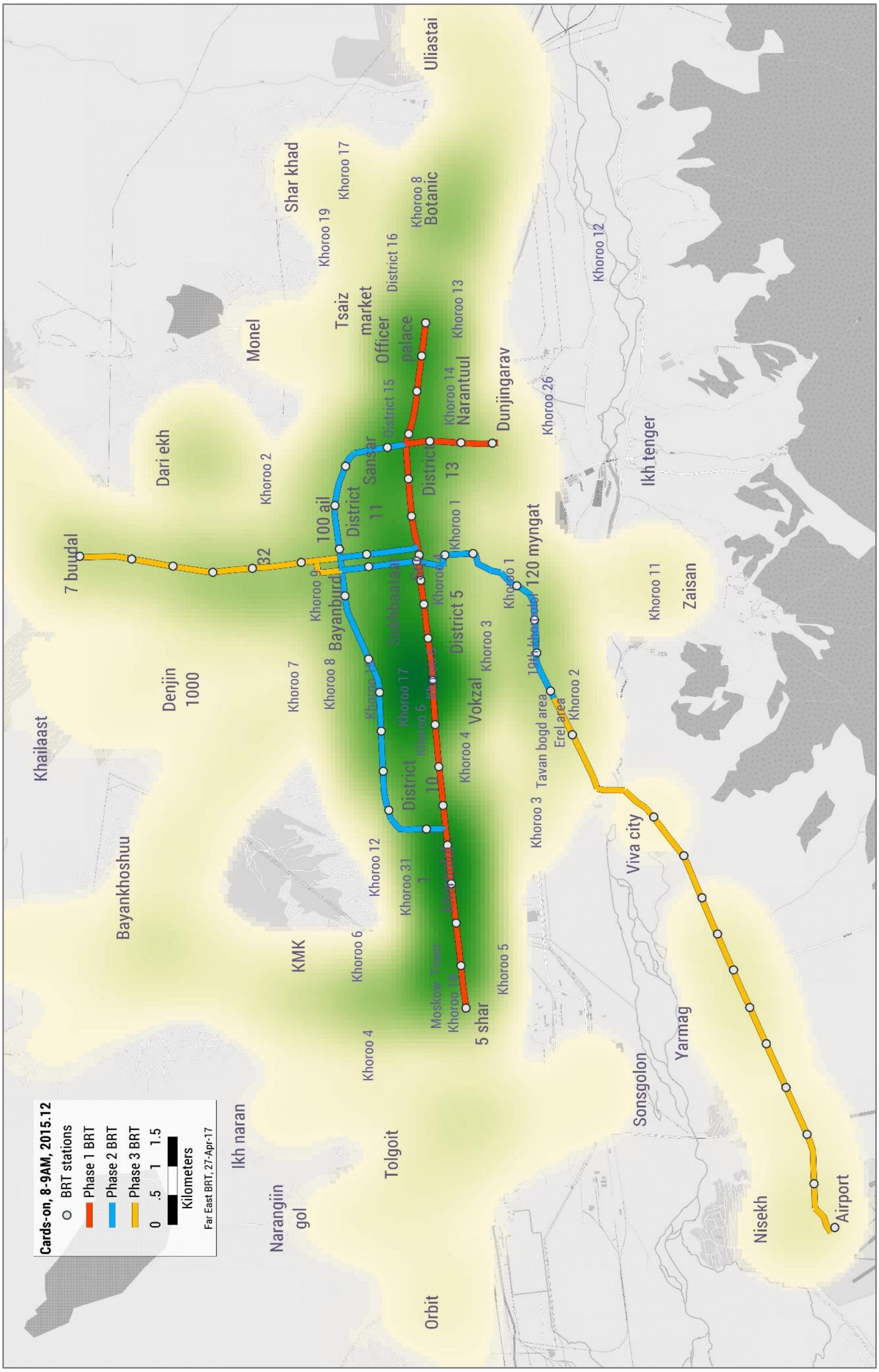
Monthly bus ridership – smart cards only (adjusted for route 1 5 shar error). From USCC data.



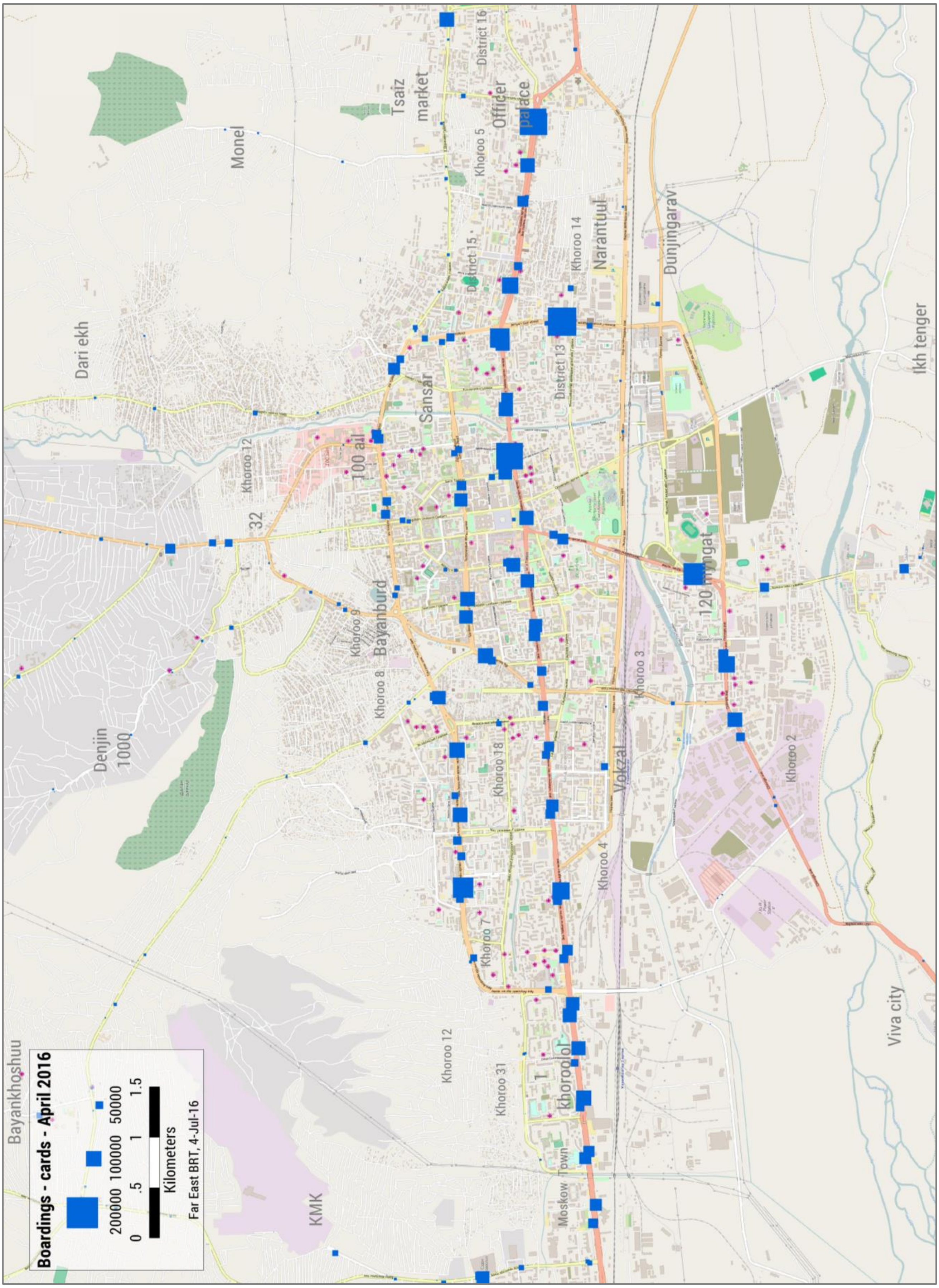
Bus boardings by smart card by day of the week, from USCC data from 21-27 Dec 2015 and 15-21 Feb 2016. Boardings are highest on Monday and then decline slightly each day to Friday. Saturday demand is around half of the weekday demand, and Sunday is around 40% of weekday demand.



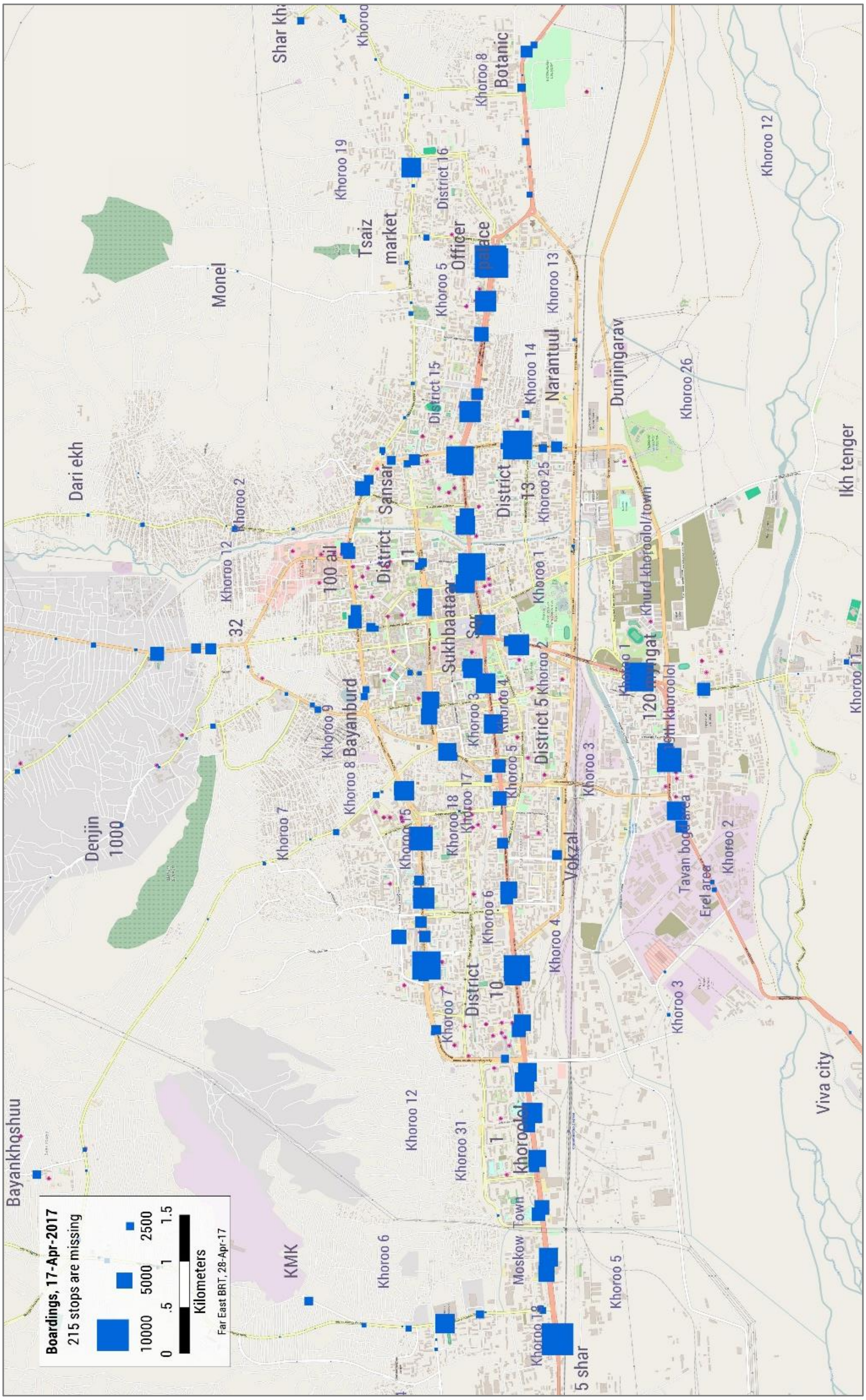
Bus demand by hour of the day, from Monday 21 December 2015, and weekday bus speed average for all bus stops during 7AM-7PM, Dec 2015 and Feb 2016.



A ‘heat map’ of 8-9AM in December 2015 boardings.



April 2016 bus boardings based on smart cards.



Smart card boarding, 17 April 2017 (with 215 missing stops).

April 2016 card boardings on buses, showing only bus stops with > 75,000 monthly boardings.

Highest demand bus stops in Ulaanbaatar according to card boardings. Note the concentration of high demand bus stops along the phase 1 BRT corridor, and that all stops are included in either the phase 1 or phase 2 BRT.

Bus stop	Side of road	April 2016 card boardings	BRT phase	BRT corridor
Хятад худалдааны төв	east	182,693	1	Namyan Ju
МУБИС	north	171,528	1	Peace Ave
Офицеруудын ордон	north	171,126	1	Peace Ave
Төв цэнгэлдэх хүрээлэн	east	142,070	2	Chinggis Ave
Офицеруудын ордон	south	141,993	1	Peace Ave
Дүүхээ төв	south	131,164	2	3/4 khoroolol
Зүүн 4 зам	north	125,975	1	Peace Ave
5 шар	south	124,803	1	Peace Ave
Ионсей эмнэлэг	south	118,491	1	Peace Ave
10-р хороолол	south	111,150	1	Peace Ave
19-р хороолол	south	104,856	2	Chinggis Ave
Жуковын музей/	north	104,782	1	Peace Ave
5 шар	north	100,537	1	Peace Ave

The April 2016 demand data provides a strong basis for guiding the BRT corridor and phase selection, in several ways:

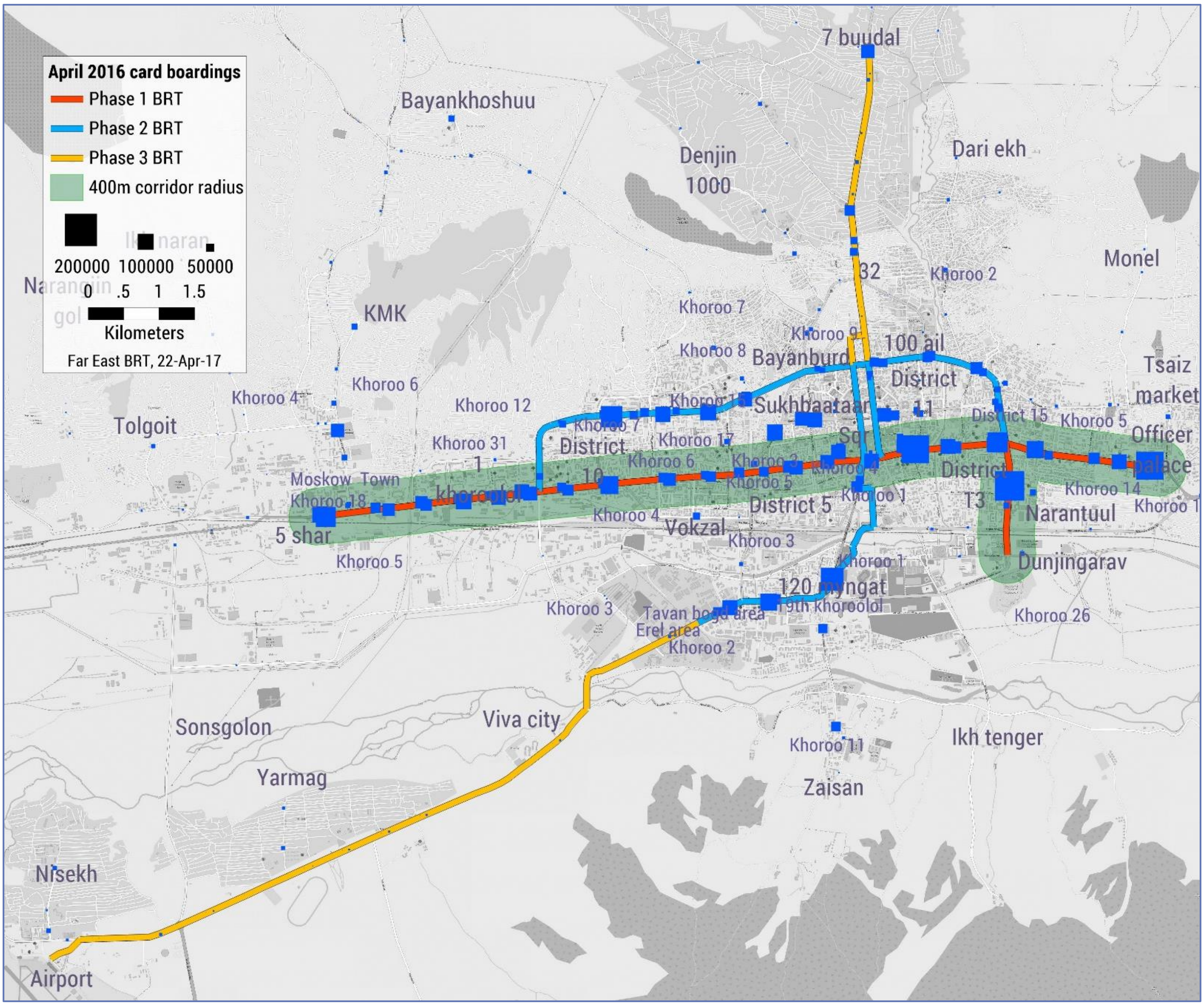
- The prominence of the Peace Avenue corridor is clear, with the highest demand bus stops concentrated along the corridor. **Forty percent of all bus boardings by card in Ulaanbaatar take place within 400m of the phase 1 BRT corridor**. This increases to 47% within 650m of the phase 1 BRT corridor. Of the 13 bus stops with more than 100,000 monthly card boardings, 10 are in the proposed phase 1 BRT corridor and 9 are in Peace Avenue.
- Demand is well distributed along Peace Avenue, not only in a few large stops. This distribution of demand is much better in terms of BRT operational efficiency, fleet allocation, system revenue and development potential than where demand is concentrated in a few stops, which is the case in the Airport Road and Chinggis Avenue corridor.
- In the 3/4 khoroolol / Ikh Toiruu corridor demand is fairly well distributed, with significant demand in the east and west portions, which helps to establish a balanced passenger flow in both directions along the corridor. The lower demand portion of the corridor around Tasgan Road and the city centre part of Ikh Toiruu provides potential for future transit-oriented development. The southwest connection in phase 2 provides an excellent connection to the high demand area southwest of the Peace Bridge, around the 19-р хороолол and 120 мянгат stops.
- The phase 3 north-south corridor is much less well balanced, reflecting the early development stages of both corridors. In the Doloon buudal corridor the demand is

concentrated at the 7 buudal bus stop in the north, with low demand along the corridor and a high peak-direction to off-peak direction ratio of around three at the 32-ын тойрог (n5) stop. In the Airport Rd corridor the demand is currently very low, but is expected to increase with large scale new developments under construction and planned in this corridor. The demand imbalance in the north-south corridors can be expected to be alleviated as both corridors develop. Both corridors have major development and densification plans which will greatly raise the level of demand at intermediate stops in coming years.

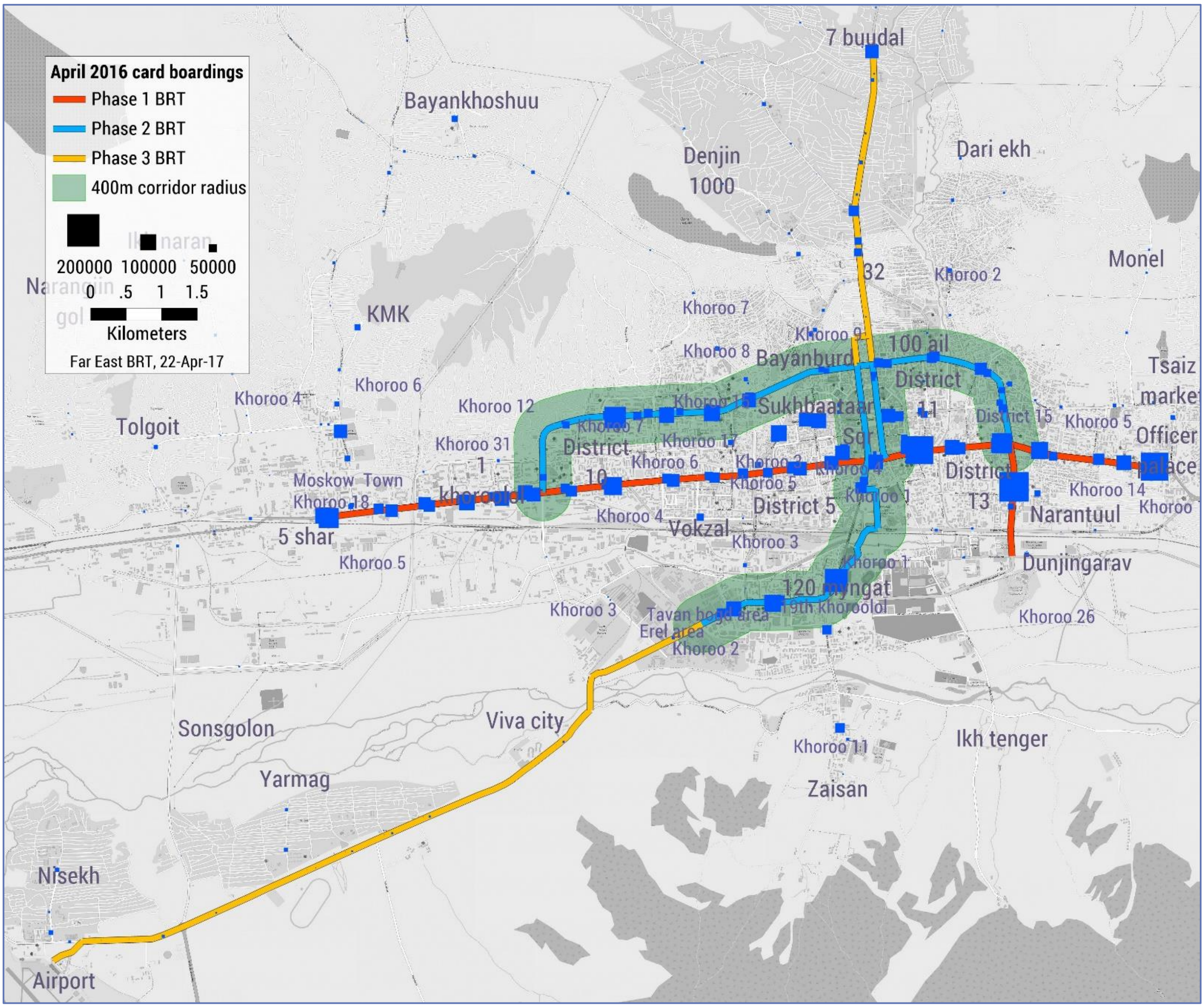
- Although Peace Avenue / Namyan Ju St is a clear first phase preference both in terms of total ridership and per-kilometre ridership (see graphs below), the second phase 3/4 khoroolol / Ikh Toiruu / southwest connection is also a very strong corridor. The bus boardings by card within 400m of the phase 1 and phase 2 BRT corridors account for 60% of all Ulaanbaatar bus boardings by card.
- At current demand levels the Airport Rd corridor is very weak. On a total boardings basis it is comparable to the Doloon Buudal corridor but taking into account the much longer corridor length, the Airport Road corridor has the lowest demand of all of the BRT corridors considered. This situation is expected to change rapidly in coming years, with many new residential and commercial developments currently under construction in the corridor, but nevertheless the low demand effectively rules out the Airport Road as a viable phase 1 or phase 2 BRT option.
- The demand analysis confirms that there is a strong justification for including Namyan Ju St in the phase 1 BRT corridor. The largest bus stop in the city by card-boardings, Хятад худалдааны төв, is located in this corridor and it also connects to a major concentration of new development in the Dunjingarav area.
- Eighty percent of all bus boardings in Ulaanbaatar take place within 400m of the phase 1, 2, or 3 BRT corridors. This means that the proposed system provides excellent coverage. When combined with the direct service operations, the BRT will provide citywide coverage.

Smart card data was also obtained for 17 April 2017, which is after the smart-card-only payment policy was implemented on 1 April 2017. This data is incomplete, because the location of 215 of the stops was not identified, including many in outer areas. The overall pattern of the demand data from 17 April 2017 is very similar to the data from April 2016, and further reinforces the desirability of the proposed phase 1 and phase 2 corridor selection. Also, in the April 2017 data the error which resulted in excessively high boarding volumes at 5 shar and Officers Palace in the 2016 data appears to have been fixed.

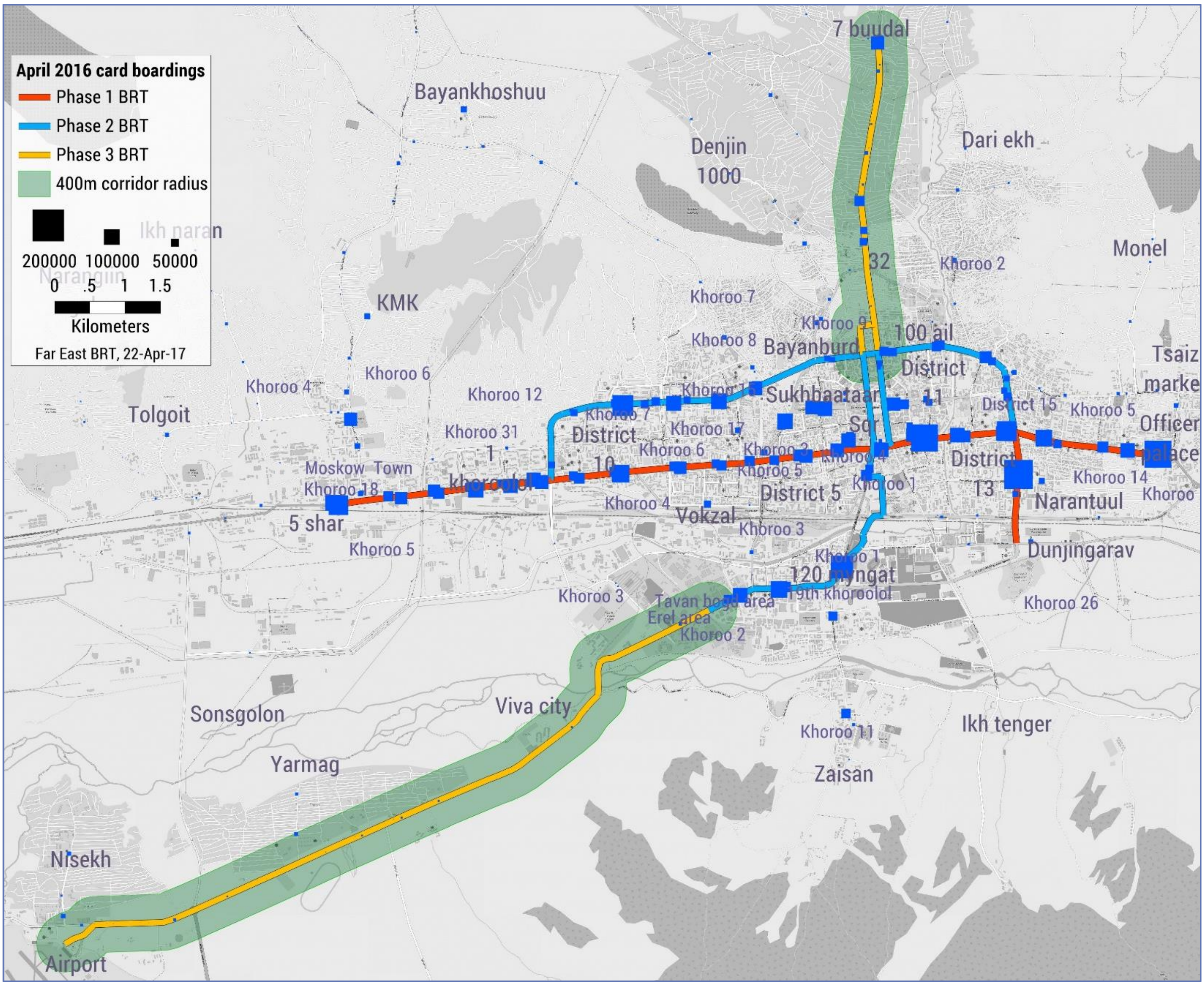
Especially now that the smart card payment is mandatory, the Urban Transport Department should urgently verify all of the locations of the 937 stops identified in the smart card data. This data should be readily available, but it needs to be carefully checked for errors or omissions. One person could carry out this task in a week or so, and the result will be an outstanding resource for BRT and bus service planning in Ulaanbaatar.



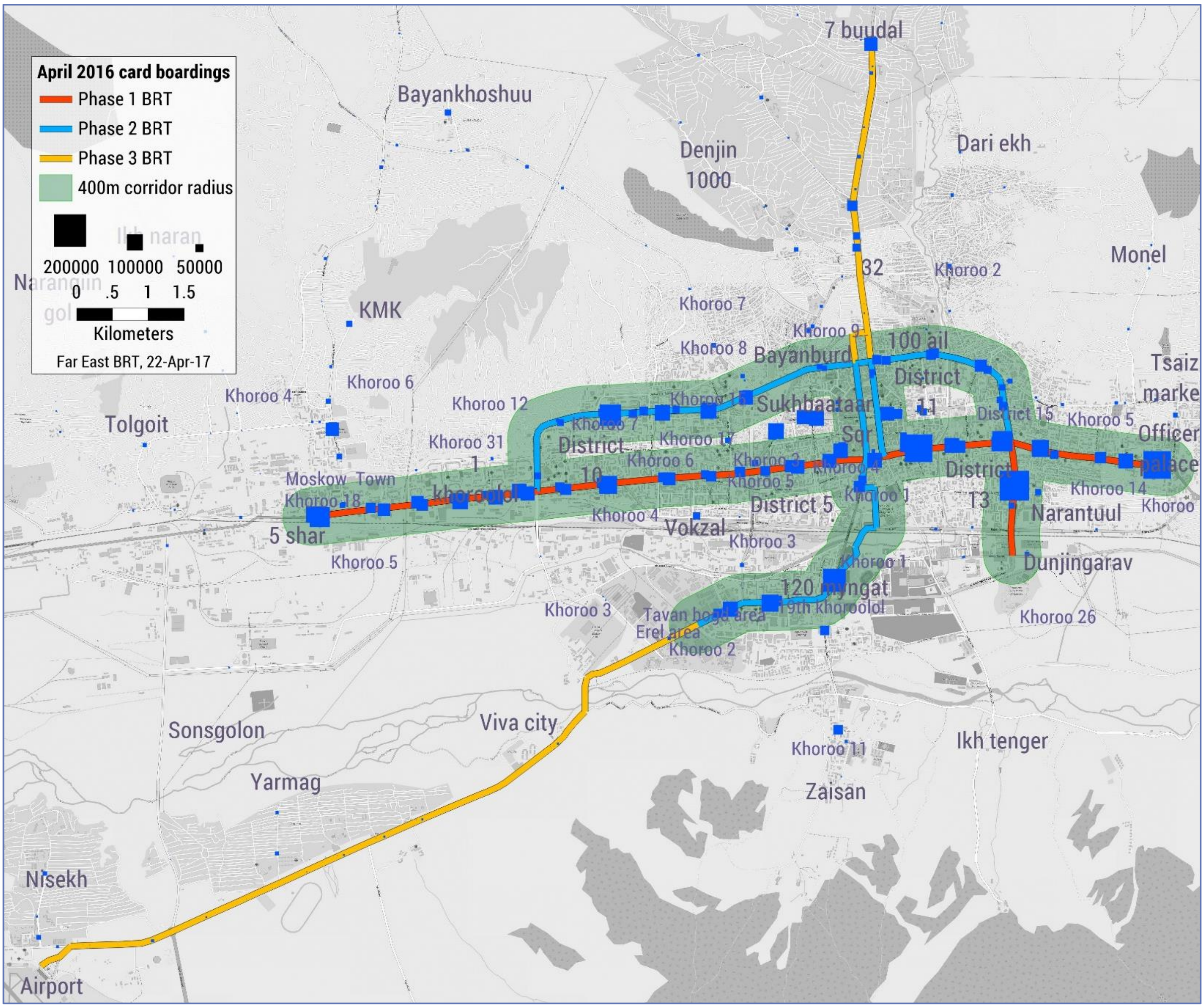
Phase 1 BRT – Peace Av & Namyan Ju: **4,333,912 boardings within 400m of corridor (39% of UB boardings)**



Phase 2 BRT – Ikh Toiruu & 3/4 khoroolol & 120 area: **3,291,985 card boardings within 400m of corridor**

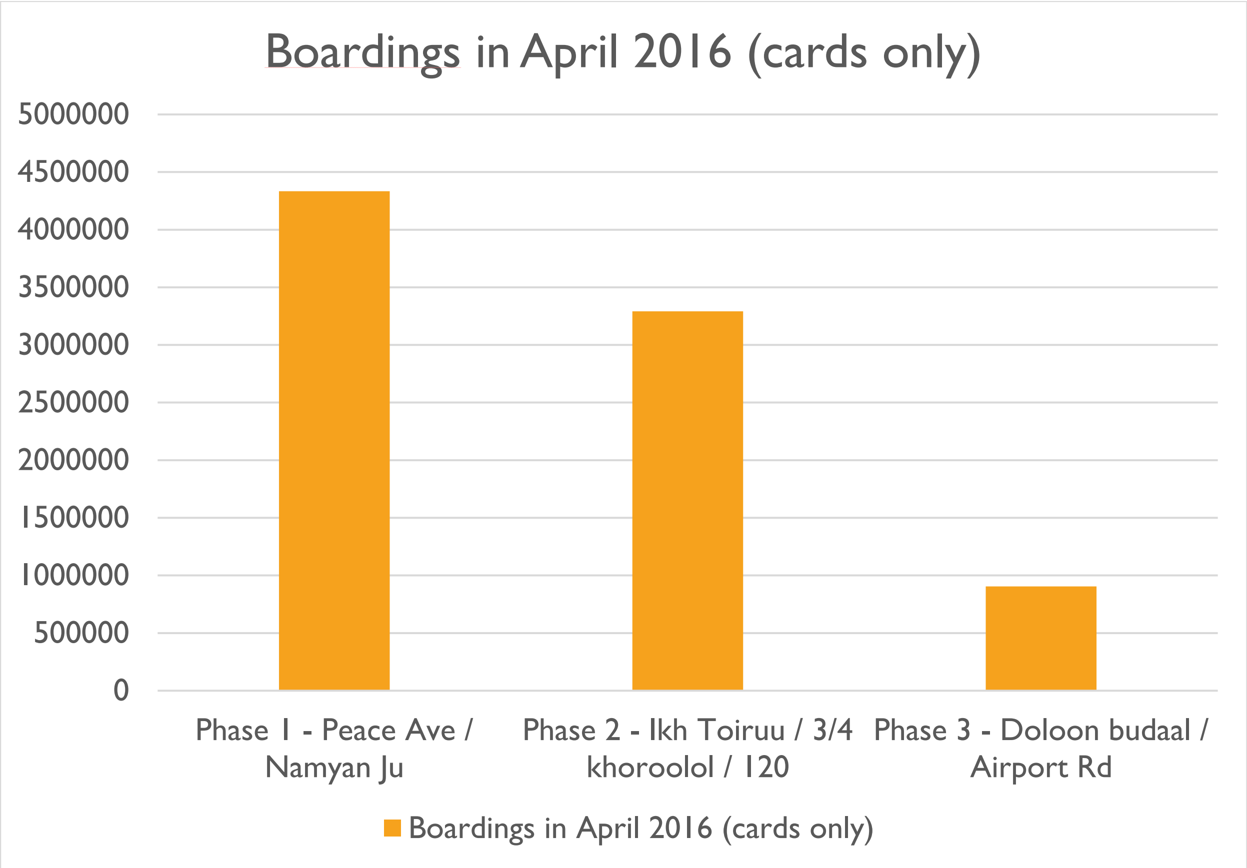


Phase 3 BRT – Airport Rd & Doloon buudal: **905,022 card boardings within 400m of corridor**



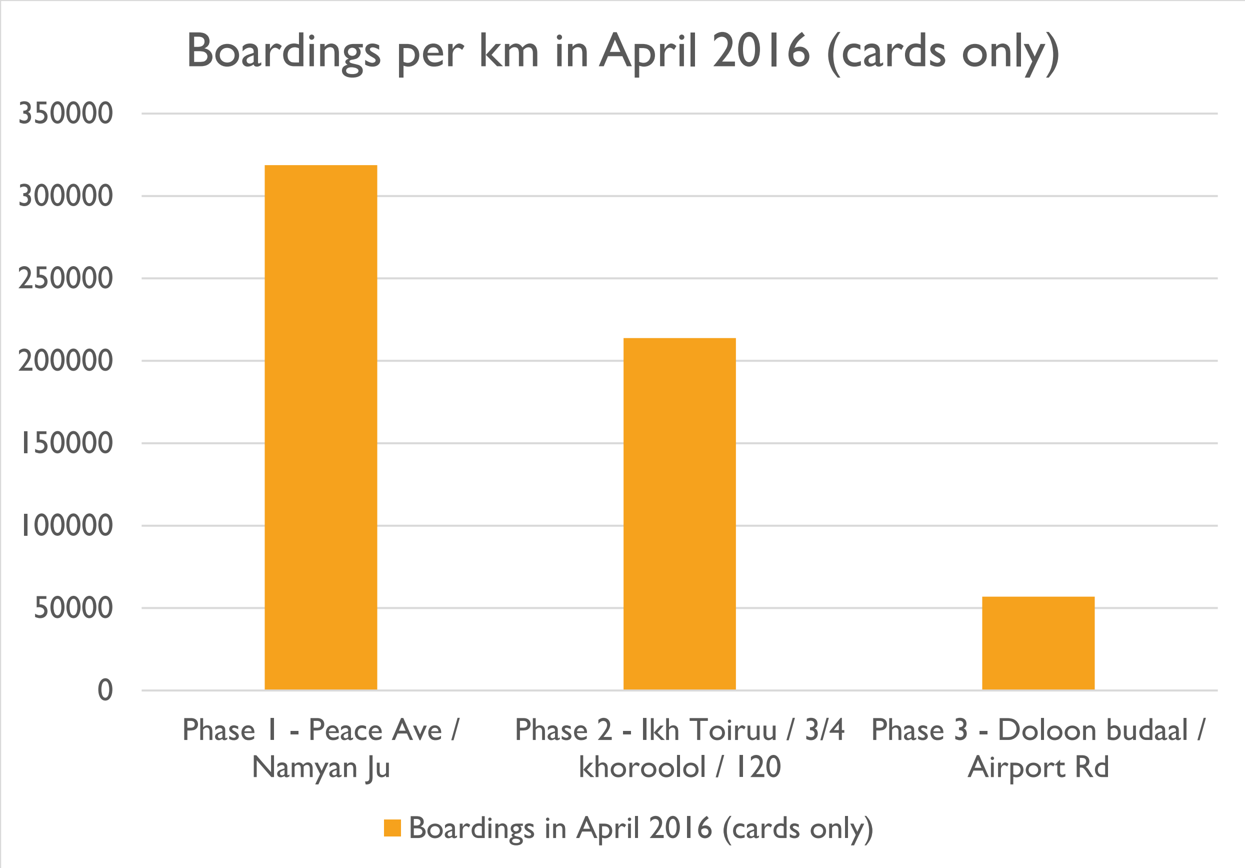
Phase 1 & Phase 2 BRT: **6,627,377 boardings within 400m of corridors (60% of UB bus boardings)**

Bus stop boardings with 400m of BRT corridors (April 2016; cards only)

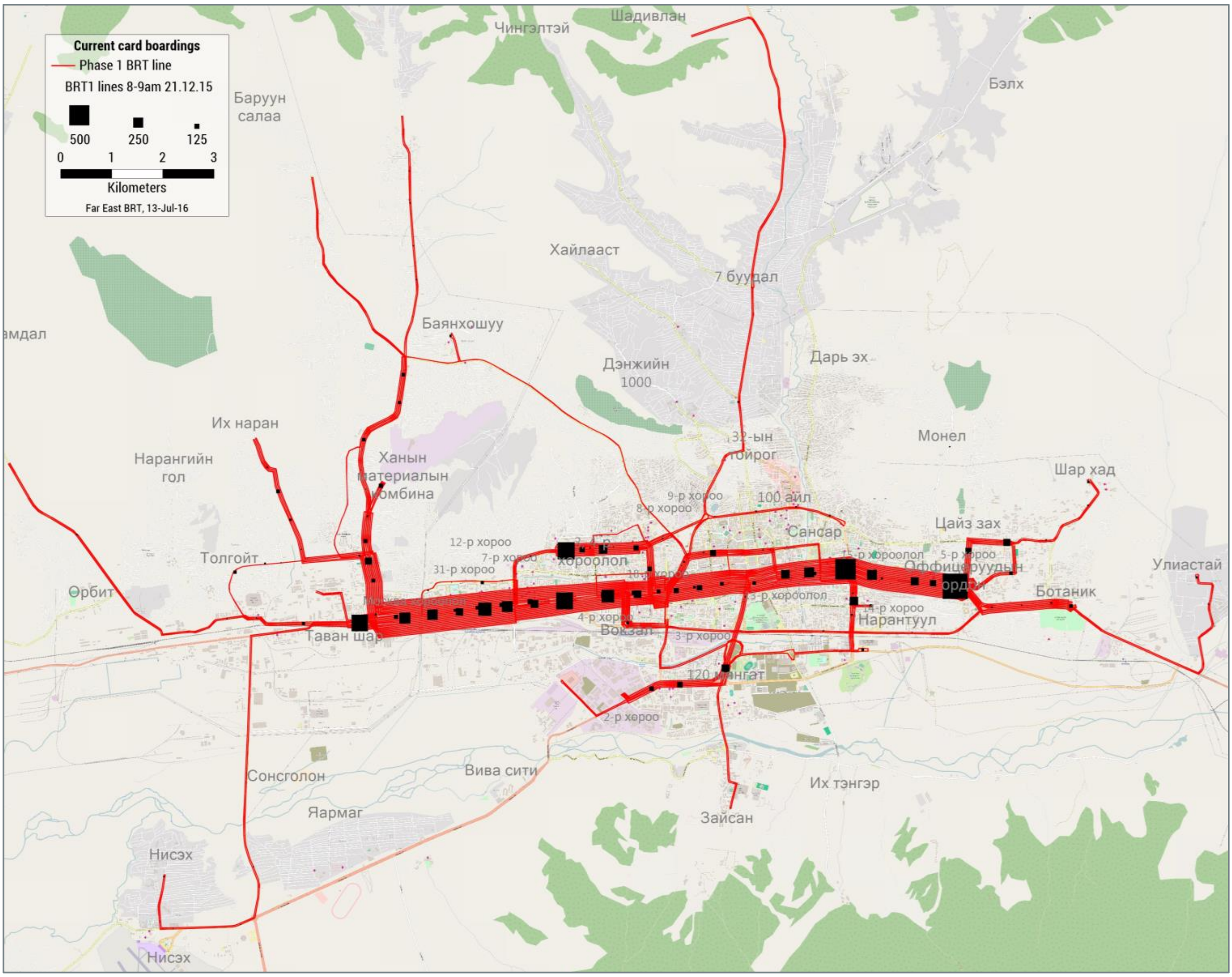


Total card boardings April 2016: 11,107,130. This leaves 2,270,687 (20% of total) boardings longer than 400m away from BRT corridors.

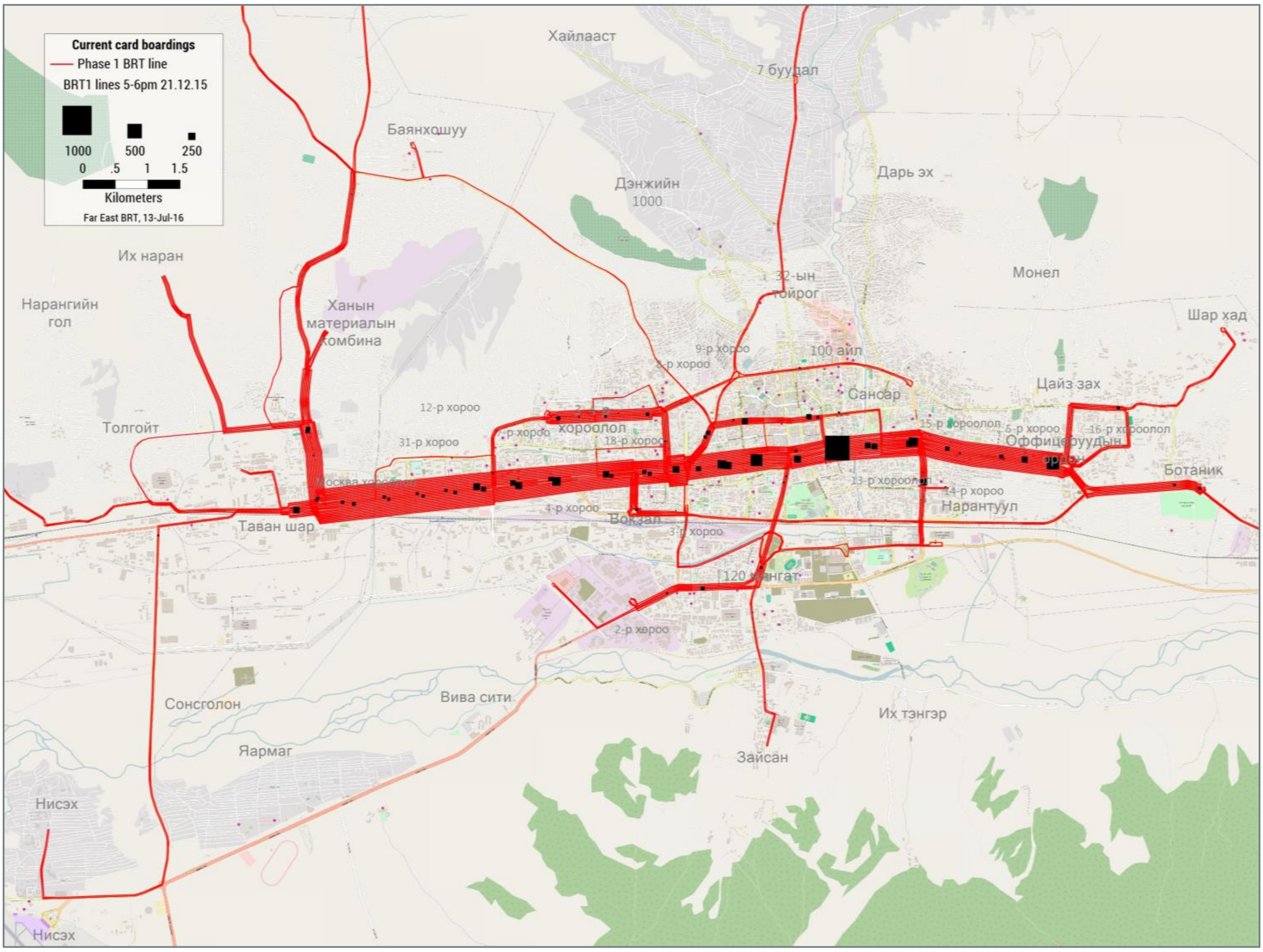
Bus stop boardings with 400m of BRT corridors – per kilometre of BRT corridor length



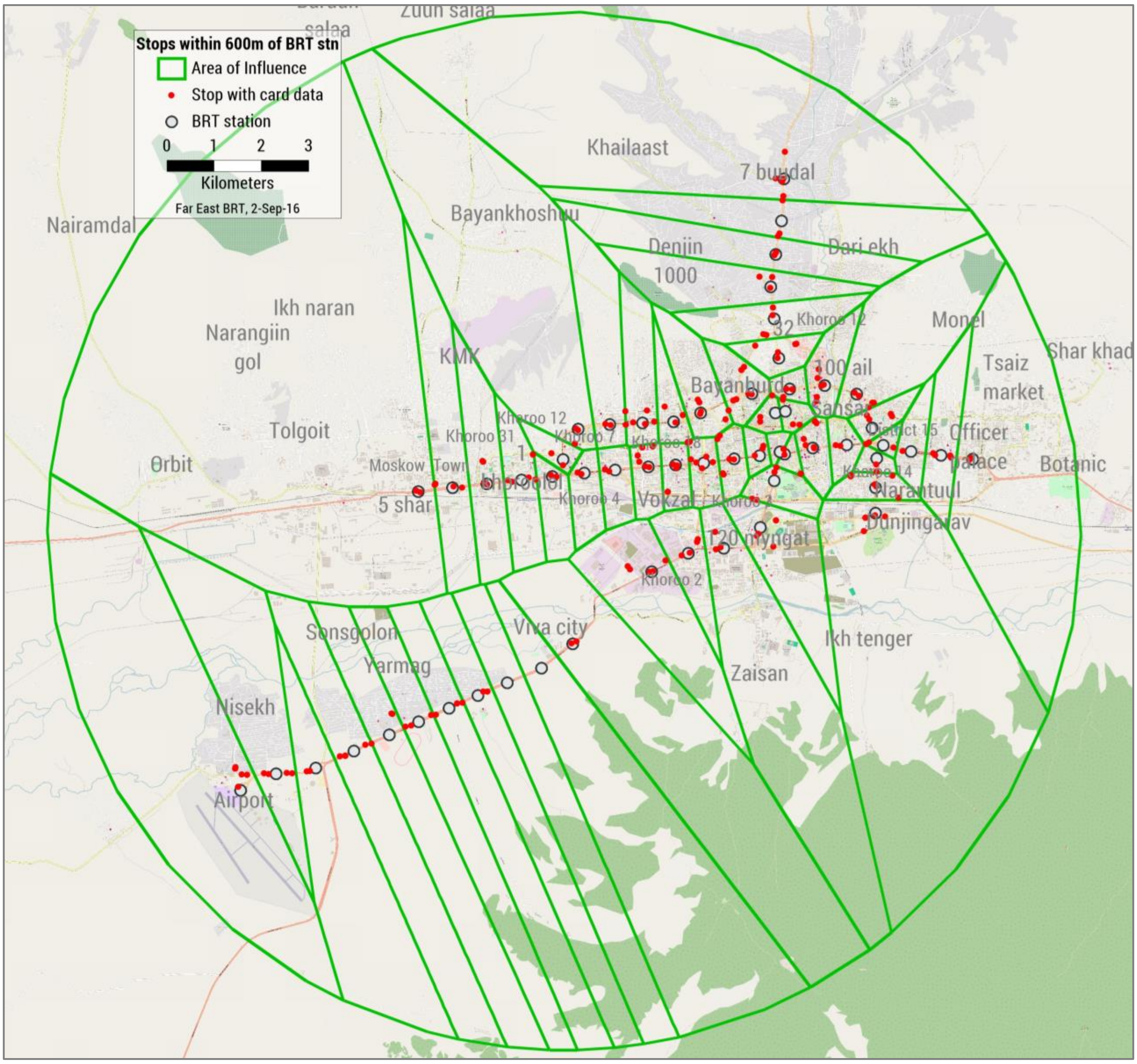
The following graphics show BRT demand from 21 December 2015 based on the preliminary route selection of phase 1 BRT routes. The raw data is from the UB Smart Card Co. This demand is incomplete because it is based only on card data, does not include any considerations of growth or mode shift, and is based on a preliminary operational concept which needs to be optimized and adjusted.



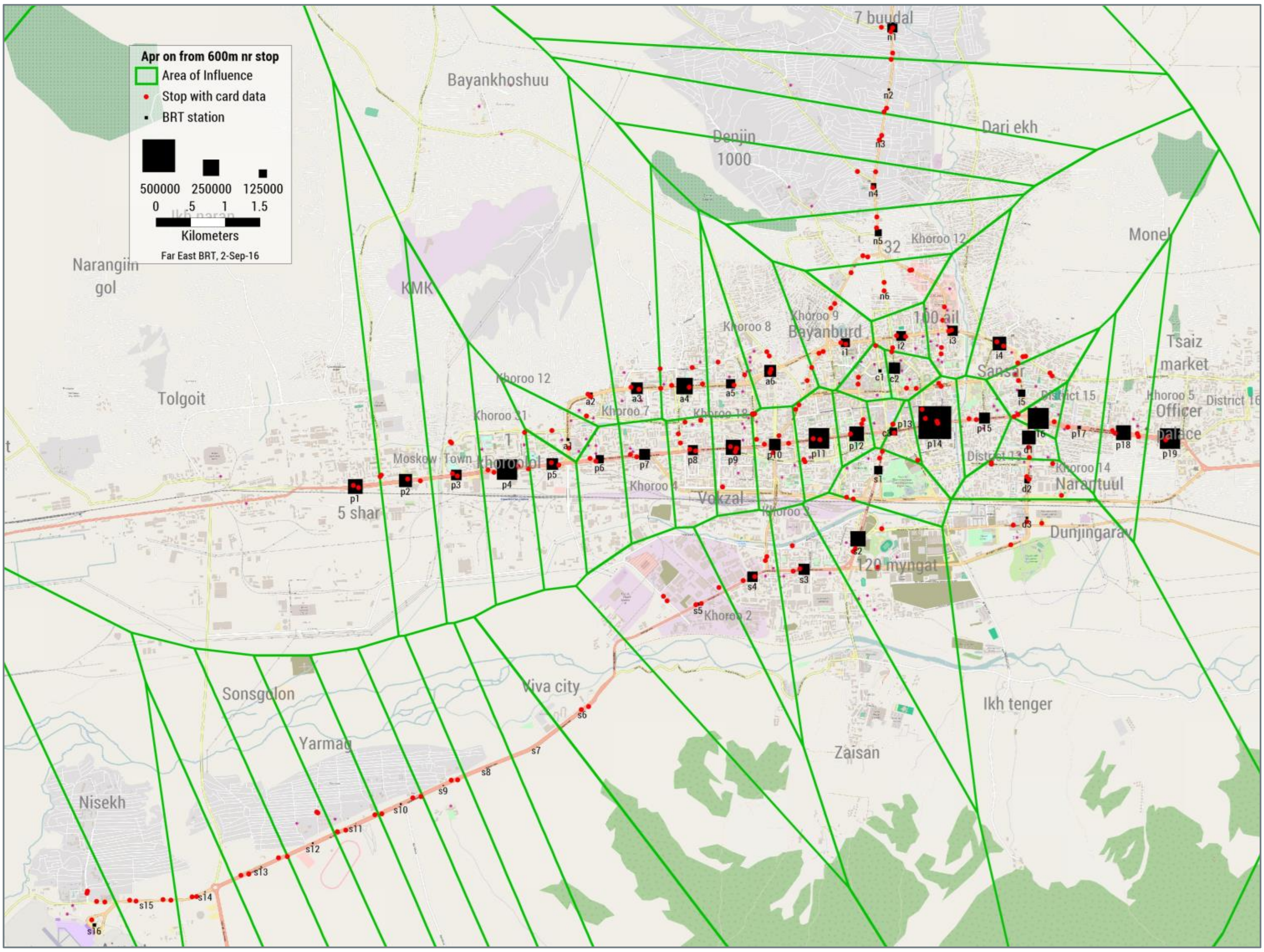
Phase 1 BRT routes: 8-9AM card boardings on 21 December 2015.



Phase 1 BRT routes: 5-6PM card boardings on 21 December 2015.



Areas of influence of BRT stations, with bus stops within 600m of stations allocated to BRT stations.



All card boardings from April 2016 within 600m of BRT stations, allocated to BRT stations.

4.3 BRT frequency

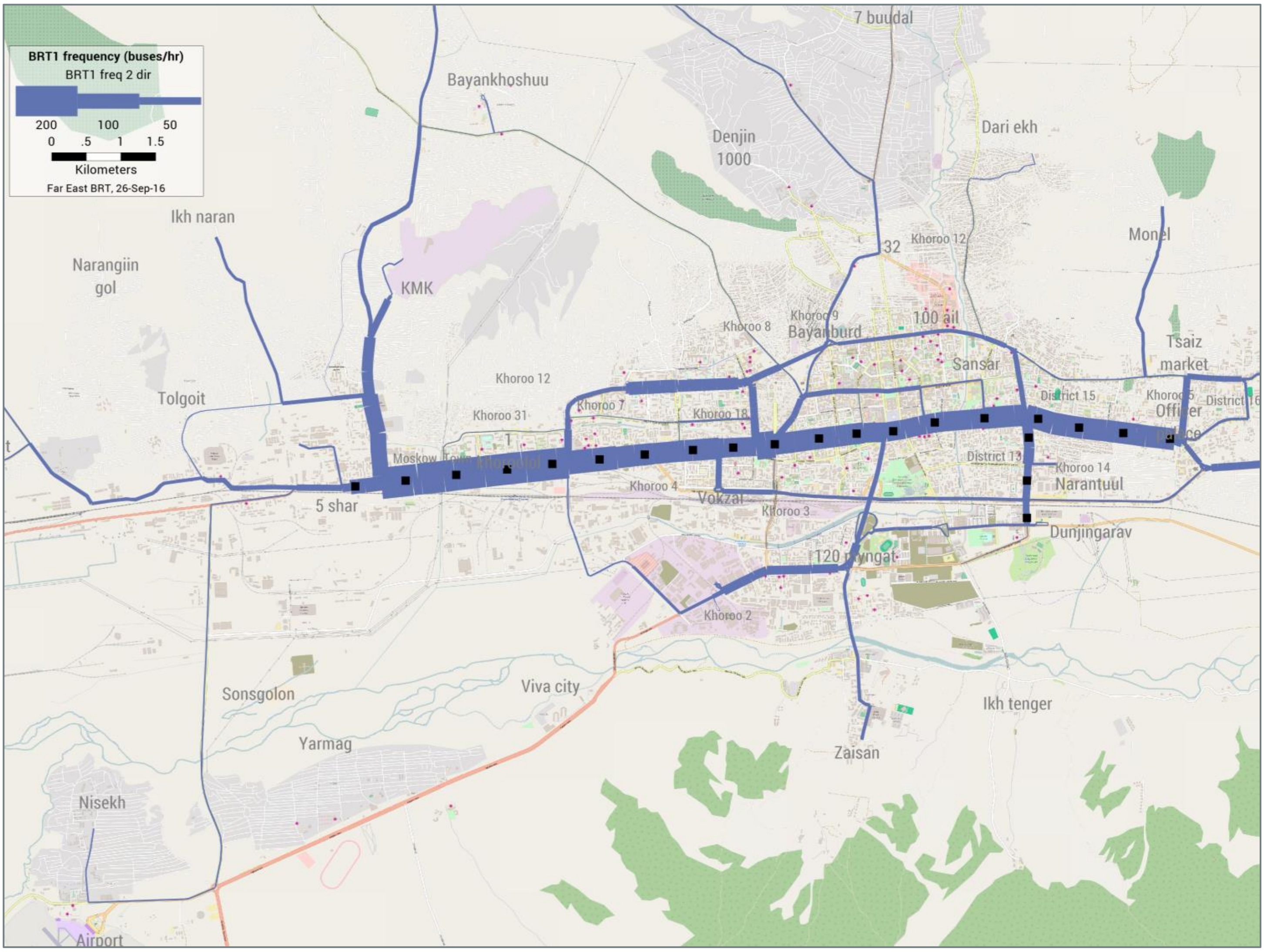
An analysis of BRT bus frequency was used to guide the selection of station substops and to help define the station dimensions. The frequency analysis is very preliminary because it is based on route selection before the BRT routes are adjusted (that is, current bus routes) and using current bus frequencies rather than optimized BRT bus frequencies. However, the results, while approximate, still provide a useful general indication of future BRT bus frequencies and in particular the relative frequencies between BRT stations.

Note that bus frequency has a large bearing on BRT station saturation, because each bus occupies the station for around 13 seconds not including the time required for boarding and alighting. Bus frequency therefore has a relatively larger bearing on BRT station saturation and station size determination than the local boarding and alighting passenger demand.

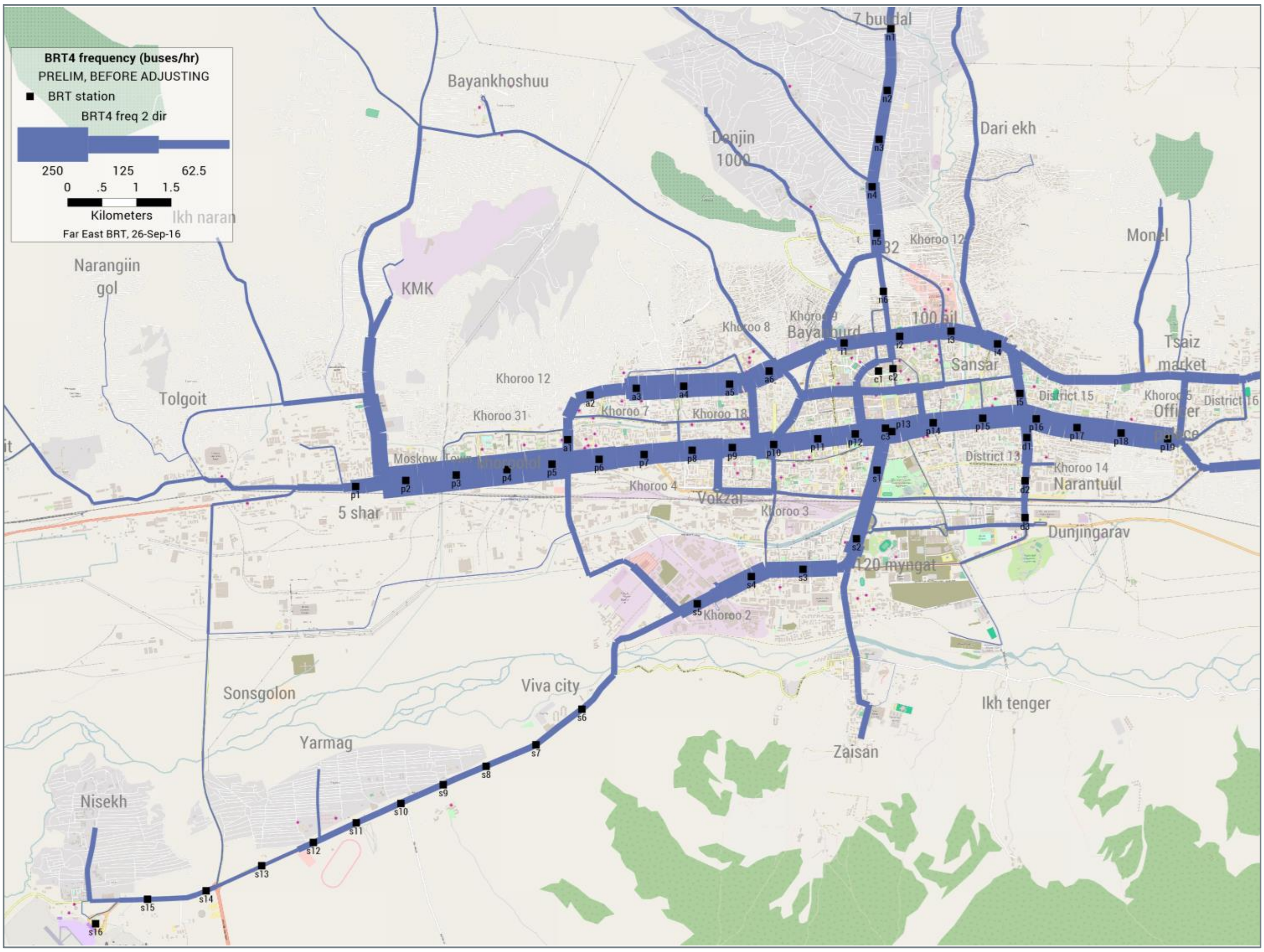
The results of the frequency analysis are shown below for phase 1 BRT routes and also for phase 3 BRT routes. Obviously, the phase 3 analysis is much less accurate because by the time the phase 3 BRT corridor is implemented there will be significant new demand especially in the Airport Rd and

Doloon Buudal corridors. Nevertheless, there are some useful impressions from the frequency analysis that can help guide the phase 1 and phase 2 BRT corridor design:

- Along Namyan Ju one substop is sufficient, with wider platforms for the high number of boarding/alighting passengers, and/or with a 15-20m offset configuration allowing greater space for waiting passengers.
- Off-corridor stations may be justified along the KMK corridor north of 5 shar
- Station a1 in the southern Ard Ayush Road in phase 2 (3-р эмнэлэг) will have quite low frequency as well as low local boarding demand even in phase 3. For this station, noting also that a road parallel to Peace Avenue is planned to connect to the KMK corridor, one substop is sufficient even to meet future demand, because the area is already developed and BRT bus frequency even in future will not be high.



Phase 1 BRT bus frequency. Preliminary – before route adjustment and based on current routes.



Phase 3 BRT bus frequency. Preliminary – before route adjustment and based on current routes.

5 BRT right-of-way

5.1 Right of way data

The BRT corridor will be built within the public right-of-way. With a few exceptions as shown following, no owned or possessed land will be affected by the project. This was an important design consideration, since land acquisition or resettlement can be a source of potential delay.

More analysis is required as part of the detailed design phase, as it is in some locations unclear where the public right-of-way ends. Most of the focus on right-of-way is on the BRT station areas, because this is where the BRT space requirements are the largest. Between stations the BRT only needs a single lane of traffic in each direction and this generally can be accommodated even without adjusting the current kerb locations.

Right-of-way considerations led to an alternative proposed station design for the Doloon Buudal corridor, with short and medium/long term option. The short-term option does not require land acquisition at the station area, but the medium/long term option in some cases will require land acquisition.

The right-of-way information was provided by a local engineering firm and by the Roads Department of the city and was collected from CAD files as well as Google Earth measurements for the other corridors. It is often unclear exactly where the public right-of-way ends near the edge of the walkway, and many of the CAD files are out of date and will need to be updated as part of the BRT project. Where buildings are built up to the edge of the walkway, the right-of-way is fairly clear, but where there is a setback space between the walkway and any walls, fences or buildings, or where the walkway is not defined, it is often not possible to precisely identify the public right-of-way. The CAD files showed the edge of the curb and in some cases the edge of the walkway, and the location of buildings, but did not show the right-of-way as a separate feature. Furthermore, in some cases it appears as if adjacent building owners have built fences or walls which intrude on the public right-of-way.

5.2 Right-of-way at stations

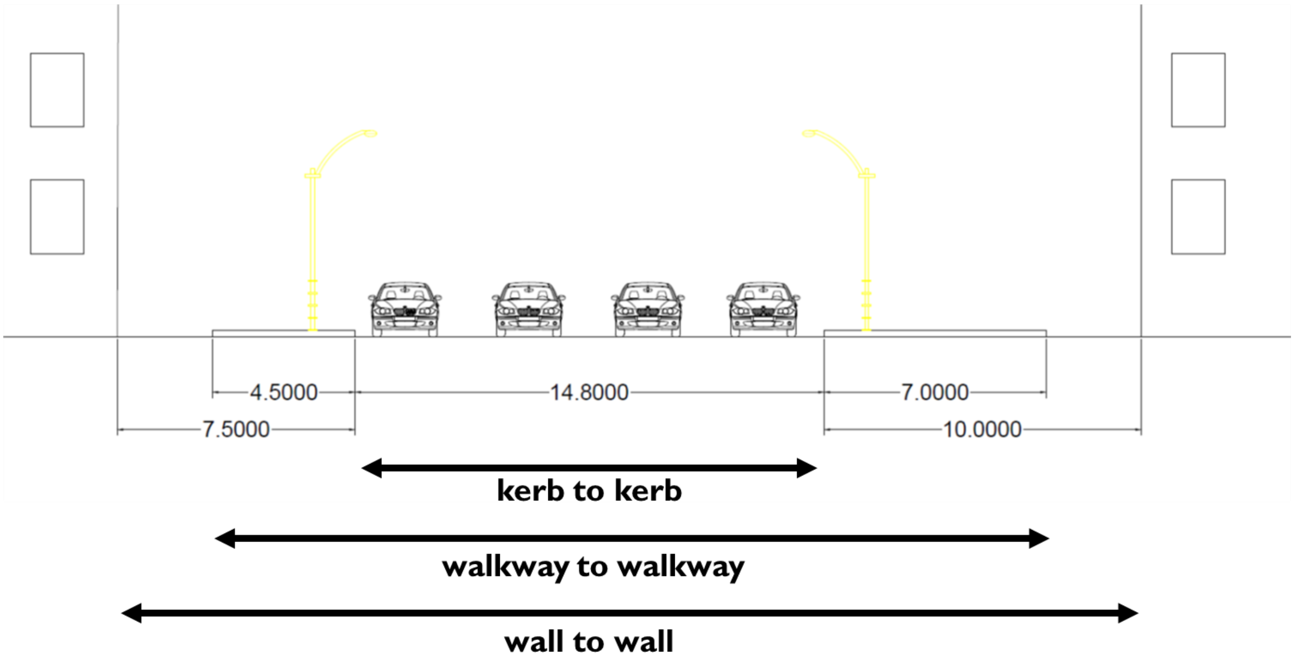
As noted, right of way at stations is in general the most critical measure in terms of any possible land acquisition or other right-of-way issues, because the space requirements for BRT are large in the station areas, and because typically the entire road right-of-way needs to be rebuilt in the station area.

Definitions used for the right-of-way analysis are illustrated following.

Kerb-to-kerb distance is important because where kerbs do not need to be modified or moved, construction costs are generally lower and construction can be faster. For right-of-way purposes the BRT implementation is therefore ‘easiest’ in places where the BRT stations, BRT lanes and mixed traffic lanes fit within the kerb to kerb distance.

Where the BRT does not fit within the 'kerb to kerb' distance, it can nevertheless still be implemented within the public right-of-way when the BRT stations, BRT lanes, mixed traffic lanes and pedestrian walkway fits between the outer edges of the walkway. In these cases, the BRT is considered as fitting 'walkway to walkway'. Construction may be more expensive and difficult but the BRT system can fit without requiring land acquisition or resettlement. Note that the outer edge of the walkway is in many cases difficult to precisely define, especially where there is a setback space between the outer edge of the walkway and adjacent buildings. The measurements provided in this report therefore need to be verified during the detailed engineering design stage.

The wall-to-wall distance was primarily measured using Google Earth and is not generally relevant to the BRT design, because nearly all stations fit within the 'kerb to kerb' or 'walkway to walkway' areas. However, in a few cases the wall to wall distance is relevant. Where a station is illustrated as fitting 'wall to wall' this generally means that some form of road widening is required beyond the current right-of-way.



Definitions: kerb to kerb, walkway to walkway, wall to wall

Definitions used for the following right-of-way graphics.

Kerb to kerb width at BRT stations.

Walkway to walkway width at BRT stations.

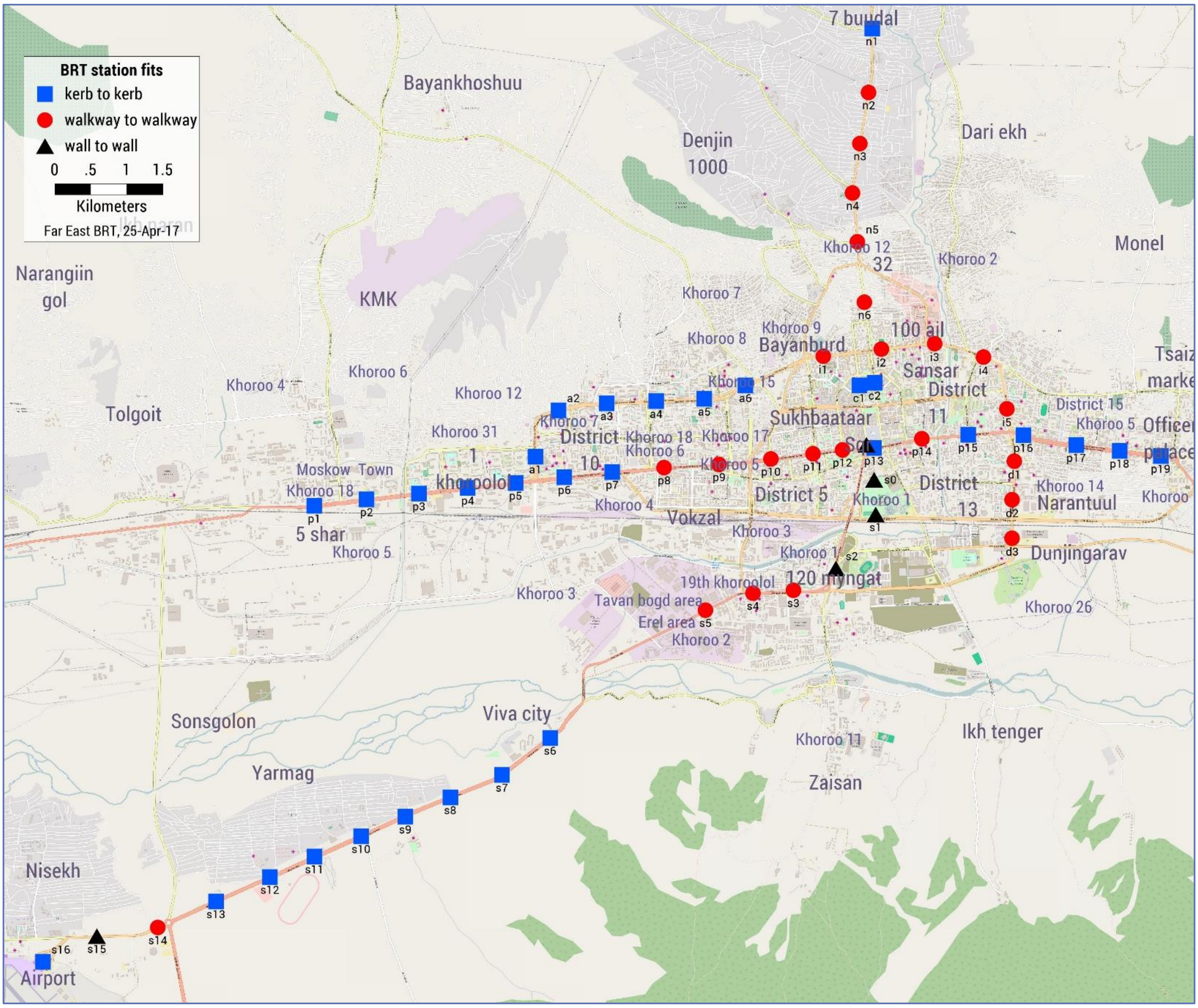
Right of way at BRT stations

Name*	Code	Corridor	BRT phase	kerb to kerb	ped to ped	wall to wall	station fits
5 шар	p1	peace west	1	37.5	56	70	kerb to kerb
Баруун 4 зам	p10	peace central	1	18.5	36	40	walkway to walkway
УИД	p11	peace central	1	18.5	38.5	38.5	walkway to walkway
Мөнгөн завъяа	p12	peace central	1	18.5	38.5	38.5	walkway to walkway
Чингисийн талбай	p13	peace central	1	38.0	52	52	kerb to kerb
МУБИС	p14	peace central	1	18.0	38	48	walkway to walkway
Бөхийн өргөө	p15	peace central	1	28.0	35	35	kerb to kerb
Зүүн 4 зам	p16	peace central	1	36.0	46	50	kerb to kerb
Жуков	p17	peace east	1	36.0	46	50	kerb to kerb
Кино үйлдвэр	p18	peace east	1	36.0	46	50	kerb to kerb
Оффицеруудын ордон	p19	peace east	1	36.0	46	74	kerb to kerb
Драгон	p2	peace west	1	37.5	59	80	kerb to kerb
32-р байр	p3	peace west	1	35.5	59	80	kerb to kerb
Хар хорин	p4	peace west	1	47.3	59	80	kerb to kerb
Саппоро	p5	peace west	1	35.8	50	80	kerb to kerb
3-р эмнэлэг	p6	peace central	1	35.0	56	80	kerb to kerb
10-р хороолол	p7	peace central	1	35.0	56	80	kerb to kerb
25-р эмийн сан	p8	peace central	1	22.0	40	45	walkway to walkway
ТБД андууд	p9	peace central	1	22.0	40	45	walkway to walkway
13-р хороолол	d1	Namyan Ju	1	16.0	32	50	walkway to walkway
УБ их сургууль	d2	Namyan Ju	1	15.7	32	40	walkway to walkway
Дунжингарав	d3	Namyan Ju	1	24.0	35	35	walkway to walkway
Баянбүрд	i1	Ikh Toiruu	2	21.5	38	41	walkway to walkway
Урлан бүтээх төв	i2	Ikh Toiruu	2	21.5	38	41	walkway to walkway
100 айл	i3	Ikh Toiruu	2	21.5	38	41	walkway to walkway
Сансарын ШТС	i4	Ikh Toiruu	2	18.5	36	36	walkway to walkway
Сансарын тунель	i5	Ikh Toiruu	2	18.0	50	55	walkway to walkway
3-р эмнэлэг	a1	Ikh Toiruu	2	40.0	67	100	kerb to kerb
Гэмтэлийн эмнэлэг	a2	Ikh Toiruu	2	29.8	39.8	45.8	kerb to kerb
III/IV хорооллын эцэс	a3	Ikh Toiruu	2	30.0	41.5	44.5	kerb to kerb

Өргөө	a4	Ikh Toiruu	2	30.0	41.5	44.5	kerb to kerb
Ахуйн Үйлчилгээ	a5	Ikh Toiruu	2	30.0	41.5	44.5	kerb to kerb
Гандан	a6	Ikh Toiruu	2	29.0	40.5	43.5	kerb to kerb
НУБ	c1	centre	3	15.0	26	28	kerb to kerb
Герман элчин	c2	centre	3	15.0	28	28	kerb to kerb
Чингисийн талбай	c3	centre	3	17.0	24	50	wall to wall
7 буудал	n1	Doloon Buudal	3	55.0	70	70	kerb to kerb
6 буудал	n2	Doloon Buudal	3	16.0	27	32	walkway to walkway
5 буудал	n3	Doloon Buudal	3	18.0	28	36	walkway to walkway
17-р сургууль	n4	Doloon Buudal	3	20.0	27	39	walkway to walkway
32-ын тойрог	n5	Doloon Buudal	3	16.0	40	40	walkway to walkway
7-р хороолол	n6	Doloon Buudal	3	17.0	27	32	walkway to walkway
Баянгол зочид буудал	s1	Chinggis Ave	3	15.5	27	87	walkway to walkway
Яармагийн 3-р буудал	s10	Airport Rd	3	28.0	42	--	kerb to kerb
Эмнэлэгийн буудал	s11	Airport Rd	3	28.0	42	--	kerb to kerb
60-р сургууль	s12	Airport Rd	3	28.0	42	--	kerb to kerb
116-р сургууль	s13	Airport Rd	3	28.0	42	--	kerb to kerb
Спорт цогцолбор	s14	Airport Rd	3	27.0	40	50	walkway to walkway
Нисэхийн дэнж	s15	Airport Rd	3	13.0	20	45	wall to wall
Нисэх	s16	Airport Rd	3	58.0	58	--	kerb to kerb
Park North	s0	Fun park	2				wall to wall
Park South	s1	Fun park	2				wall to wall
120 мянгат	s2	Chinggis Ave	2	15.2	18	42	wall to wall
19-р хороолол	s3	Chinggis Ave	2	20.5	32	55	walkway to walkway
Таван богд	s4	Chinggis Ave	2	20.5	32	42	walkway to walkway
Эрэл	s5	Chinggis Ave	2	20.5	32	60	walkway to walkway
Viva city	s6	Airport Rd	3	28.0	42	--	kerb to kerb
British school	s7	Airport Rd	3	28.0	42	--	kerb to kerb
Яармагийн 1-р буудал	s8	Airport Rd	3	28.0	42	--	kerb to kerb
Яармагийн 2-р буудал	s9	Airport Rd	3	28.0	42	--	kerb to kerb

BRT station fits along the BRT corridors

Corridor	Stations fit kerb to kerb	Stations fit walkway to walkway	Stations fit wall to wall
Phase 1 – Peace Ave & Namyan Ju	13	9	-
Phase 2 – Ikh Toiruu & 3/4 khoroolol & 120 area	8	8	4
Phase 3 – Doloon Buudal & Airport Rd	10	5	1



Right-of-way at BRT stations.

According to this analysis, the stations which appear to require road widening beyond the current right-of-way are s15, c3, s0, s1 and s2.

At s15 near the airport, with current stop name Буянт ухаа цогцолбор/Buyant ukhaa Sports Complex, there is wide space available on both sides of the road, and it likely that segregated BRT lanes are not required at that location, especially noting that the airport will likely function only as a training facility once the new airport is opened in 2017. There is ample space available at the road edges for widening there if required, and it does not seem to require any acquisition. In any case this is not a critical station for the BRT system.

At station s2 along Chinggis Avenue south of Peace Bridge, with current stop name 120 мянгат/120 myngat and Төв цэнгэлдэх хүрээлэн/National stadium on the west and east side respectively, there is a public park and plaza available on the western side of the road. This is a critical station for the BRT system and one of the highest demand bus stops in the city. Although the road needs to be widened beyond the current right of way, space is available in the form of publicly owned park on the west, though it would be preferable to use the currently vacant, open and unpaved space on the eastern side of the road, as indicated in the platform placement at www.ubbrt.net. The ownership of this land needs to be verified. If the land is under public ownership, it would be an excellent option for BRT platform placement. If the land is privately owned, negotiation could be held with the owner to use the land as a BRT station, perhaps in return for expanded density or other development rights. An equally attractive alternative is to locate this station on the privately owned plaza on the eastern side of the road, 175m north of the current bus stop location. This option should be explored in follow-up discussions with the land owner. Locating a BRT station would greatly enhance the access to the development there and could be expected to increase the land values.

Four approximate station location options for the station south of Peace Bridge (s2, 120 myngat). The plaza to the north may be the best option, but this land is privately owned. A BRT station in this plaza location would greatly enhance accessibility to the adjacent buildings owned by the same owner, and could be expected to boost land values accordingly.

At c3 at the southwestern edge of Chinggis Square in the city centre, the BRT station requirements still need to be determined, as it relates to the traffic circulation in this area. Assuming a one-way southward traffic flow on the western side of Chinggis Square, a BRT station at this location is proposed so that north to south buses can stop in close proximity to Chinggis Square. There is currently ample space available station placement at this location, between Peace Avenue and the current car parking area south of the main square. This is publicly owned land and does not require any private acquisition.

The s0 and s1 stations (Park North and Park South) require some land acquisition from the currently unused sites. As with station s2, if the land is privately owned, negotiation could be held with the owner to use the land as a BRT station, in return for expanded density or other development rights.

This preliminary analysis of right of way, however, makes various assumptions which need to be verified in follow-up studies of the corridors. The assumptions include:

- The area currently in setback locations along Namyan Ju St is publicly owned right of way. This especially relates to stations d1 and d2.

- In the Doloon Buudal corridor, stations n2, n3, n4, n5 and n6 will have a short term and medium/long term variation, with the possible exception of n5, where the higher capacity long term option may not be needed due to lower bus frequencies. The short-term variation is designed to fit within the right of way (though noting that the outer edge of the walkway is often not clearly delineated in this corridor) while retaining two lanes of mixed traffic flow in each direction. The medium to long term option involves a high capacity BRT system but requires either that mixed traffic in one direction is reduced to one lane, or that the road is widened beyond the current right of way.

5.3 Right of way between stations

Right of way between stations is less difficult than right-of-way at stations, because BRT only requires one segregated lane per direction between stations. In general, the Peace Avenue and 3/4 khoroolol / Ikh Toiruu corridors provide the best conditions, with BRT fitting kerb to kerb in the sections between stations. The Namyan Ju St section is more problematic but provides major benefits in terms of BRT system demand and coverage. The Chinggis Avenue and Airport Rd corridors have more potential complications and difficulties and also provide lower benefits in terms of passenger demand.

Where the BRT fits within the existing kerb to kerb space, construction can potentially be faster and cheaper if kerbs do not need to be moved, though it is possible that kerbs will need to be rebuilt anyway or that the government will take the opportunity to rebuilt the utilities even if not strictly necessary according to the BRT right of way requirements. Furthermore, it is possible that although the functioning BRT does not require widening beyond the current kerbs, the traffic management during construction will require a temporary widening which could mean that the current kerbs still need to be moved.

The north to south corridor from 7 buudal to 120 myngat / National Stadium south of Peace Bridge, except for the proposed one-way city centre portion, mostly fits ‘walkway to walkway’, meaning that no widening is required but the roadway will need to be reconstructed with different kerb locations. This increases the cost and complexity of construction.

There are two locations with two-way traffic which cannot accommodate segregated BRT lanes while maintaining two lanes of mixed traffic in each direction, both along the Chinggis Avenue / Airport Rd corridor. The Yarmag Bridge along the Airport Rd has a new four lane bridge alongside currently under construction, which will comfortably accommodate BRT plus 2 lanes of mixed traffic in each direction, assuming that the old bridge is retained. If not, bus speeds are currently high in this location, and BRT can operate in mixed traffic without major problems.

Peace Bridge is a much more critical location for the BRT operation. Peace Bridge cannot accommodate two lanes of mixed traffic in each direction in addition to one BRT lane in each direction, as the bridge can only accommodate four total traffic lanes. However, there are four possible solutions to the limitations of Peace Bridge:

1. A form of ‘congestion control signal’ can be used, which enables two lanes of mixed traffic in both directions at the bridge. This involves having a signal just before the

bridge/bottleneck approach which is activated by detectors indicating congestion on the bridge. BRT buses do not need to stop for that signal, but the mixed traffic stops. In this way the mixed traffic queuing is moved from the bridge/bottleneck, to just before the bridge/bottleneck. There is no difference in actual traffic flow capacity, and two lanes are enabled in each direction for the mixed traffic, with no segregated BRT lanes in the bridge part.

2. Peace Bridge has one segregated BRT lane in each direction, and one mixed traffic lane in each direction.
3. Peace Bridge has one segregated BRT lane in each direction, and two mixed traffic lanes in a single direction.
4. An alternative alignment developed in late 2016 and early 2017, which is the southwest corridor alignment recommended and presented in this report.

The Namyan Ju St section appears to mostly fit 'walkway to walkway', but there are some encroachments in the form of temporary vendor structures which may need to be removed. The small section marked in red, indicating that the BRT fits 'wall to wall' and thus requires widening beyond the current right of way, relates to a shop erected at that location. The two-storey structure appears to be temporary and appears to be located within the public right of way, though it is not known what form of usage rights has been conferred. The second 'red' area indicating required road widening to accommodate the BRT between stations is near the airport and as mentioned above is not considered critical for BRT operation. Widening in this location is probably preferable, though, and there appears to be ample space available.

BRT fits between stations. A modified alignment was developed to avoid Peace Bridge.

6 BRT corridor comparison

Before work on the BRT can proceed to detailed design, engineering design and construction, and before a BRT operational plan can be devised, and before the traffic circulation can be determined, BRT corridors need to be determined. Most of the key considerations have already been outlined above, with the exception of passenger time savings which are summarized in the following table.

Bus passenger time saving benefits due to speed improvements from BRT

	BRT stations with current speeds <10km/hr	BRT stations with current speeds <15km/hr
Peace Ave & Namyan Ju (phase 1)	**82%** (18 stns)	**95%** (21 stns)
Ikh Toiruu & 3/4 khoroolol & 120 area (phase 2)	**55%** (11 stns)	**75%** (15 stns)
Doloon Buudal and Airport Rd (phase 3)	**22%** (4 stns)	**56%** (10 stns)

The key factors considered for corridor comparison are:

1. **Current bus passenger demand**. Current bus passenger demand is given the highest weighting of 30 points together with physical space availability. BRT provides benefits to bus passengers and should be prioritized where ridership is high. Phase 1 along Peace Avenue and Namyan Ju St scores the maximum 30 points, reflecting the concentration of the highest demand bus stops and bus flows along these corridors. Phase 2 has very strong ridership, especially considering the extension to the 120 area south of Peace Bridge, and scores 25 points. Phase 3 has no areas of very high demand, with the exception of 7 buudal, but is planned for major future development, and is awarded 5 points for demand.
2. **Current bus speeds**. While BRT provides a wide range of additional benefits beyond improving speeds, improving bus speeds is a primary consideration in implementing a BRT system. Locations with low current bus speeds are generally preferred, because BRT in these locations provides larger potential speed increases. Conversely in areas where bus speeds are already high, BRT provides little or no passenger time savings at least for the on-bus portion of trips. This factor is given a weighting of 20 points. Phase 1 and phase 2 both have extremely low current bus speeds and receive the maximum 20 points. Phase 3 has higher speeds, because the bus speed in the Airport Road corridor and (to a lesser extent) in the Doloon buudal corridor is currently fairly high, mostly exceeding 15km/hr and in many areas even exceeding 30km/hr. For this reason, the Airport Rd & Doloon buudal corridors receives a score of 0 for bus speed.
3. **Physical space available**. Available space or right-of-way is a key consideration in BRT implementation, especially in Ulaanbaatar where there is a desire to avoid any land acquisition so that construction is not delayed. This factor is allocated 30 points. Peace Avenue has adequate right of way, though the Namyan Ju St section is more difficult, as

discussed in the 'right of way' section of this report. Phase 1 receives the 25 points for space availability. Phase 2 receives only 10 points. Ikh Toiruu and 3/4 khoroolol have good space availability, but there are major space limitations in the area immediately south and north of Peace Bridge. Phase 3 receives 20 points due to the relatively tighter space along the Doloon buudal section requiring a short and medium/long term station option. The airport road corridor has adequate space availability.

4. **'On the way' – serving many trips / TOD pattern**. This factor is given a weighting of 10 points and reflects the location of the corridor within the city. Where the corridor serves many different trips, the score is higher. Phase 1 and phase 2 both receive the maximum 10 points, as these corridors correspond with the largely east-west demand pattern in the city, and serve trips coming from and going to many different areas around the city. Phase 2 serves the major north-south demand orientation in Ulaanbaatar, to the area southwest of Peace Bridge. Phase 3 along Doloon buudal and the Airport Road get zero points because these corridor do not serve major areas beyond them. Doloon buudal is a partial exception, because the corridor does serve the Chingeltei area in the northwest, but an overall score of zero is allocated to phase 3.
5. **Mixed traffic impacts**. Especially for the first corridor, it is important that the BRT does not dramatically degrade the mixed traffic speeds along the BRT corridor. If mixed traffic is negatively impacted, car drivers may oppose the project, which could undermine political and wider public support. This factor is allocated 10 points. Phase 1 and phase 2 receive the maximum 10 points because in both corridors the current bus volumes are high, and major improvements for both buses and mixed traffic will be possible. These are both clear 'win-win' corridors where the BRT system can lead to improvements in speed and capacity for both buses and mixed traffic, which should help guarantee a high level of public support and perceived success for the project. The currently highly inefficient 4 phase intersections are also primarily concentrated in and around the phase 1 and phase 2 BRT corridors. Improving these intersections will result in major benefits for both BRT and mixed traffic. Phase 3 gets zero points because bus volumes are currently relatively low, and mixed traffic speeds are already quite good. Although mixed traffic volumes will not be degraded, they will also not be improved by BRT in these corridors, at least in the short term, noting also that these corridors currently have few 4-phase intersections.

These scores are of course debatable and individual scores and weightings could be adjusted marginally up or down, but nevertheless a clear order of priority emerges from the analysis. In particular: Phase 1 and phase 2 are the best corridors for the initial BRT implementation, and phase 3 should implemented subsequently.

One key consideration regarding the Peace Ave & Namyan Ju versus Ikh Toiruu & southwest connection area is that the proposed phase 2 corridor has more challenging land-related and construction issues, including a flyover over the railway and Narnii Road. This reinforces the allocation of this corridor to phase 2, allowing more time for these issues to be resolved and for the flyover to be built.

BRT corridor comparison scoring. The result is a clear priority for phases 1, 2 and 3.

Factor	Weight	Phase 1 (Peace Ave & Namyan Ju)	Phase 2 (Ikh Toiruu & 3/4 khoroolol & 120 area)	Phase 3 (Doloon Buudal & Airport Rd)
High current bus passenger demand	30	30	25	5
Low current bus speeds	20	20	20	0
Physical space available	30	25	10	20
'On the way' – serves many trips / TOD pattern	10	10	10	0
Potential positive mixed traffic impacts	10	10	10	0
TOTAL SCORE	100	**95**	**75**	**25**

The recommended BRT implementation phases are very clear:

Phase 1: Peace Avenue & Namyan Ju

Phase 2: 3/4 khoroolol & Ikh Toiruu & 120 area (southwest connection)

Phase 3: Doloon Buudal & Airport Road

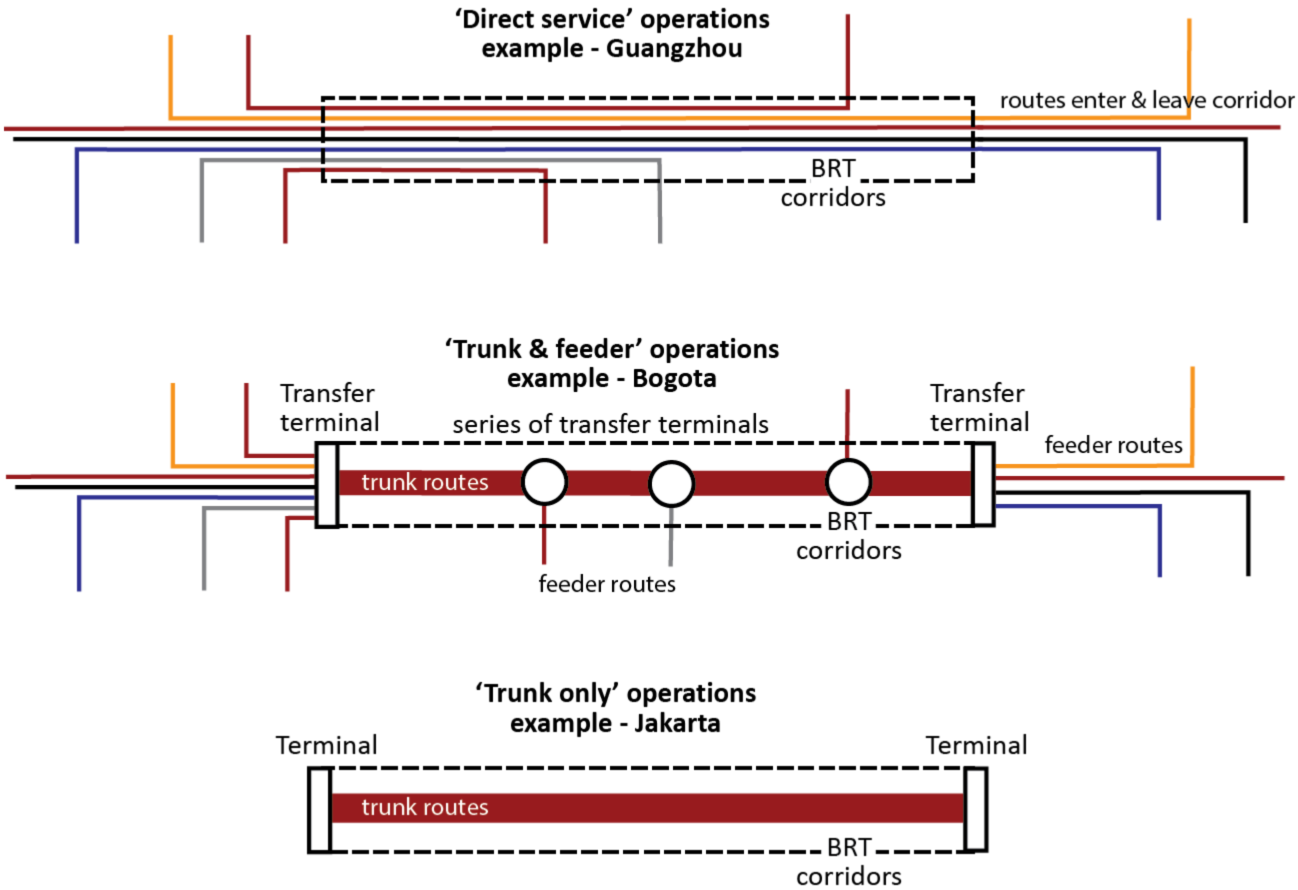
Peace Avenue & Namyan Ju should be implemented first. Ikh Toiruu & 3/4 khoroolol & 120 area, along with Sukhbaatar St and Olympic St in the central area, should be implemented second. The Airport Road and Doloon buudal corridors should be implemented third, according to demand developments along the corridors in the next few years. The actual construction in Doloon buudal and the Airport Road could be adjusted according to demand developments and other projects along these corridors. The demand in these corridors is not interrelated, and construction can proceed either in parallel or independently.

7 BRT route selection and operations

BRT route selection and operations is closely related to BRT corridor selection and station design. In order to make preliminary recommendations on BRT stations it was necessary to also adopt a preliminary BRT operational concept.

A BRT operational plan was devised for an east-west corridor option under PPIAF funding during February to April 2016, but this plan was based on a corridor selection along 3/4 khoroolol and Ikh Toiruu which was subsequently heavily modified and was then in early July 2016 abandoned in favour of the far better Peace Avenue alternative. However, although the details are no longer relevant, the basic principles and approaches established in that earlier BRT operational plan by BRT Plan International are valid.

The Ulaanbaatar BRT should have a 'direct service' operational approach which means buses can enter and leave the BRT corridor. Following the example of Guangzhou in 2010, which was planned and designed by Far East BRT experts at the time working for GMEDRI and ITDP, few new BRT system in Asia are operating under a trunk-feeder or trunk-only operational model, as the direct service approach provides major benefits.



Trunk & feeder vs direct-service operations. The Guangzhou BRT does not require any transfer terminals, hubs, or interchanges. Yichang also applies a 'direct service' model. A direct service operational model is proposed for Ulaanbaatar.

8 BRT stations

8.1 Introduction

A substop is a station subdivision or 'module'. When equipped with overtaking lanes, one BRT station can be divided into multiple substops. In order to function, substops require overtaking lanes or a functional equivalent such as in the 'directional' BRT stations used in Lanzhou and Yichang.

BRT stations can be broadly divided according to capacity by whether they have overtaking lanes and substops, and whether the stations have more than one bus docking position in each direction and substop. High capacity systems feature BRT stations with overtaking lanes and multiple substops. Medium capacity systems do not have overtaking lanes, but have multiple stopping areas. Low capacity BRT systems have stations with no overtaking lanes and only one stopping position in each direction.

Using the criteria mentioned above, the following table categorizes BRT systems as either high, medium or low capacity. The categories in the table are based on BRT station design capacity rather than the actual operating capacity. (Note that BRT system capacity is also influenced by factors other than BRT stations, including the operational and intersection design, bus size, express services, the number and width of doors, fare collection systems, crowding in buses and stations, etc.).

The Ulaanbaatar BRT generally requires a high capacity BRT design, with multiple substops and (functional) overtaking, with the possibility of accommodating high capacity BRT vehicles, and with multiple stopping areas at each substop. All of these features are incorporated in the proposed BRT design. With the high capacity BRT design proposed in this report, building upon the design proposed in 2011, the Ulaanbaatar BRT will meet passenger demand levels in the city for at least the next several decades.

By 2030 Ulaanbaatar could be the second BRT system in Asia to exceed 10,000 pphpd (after Guangzhou), if the Ulaanbaatar Metro Study from May 2013 is used as a guide. In the short term the Ulaanbaatar BRT will exceed 5,000 pphpd at the peak point. The projected demand numbers need to be derived when the detailed operational design is carried out, which is one of the recommended next steps.

Classification of selected BRT systems into high, medium and low capacity stations. Subject to the operational design, Ulaanbaatar will likely exceed 5,000 pphpd upon opening.

City	overtaking lanes & substops > 75% of stations	>1 stopping area >75% of stations	design capacity*	>1 stopping area per substop	actual throughput (pphpd)	year of throughput count
Bogota	Yes	No	HIGH	No	37,700	2013
Guangzhou	Yes	Yes	HIGH	Yes	20,800	2016
Istanbul	No	Yes	MEDIUM		18,900	2012
Lima	Yes	No	HIGH	No	13,950	2011
Cali	Yes	No	HIGH	No	11,100	2013
Xiamen	No	No	LOW		9,850	2015
Chengdu	No	Yes	MEDIUM		9,320	2015
Brisbane	Yes	Yes	HIGH	Yes	8,750	2015
Mexico City	No	Yes	MEDIUM		7,550	2013
Zhengzhou	No	Yes	MEDIUM		7,230	2014
Lanzhou	Yes	Yes	HIGH	Yes	6,630	2015
Quito	No	No	LOW		6,000	2008
Urumqi	No	Yes	MEDIUM		5,470	2015
Yichang	Yes	Yes	HIGH	Yes	5,400	2015
Jakarta	No	No	LOW		3,400	2013
Changzhou	No	No	LOW		2,980	2015
Paris	No	No	LOW		2,900	2016
Beijing	No	No	LOW		2,850	2015
Jinan	No	No	LOW		2,050	2014
Leon	No	No	LOW		1,950	2013
Nantes	No	No	LOW		1,200	2011
Los Angeles	Yes	Yes	HIGH	Yes	1,000	2013
Nagoya	No	No	LOW		500	2013
Bangkok	No	No	LOW		200	2017
Kuala Lumpur	No	No	LOW		120	2015

* Note that this is an overall estimate of capacity. In some cases cities have a combination of ‘low’ (with only one stopping area per direction) and ‘medium’ (with two stopping areas per direction) stations. Source: data from **www.brtdata.net**, accessed 1 August 2016, with Bangkok data updated based on surveys in January 2017. Throughput counts are all based on actual field counts. Actual system capacity is determined not only by stations, but by a range of operational factors.

8.2 Ulaanbaatar BRT station configurations

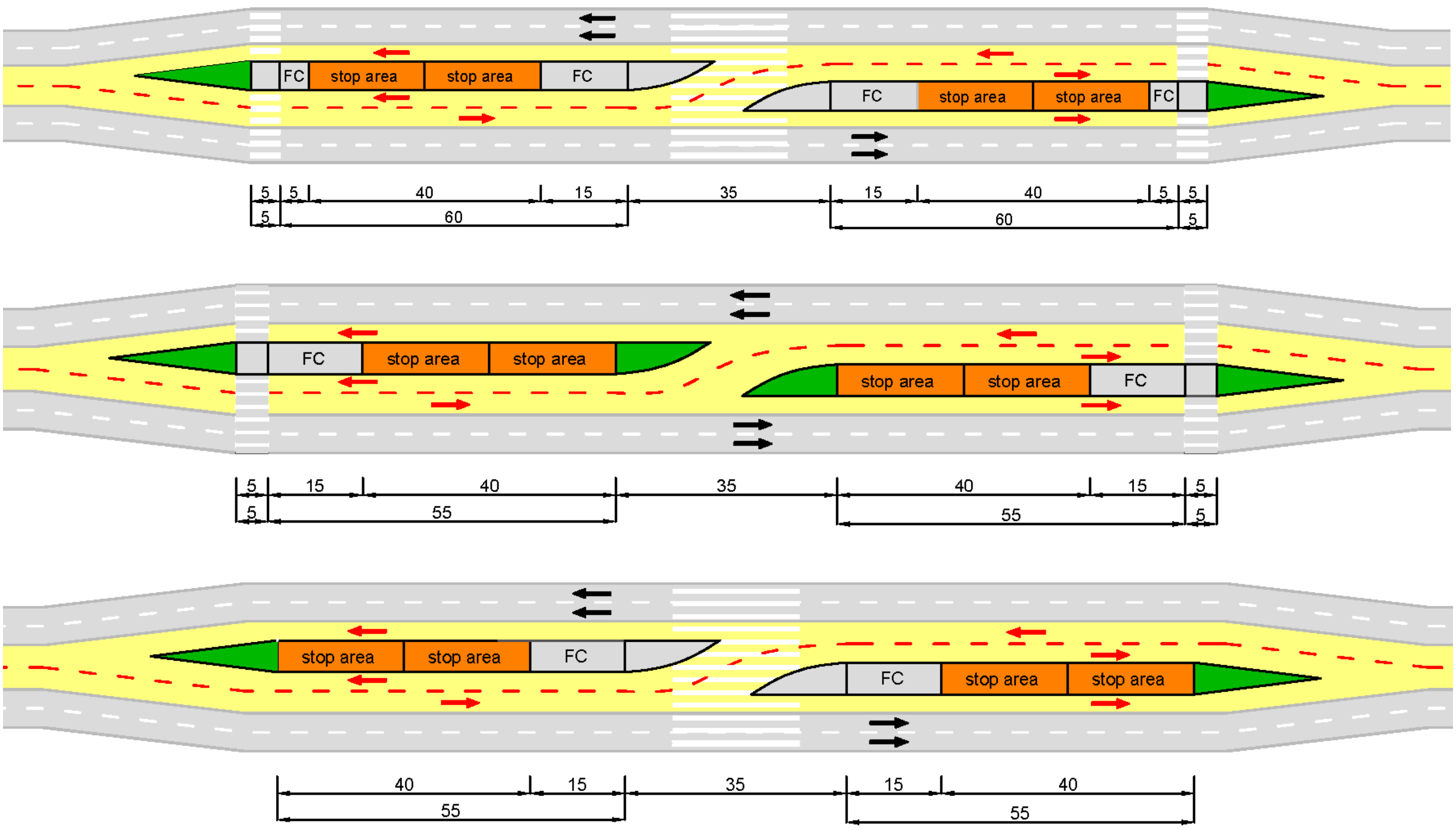
The Ulaanbaatar will feature multiple different station configurations. Station configurations are based on the demand and operational requirements, road conditions, and right of way.

Note that between stations the BRT space requirement is 3.5m in each direction, for a total of 7m in two directions. The largest and most difficult space allocation is at the stations, which is the focus of the following layout graphics.

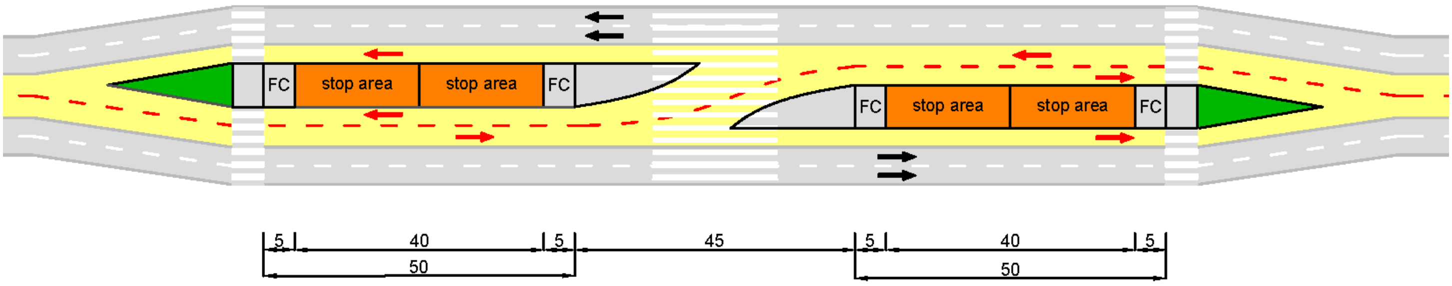
8.2.1 Directional stations

The layout and dimensions of the directional stations is outlined below. Most of the directional stations are either 5m or 6m wide. Seven of the directional stations are 9m wide, based on the specific right-of-way conditions in the western part of Peace Avenue.

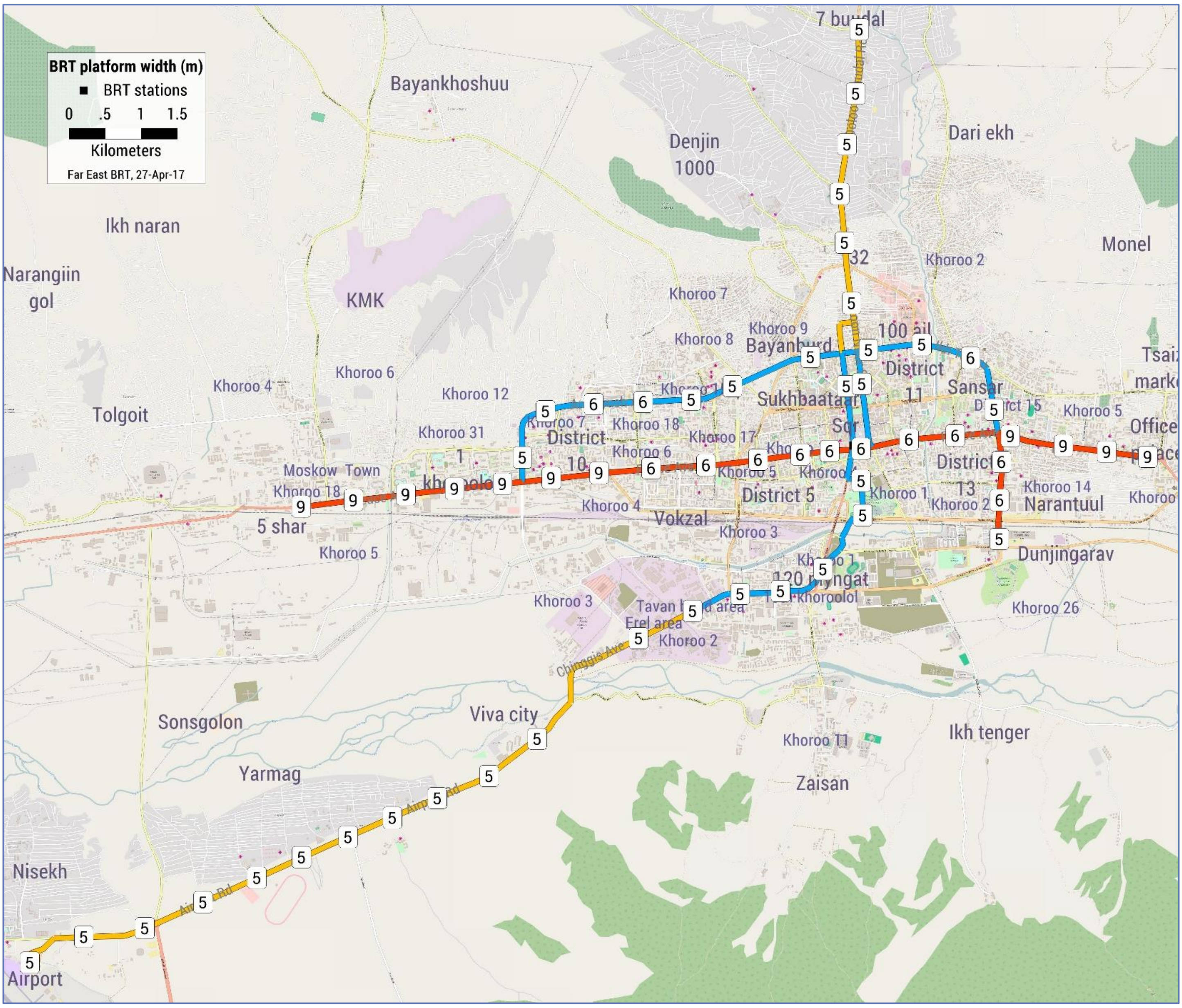
The standard directional stations of 5-6m platform width require 35m between stations to accommodate a 35km/hr BRT bus speed.



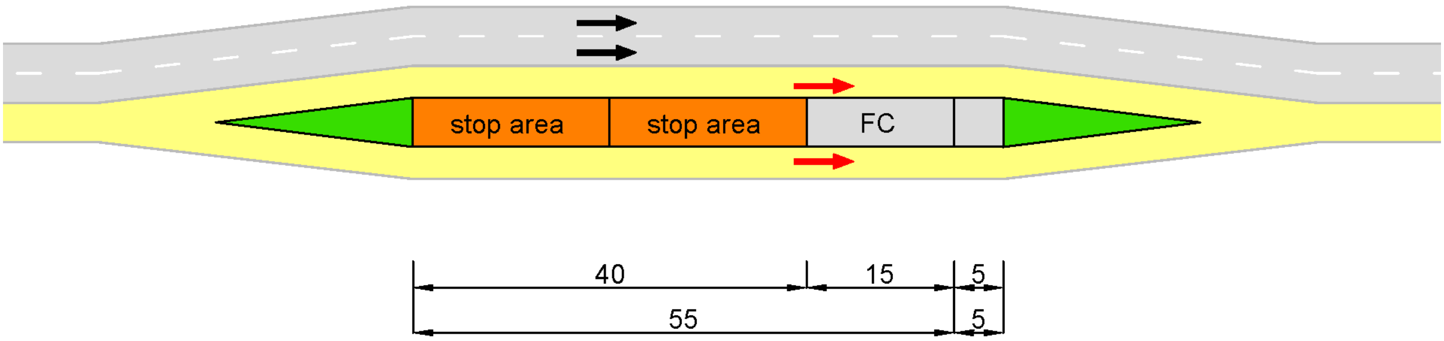
Standard directional station with 2 substops, 5m or 6m wide platforms. The total length including minimum 35m dividing space is around 150m, with some variation according to the fare collection points. The platforms can be placed further apart if needed, according to the local site characteristics, nearby intersections, and access plan. The central vs side access depends on nearby intersections (especially where signals require u-turns) and on whether access is signalized or unsignalized.



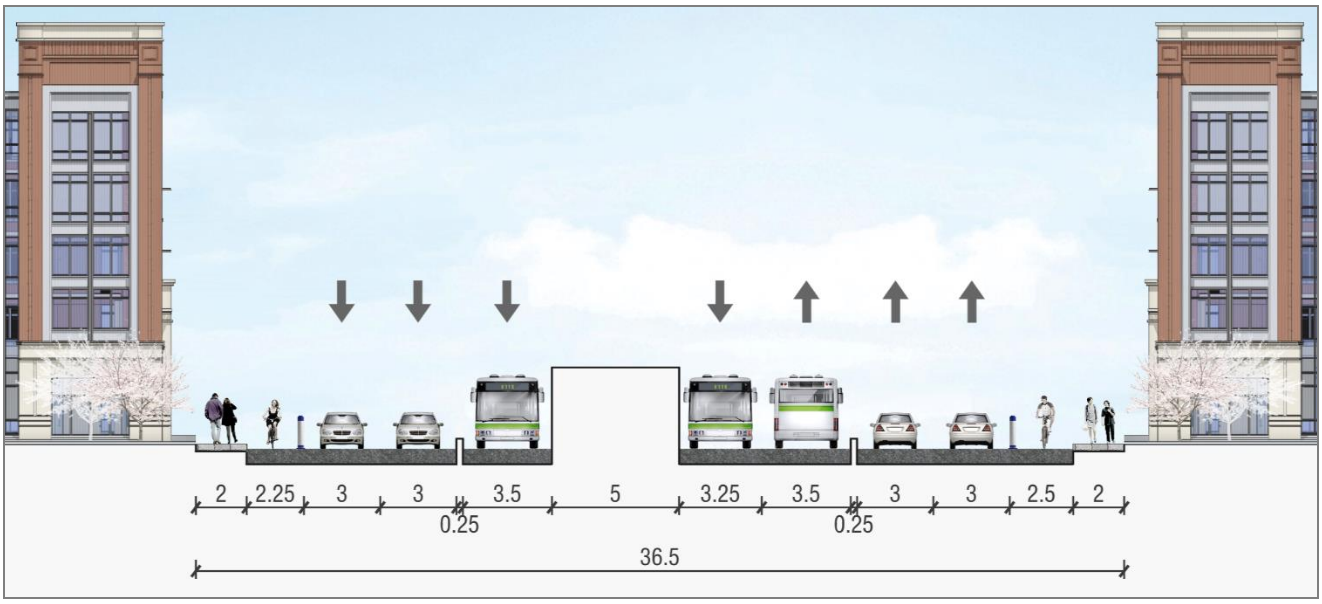
Directional station with wider platform (9m). Proposed platform widths are shown following.



BRT station platform widths (m). These widths may need to be revised during the detailed engineering design, but all platforms will be at least 5m wide.

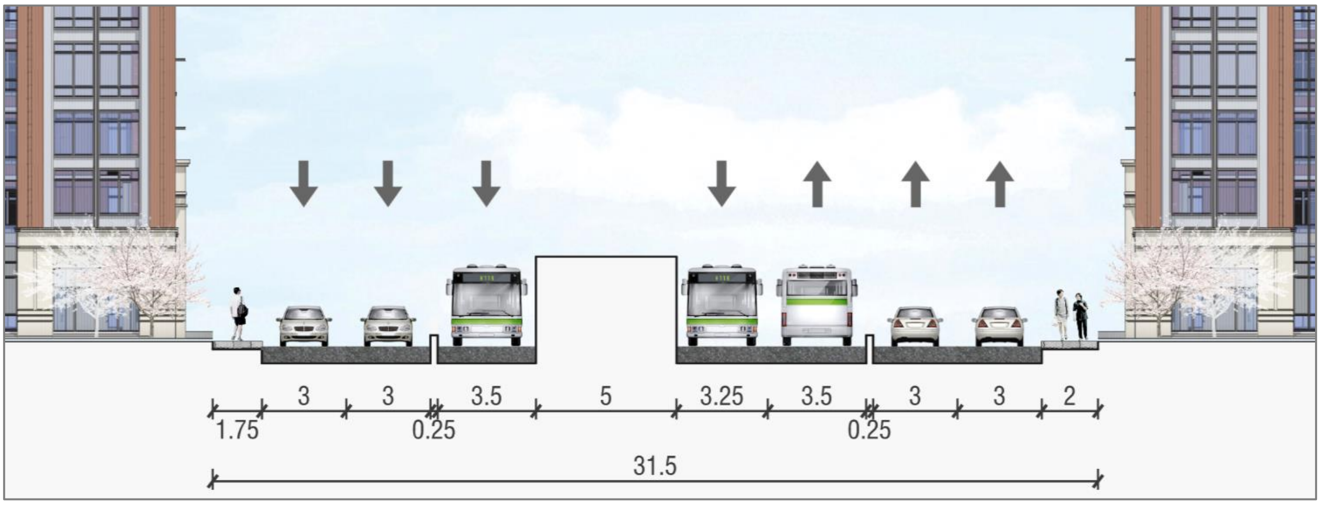


One-way directional station.



Standard directional station with bike lanes. This configuration requires > 36.5m ROW at stations.

Note: 2m for the walkway is considered the minimum width, and is not the preferred width. The preferred walkway width is 3-6m, with wider walkways enabling additional landscaping improvements.

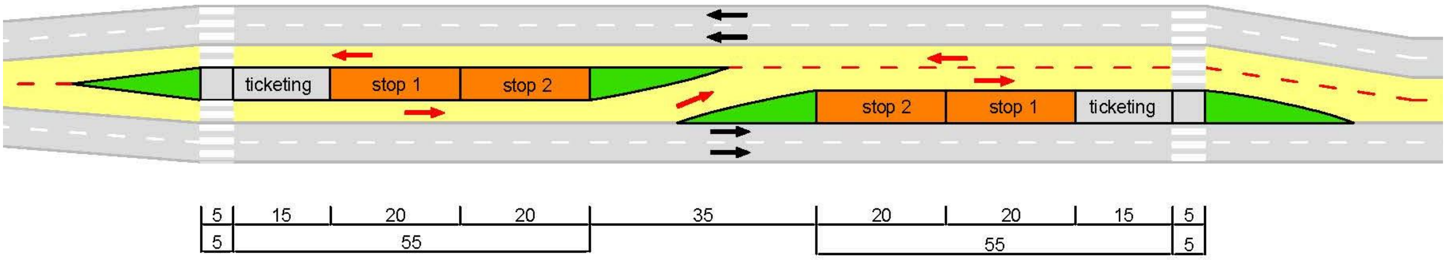


Directional station without bike lanes. Configuration requires min. 31.5m ROW at stations.

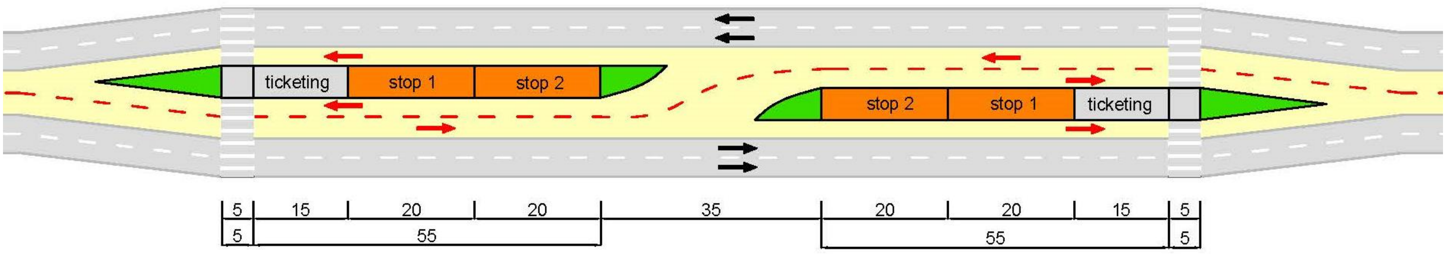
Note: 1.75m for the walkway is considered the absolute minimum width, and is not the preferred width. The preferred width is 3-6m, with wider walkways enabling additional landscaping improvements.

8.2.2 Short term vs medium / long term station

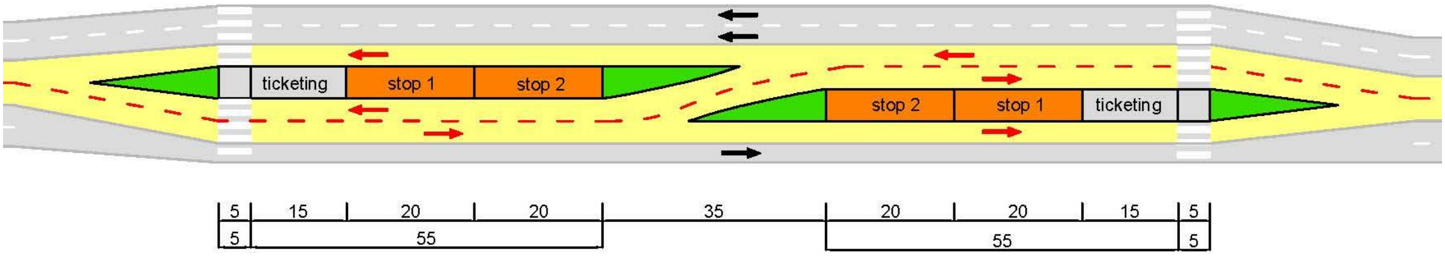
The proposed stations for the Doloon Buudal corridor are a world-first configuration devised by Far East BRT for this project allowing low capacity operation in the short term and high capacity operation in the medium/long term. This configuration is well-suited to the demand, traffic and right of way conditions in this corridor.



Short term (Doloon Buudal, N2-N6)

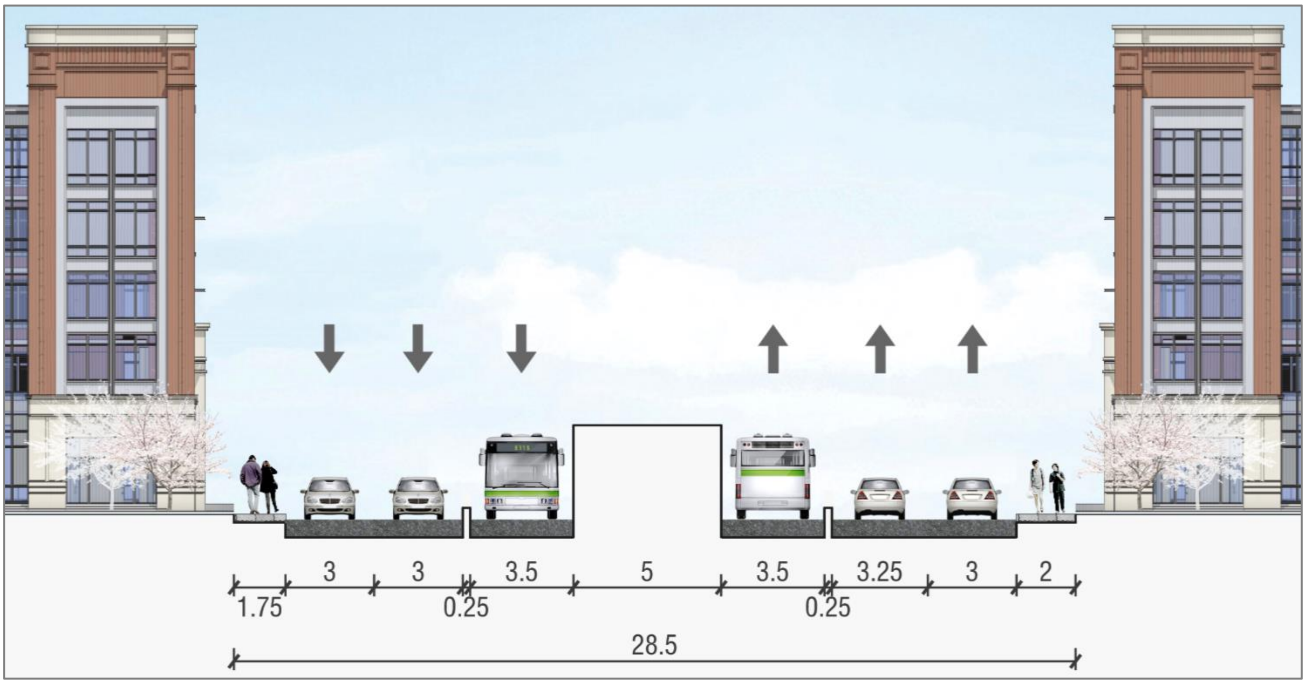


Medium / long term, option 1 – mixed traffic in two directions but requires widening on one side



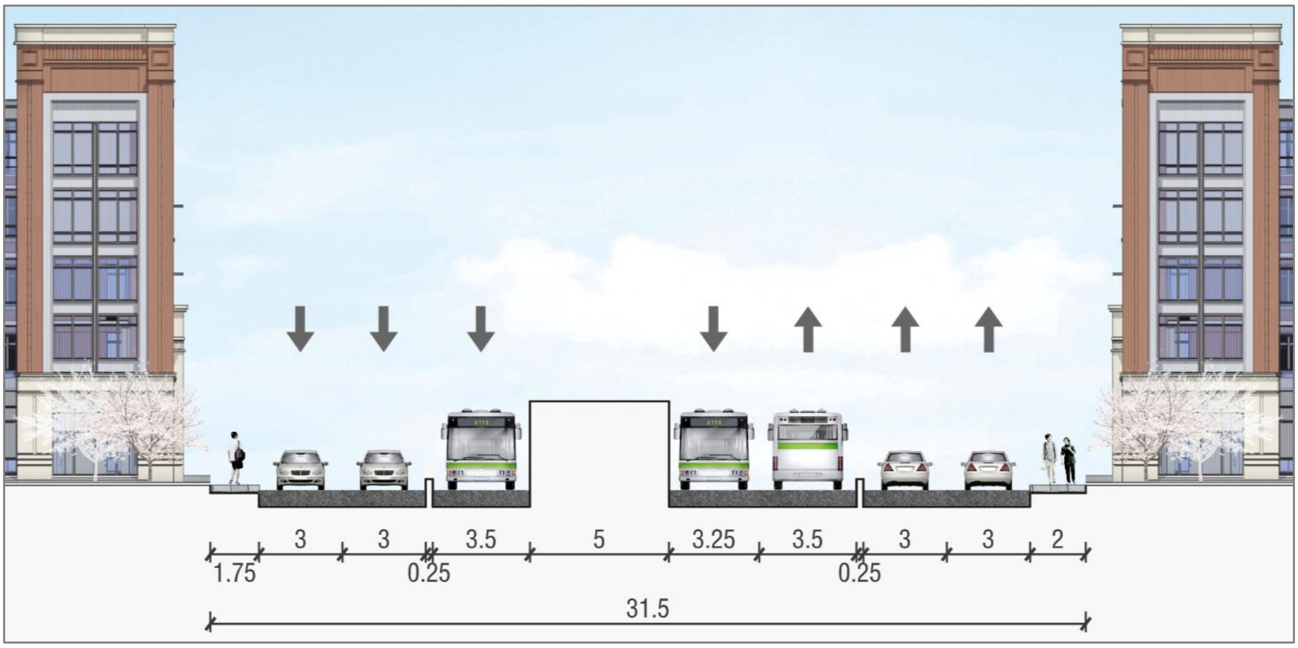
Medium / long term, option 2 – no widening required but mixed traffic reduced to one lane in one direction. Stations will generally require access at both ends of each platform.

An analysis of turning movements shows that assuming a stopping gap distance of 30cm is acceptable, which assumes that the platform boarders used in Yichang will also be used in Ulaanbaatar (see http://www.fareastbrt.com/en/feature/ycbrtjan162), a distance between the two platforms of 20m will suffice for both 12m and 18m BRT buses at speeds of at least 20km/hr. In the current design a gap of 35m is proposed to enable easier bus maneuvers.



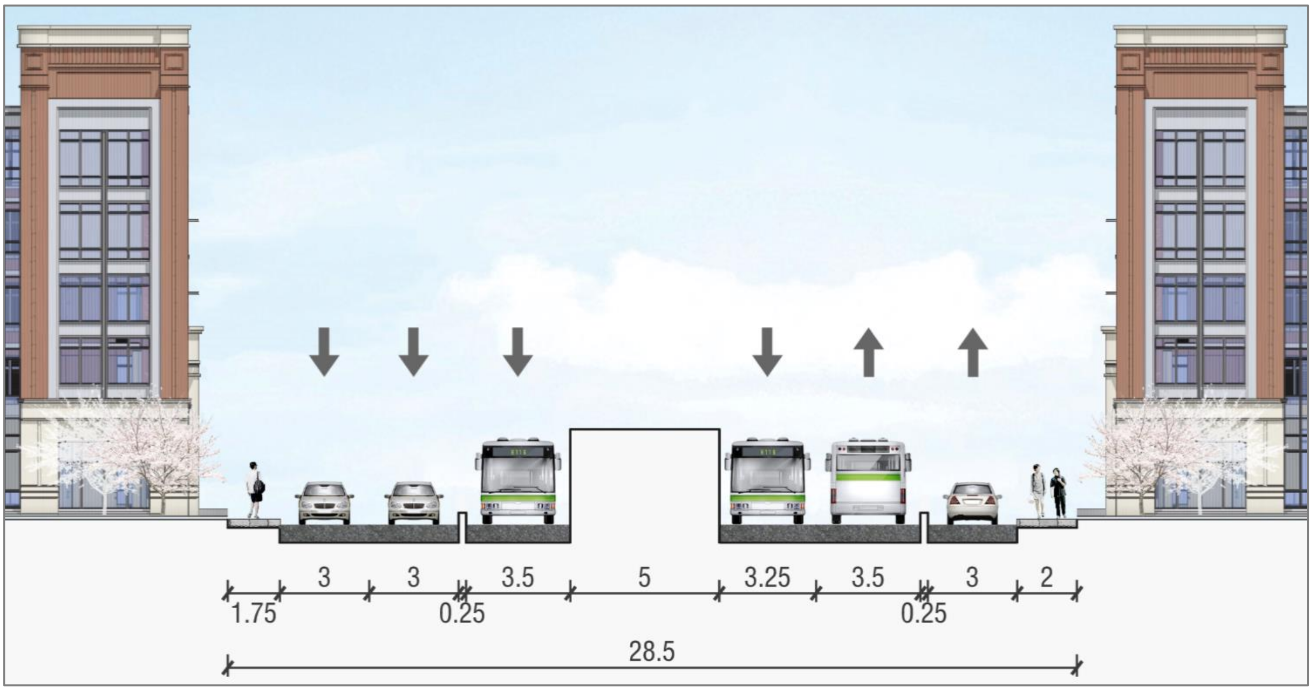
Short term option for stations N2 to N6 (Doloon Buudal).

Note: 1.75m for the walkway is considered the absolute minimum width, and is not the preferred width. The preferred width is 3-6m, with wider walkways enabling additional landscaping improvements.



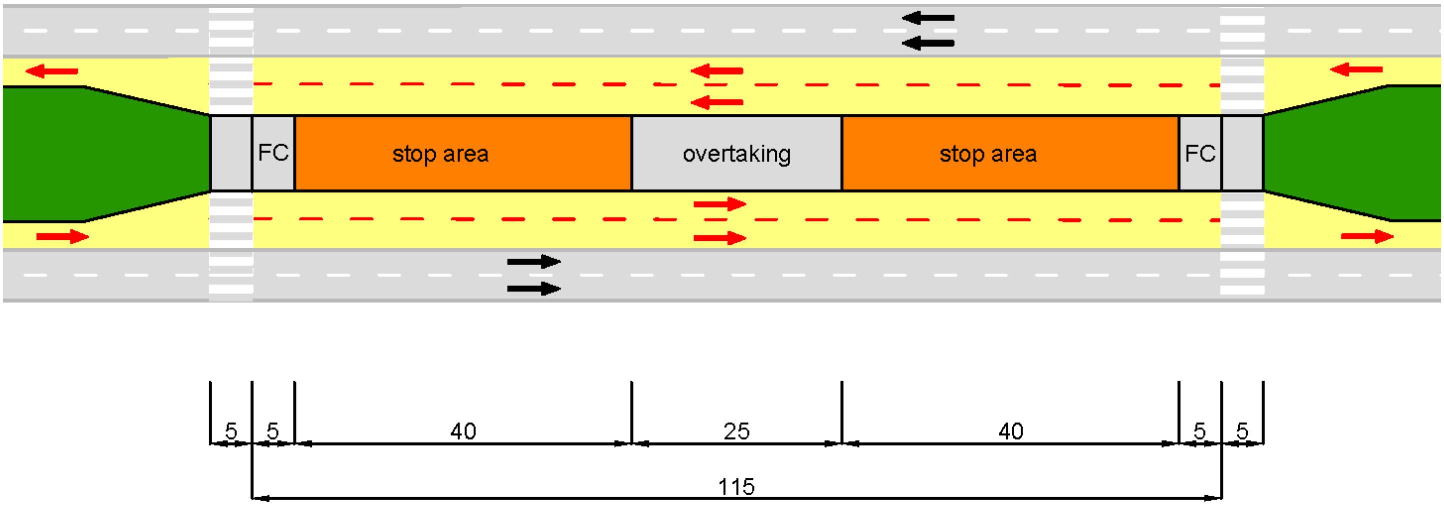
Medium/long term option for stations N2 to N6 (Doloon Buudal) – with road widening.

Note: 1.75m for the walkway is considered the absolute minimum width, and is not the preferred width. The preferred width is 3-6m, with wider walkways enabling additional landscaping improvements.

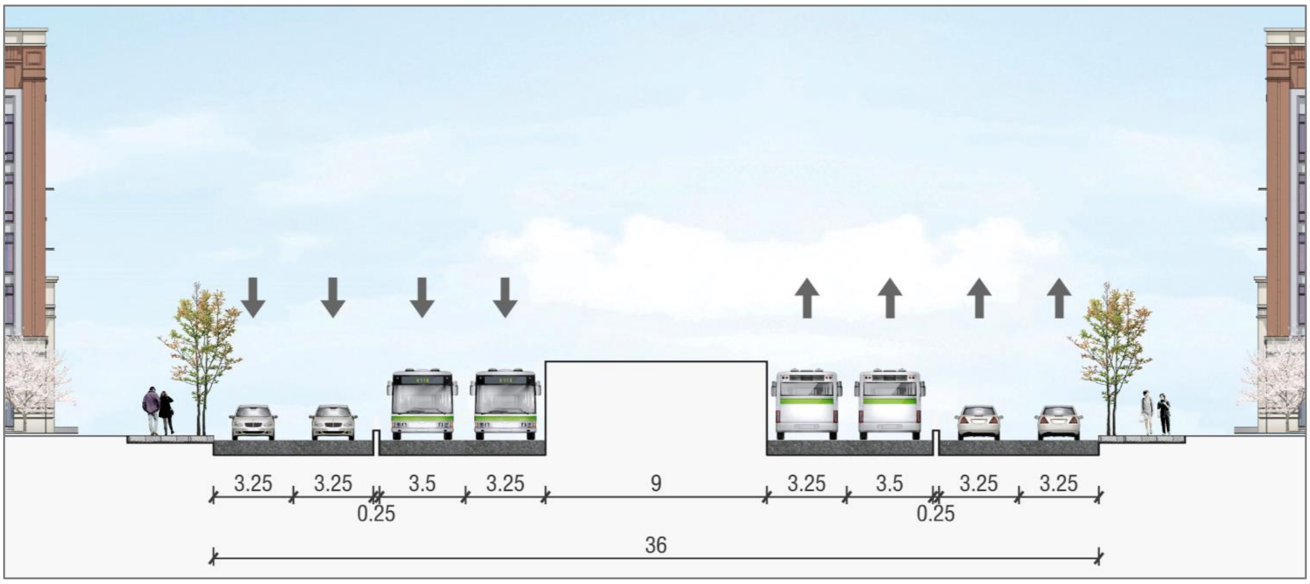


Medium/long term option for stations N2 to N6 (Doloon Buudal) – without road widening.
Note: 1.75m for the walkway is considered the absolute minimum width, and is not the preferred width. The preferred width is 3-6m, with wider walkways enabling additional landscaping improvements.

8.2.3 Two substop island stations

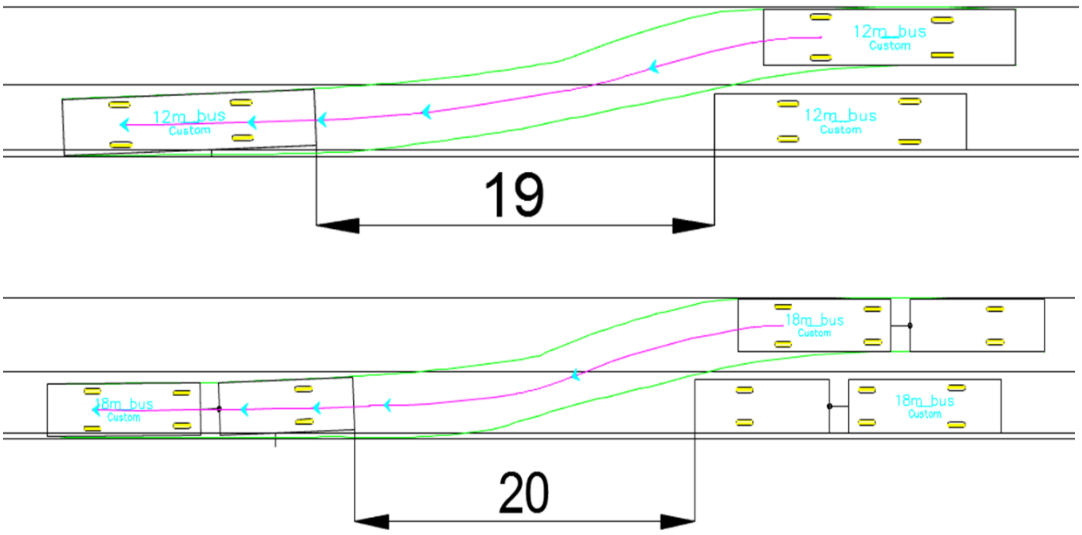


Standard island station, with two sub-stops. This station is recommended for the eastern part of Peace Avenue, which has an existing wide median. The total station length is 115m.



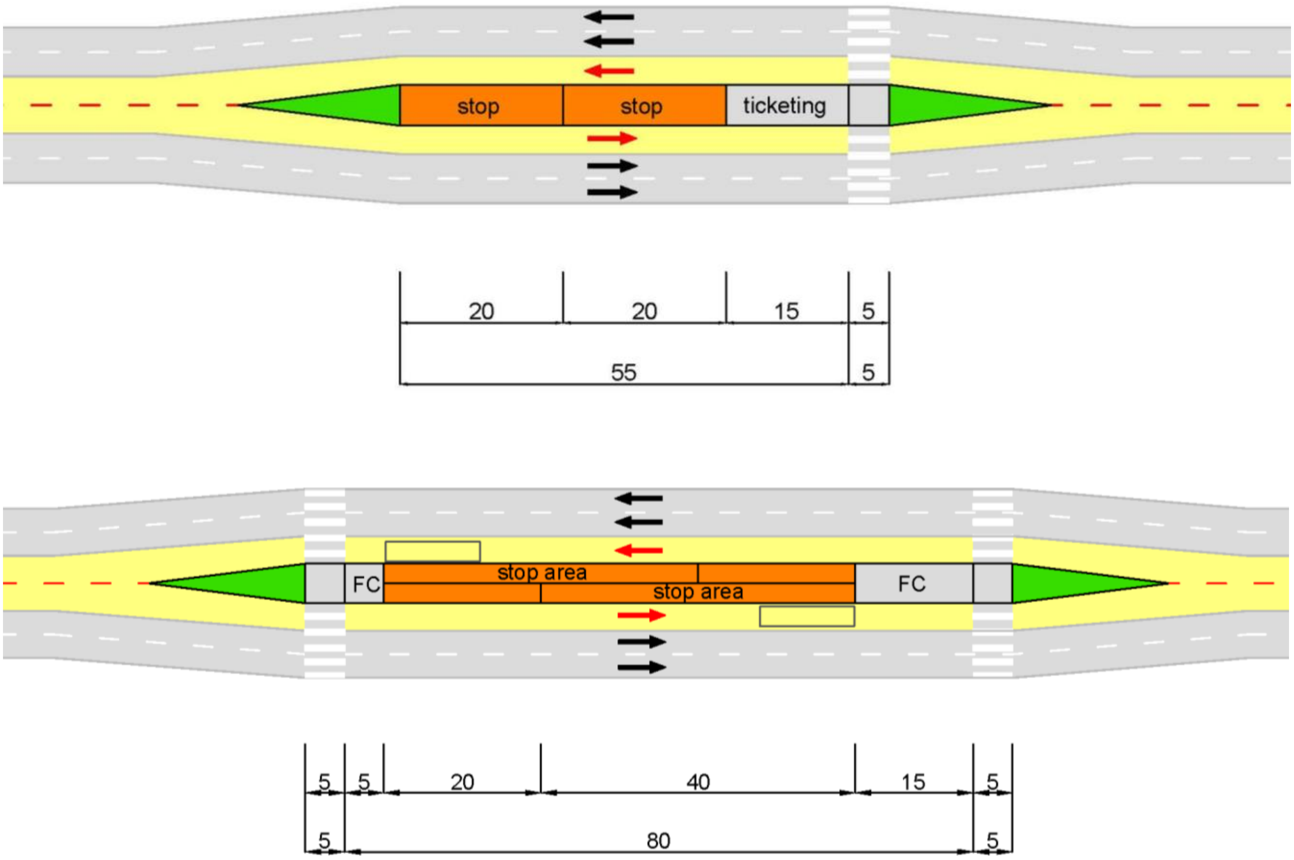
Cross-section for island stations (Peace Avenue east of East Cross intersection)

An analysis of turning movements shows that assuming a stopping gap distance of 30cm is acceptable, which assumes that the platform boarders used in Yichang will also be used in Ulaanbaatar (see http://www.fareastbrt.com/en/feature/ycbrtjan162), a distance between substops in the central platform of 20m should suffice for both 12m and 18m BRT buses at speeds of at least 20km/hr. In the current design a gap of 25m is proposed to enable easier bus maneuvers.

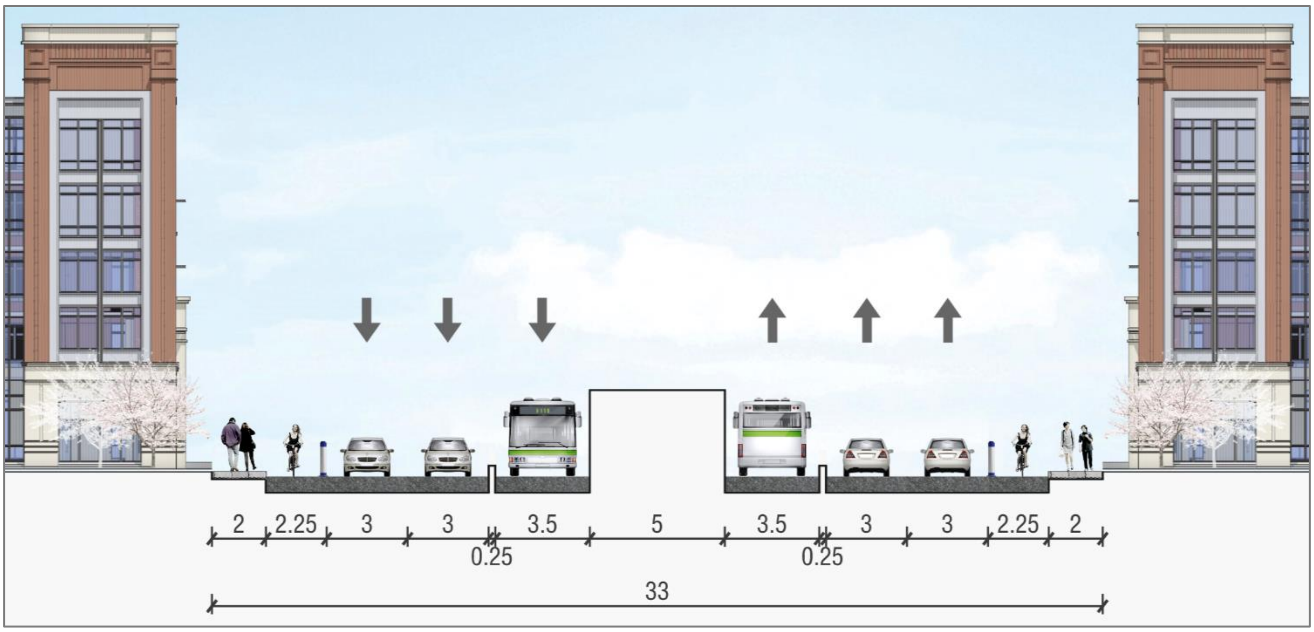


Distance between substops in the central platform island stations, allowing for overtaking and stopping at the rear stopping position at the substop in front, for both 12m and 18m BRT buses.

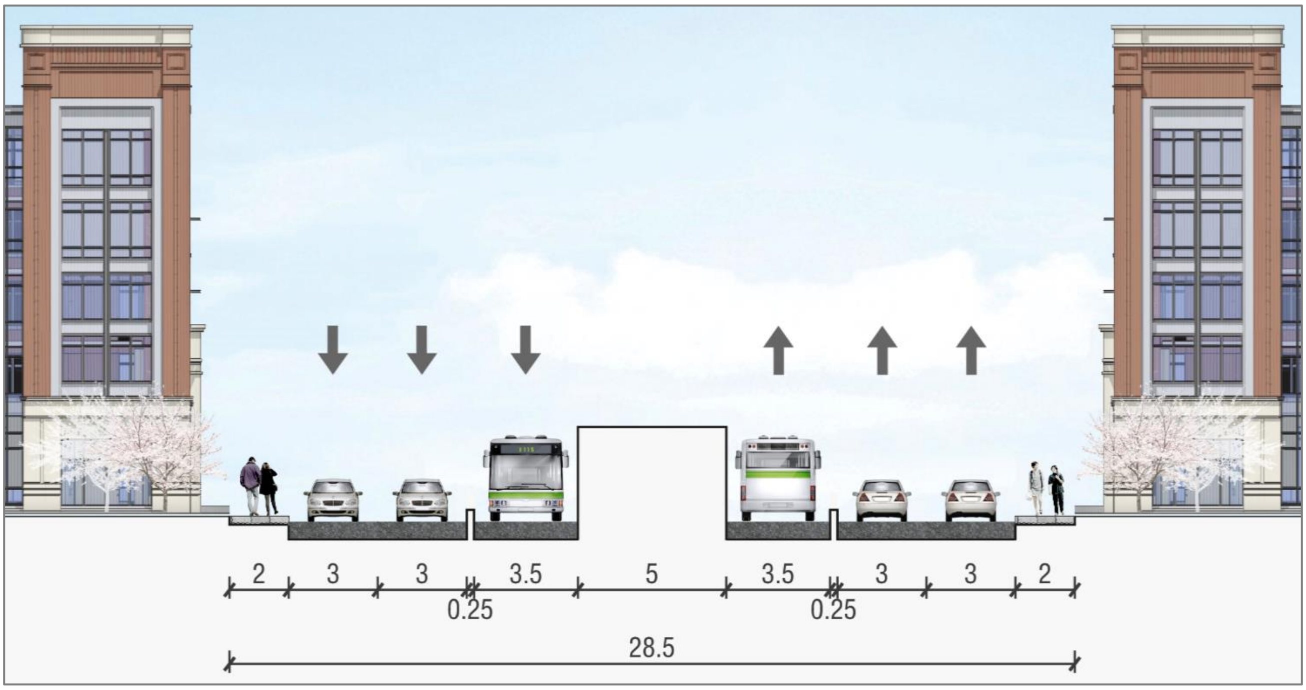
8.2.4 One substop island stations



One substop island station – standard (top) and longer offset variation (above). The offset design, along with a 1m wider platform (6m in total) is planned for the Namyan Ju corridor.



One substop island station – with bike lanes

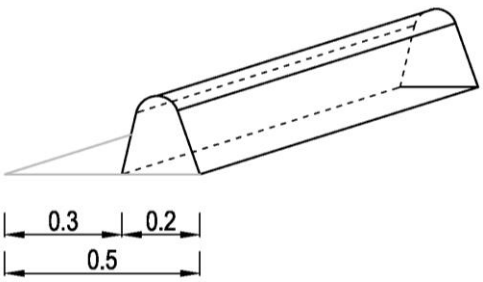


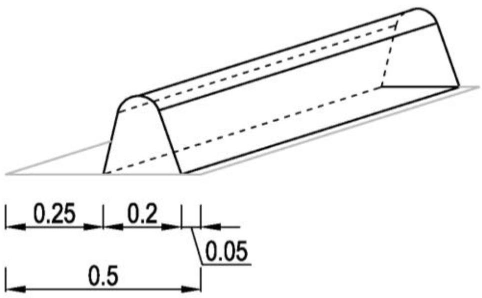
One substop island station – without bike lanes

Note: 2m for the walkway is considered the absolute minimum width, and is not the preferred width. The preferred width is 3-6m, with wider walkways enabling additional landscaping improvements.

8.3 BRT lane dividers

Lane divider configuration at stations (below left) and between stations (below right). Lane divider height is 0.2m. This is based on the Bogota (photo left) lane divider specification. Length is 1.5m to 2m but needs to be assessed based on climate conditions.





BRT lane divider in Bogota.

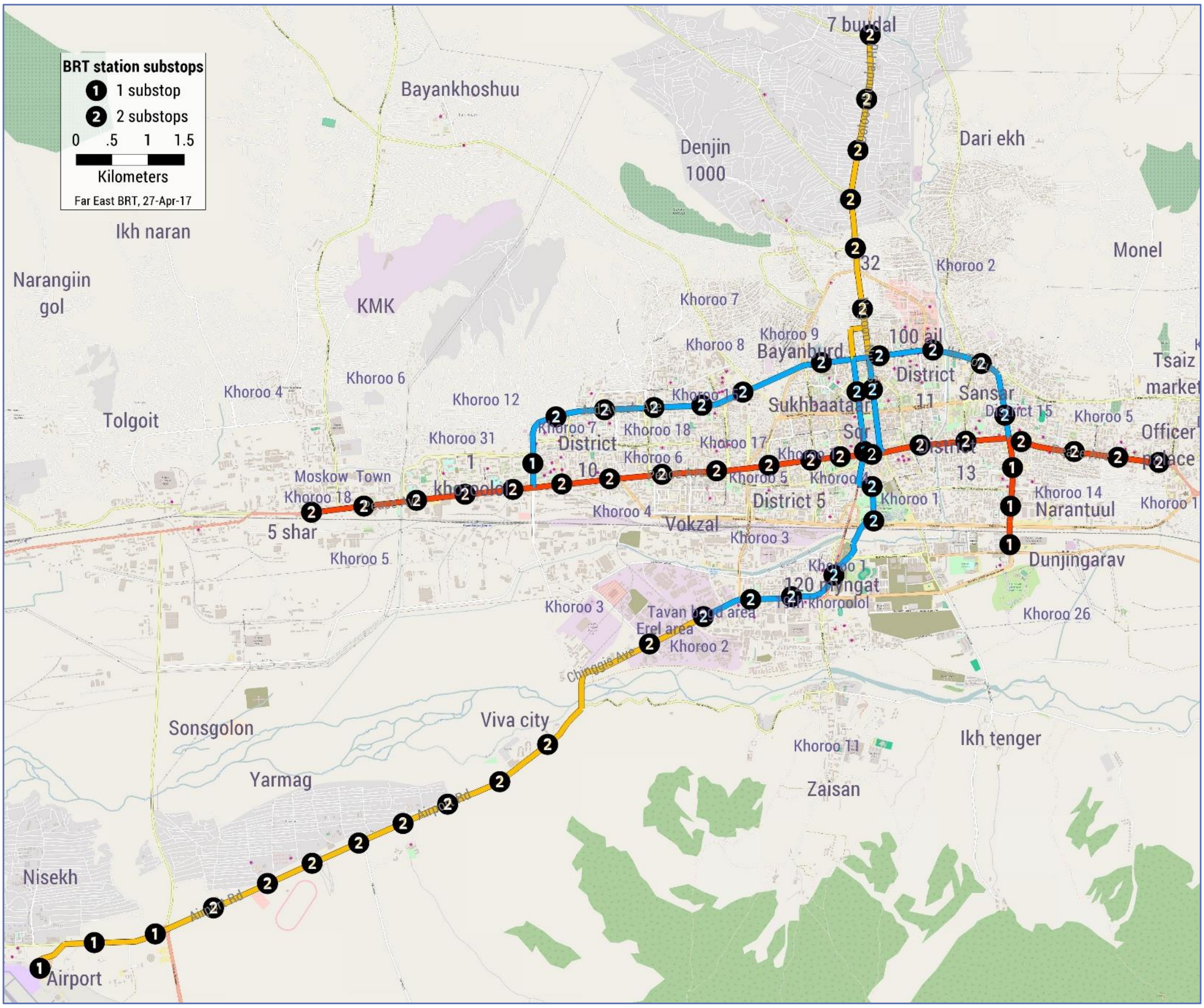
8.4 BRT station substops

Station substop requirements are a key consideration in BRT planning and design.

Two substops are proposed in the large majority of BRT stations in Ulaanbaatar. This provides capacity for future demand growth.

Current assessment is that three substops are not needed in any stations, though for Peace Avenue it would be preferable to verify this with further operational design and analysis. Operational analysis using smart card data supplemented by on-bus and at-stop counts should be carried out as soon as possible and certainly during the early detailed design stage. This is particularly important for the stations along the Peace Avenue corridor in locations where transfer volumes may be significant.

One substop is considered sufficient for the Namyan Ju corridor, where local demand is high but bus frequency is much less than in Peace Avenue. Even considering future demand increases, one substop is considered sufficient for Namyan Ju.



Proposed substop allocation. Most stations require two substops.

BRT station types and total platforms

BRT station types	60 total BRT stations	106 total BRT platforms
2 substops	53	
1 substop	7	
Directional (Yichang style)	46	92
Island	11	11
One-way directional	3	3

8.5 Off-corridor stations

The possibility of off-corridor stations is still being assessed. Off-corridor stations can be considered where there is high boarding demand from BRT routes in the section of the route operating outside the BRT corridors. The main candidate stations for the phase 1 BRT implementation based on preliminary demand analysis are:

1. КМК
2. Эрдэнэ толгой
3. Парадокс / Москва ресторан

Of these options, 1 (КМК) and 2 (Эрдэнэ толгой) are the preferred options for off-corridor stations, as neither are located in the first four proposed BRT corridors.

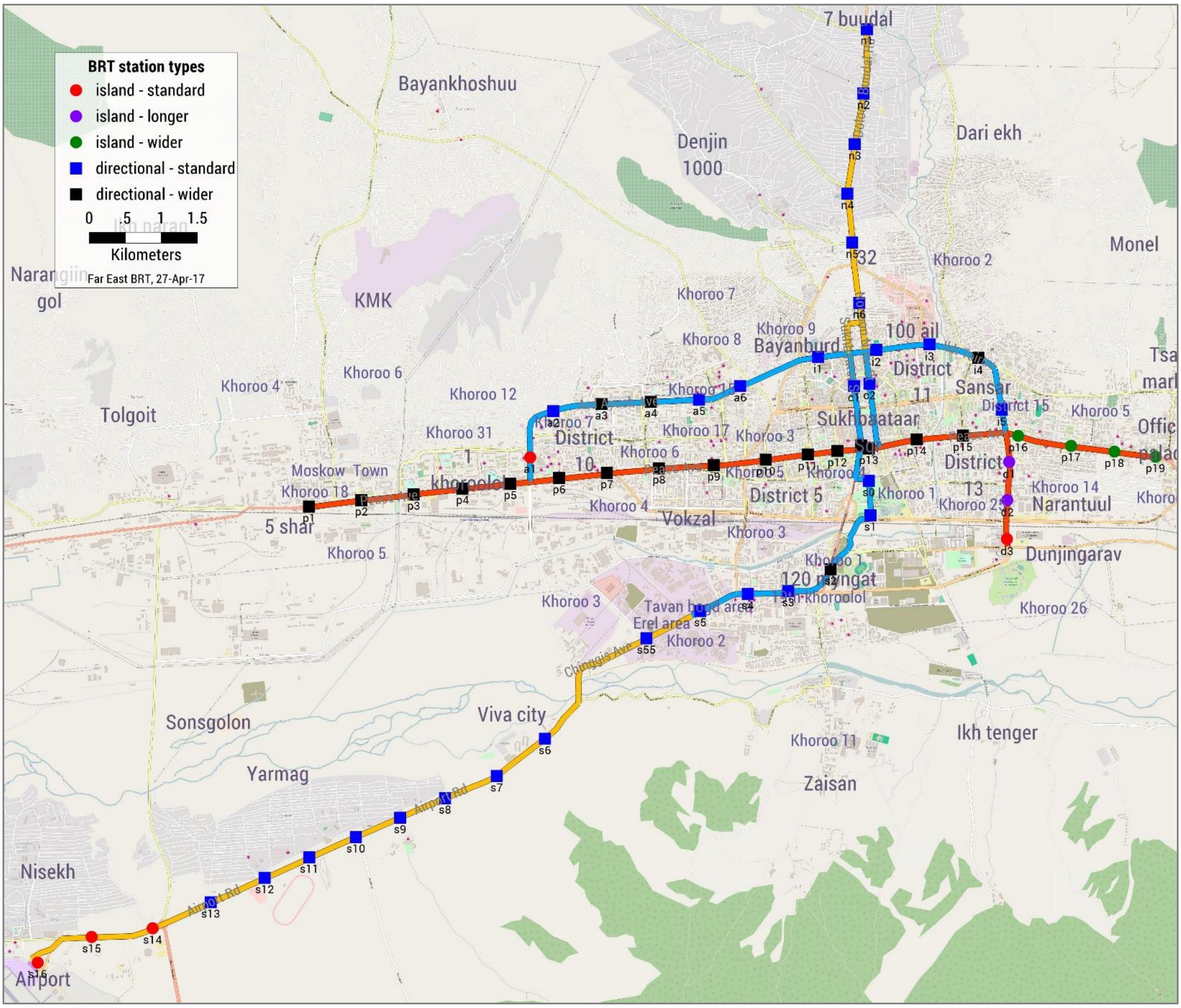
Note that this preliminary assessment is based on card data, which is incomplete. The card data from April 2017 had around 215 missing bus stops. The analysis may change when the card data is supplemented with on-bus and at-stop counts, or when the card data is fully revised with accurate bus stop location information.

8.6 BRT station types

Station types are proposed based on consideration of whether the road has an existing median, the right-of-way, and the desirability of accommodating buses with doors only in the right side. Island stations are proposed in the eastern section of Peace Avenue with a wide median partly because the median slopes downward, which would make a directional station more complicated, and also because the stations can still be 9m wide. In the western part of Peace Avenue which also has a median, an island configuration would have required narrower platforms of around 6m. With directional stations in this section of the corridor, widths of 9m can be implemented, and the stations are also then able to accommodate some of the existing, right-side-door buses.

Proposed BRT station types

	Island	Directional	One-way directional	Total
Phase 1	7	15	0	22
Phase 2	1	16	3	20
Phase 3	3	15	0	18
Total	**11**	**46**	**3**	**60**



Proposed BRT station types.

BRT station types have implications for fleet requirements which must be considered, since island stations require new BRT buses with doors in both sides of the bus.

Phase 1 BRT routes impacted by island stations, which require new BRT buses.

Island station sections	Routes
Total phase 1 BRT routes (unadjusted)	32
ISLAND STATIONS NAMYAN JU	
Routes using island stations	7
Routes not using island stations	25
ISLAND STATIONS NAMYAN JU & PEACE EAST	
Routes using island stations	18
Routes not using island stations	14

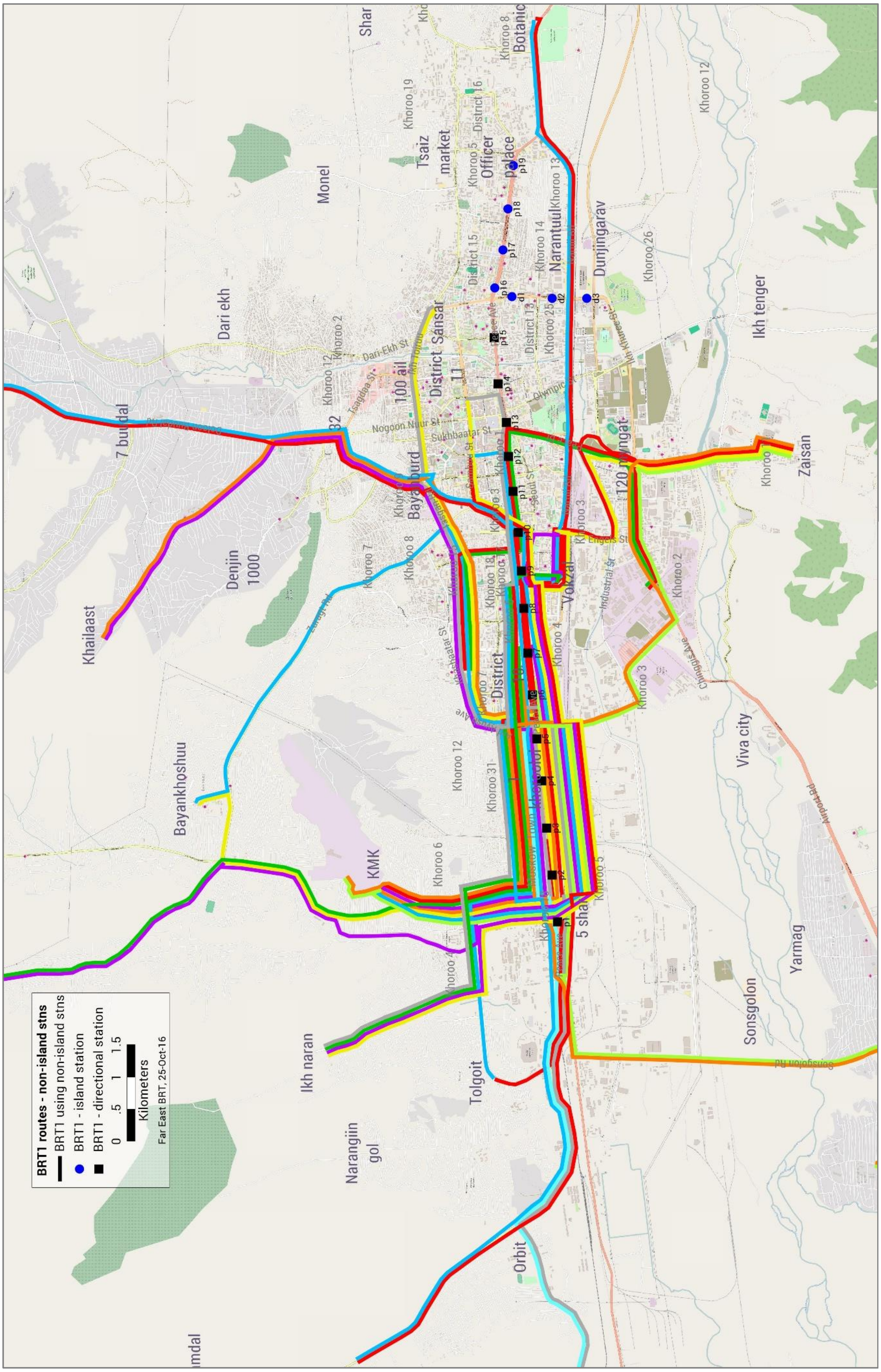
Notes:

1. This is a very preliminary assessment, before route adjustment. After routes are adjusted the figures will change.
2. Ideally all BRT buses will be new, with doors in both sides. Routes using island stations require left side doors. Although doors can be retrofitted in some buses, the cost and current bus conditions probably make this infeasible. However, the possibility of installing doors in the left side of some of the newer buses can be investigated.
3. Further operational design is required to determine the minimum new fleet requirement including the breakdown of doors in right side only vs doors in both sides.
4. PRELIMINARY INDICATION: **roughly half of the phase 1 BRT fleet** will need to be new buses with doors in both sides.

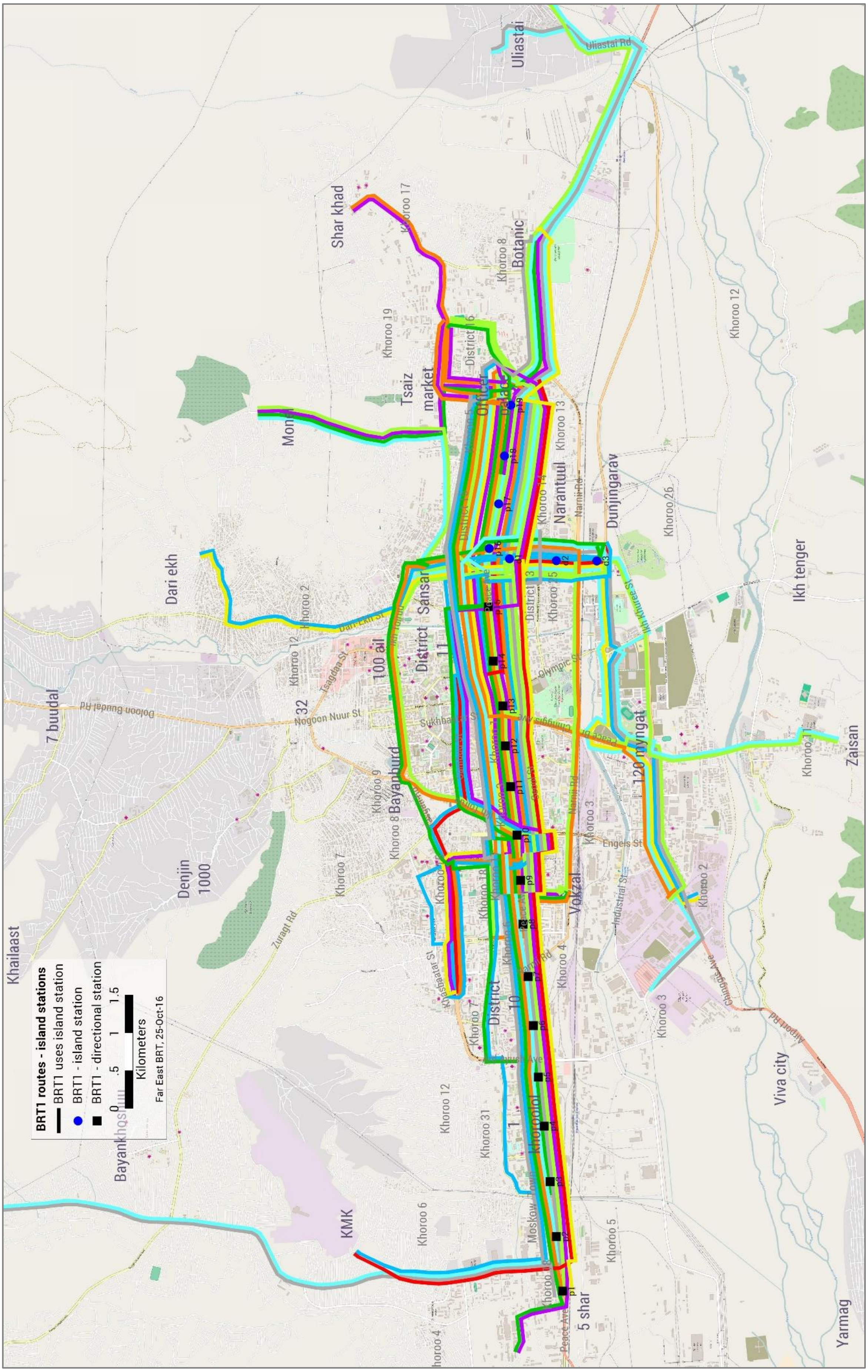
The following graphics show that in the proposed approach involving island stations in Namyan Ju and Peace Avenue east of East Cross, 18 out of 32 phase 1 BRT routes (before adjustment) will use island stations and require new BRT buses with doors in both sides. The remaining 14 routes do not use island stations and can accommodate existing buses with doors only in the right side of the bus.

In a scenario where only Namyan Ju has island stations, only 7 of the 32 phase 1 BRT routes (before adjustment) would use island stations.

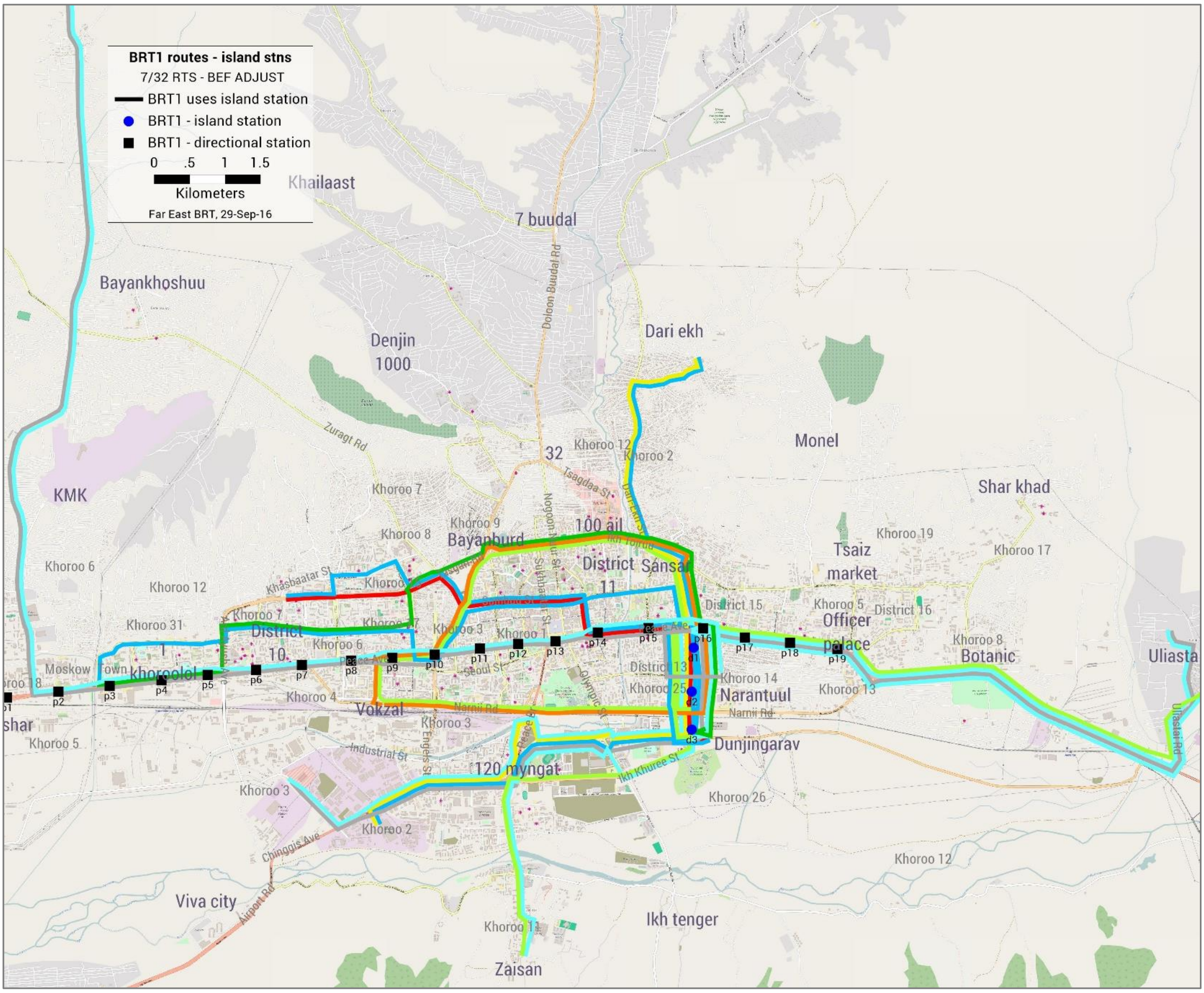
The recommended approach, as below, is for island stations in Namyan Ju and in the section of Peace Avenue east of East Cross intersection.



Phase 1 BRT routes (before adjustment) using non-island stations, and therefore potentially accommodating some of the current right-side door only buses.



Phase 1 BRT routes (before adjustment) using island stations, and therefore requiring new BRT buses with doors in both sides.



Phase 1 BRT routes (before adjustment) using island stations under a scenario where only the Namyan Ju corridor has island stations requiring new BRT buses.

8.7 BRT station renderings

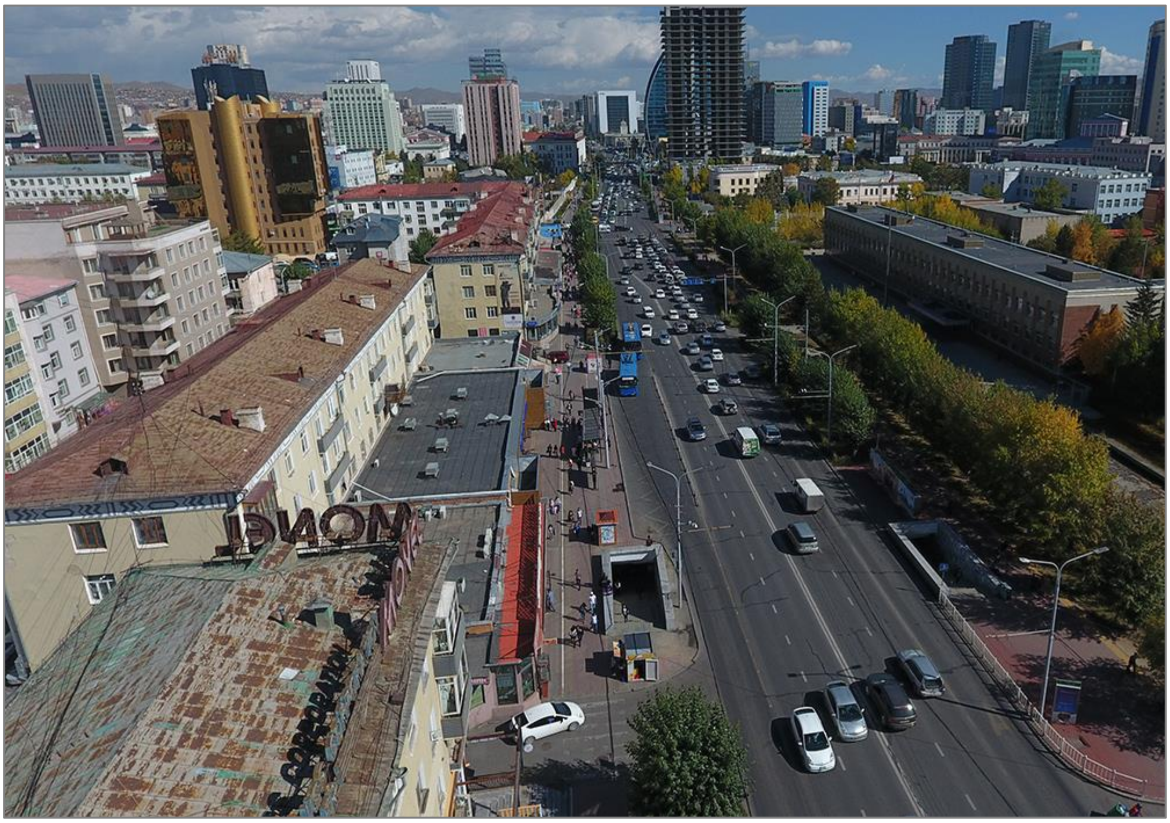
BRT station renderings are shown following, and at http://ubbrt.net/render.htm.

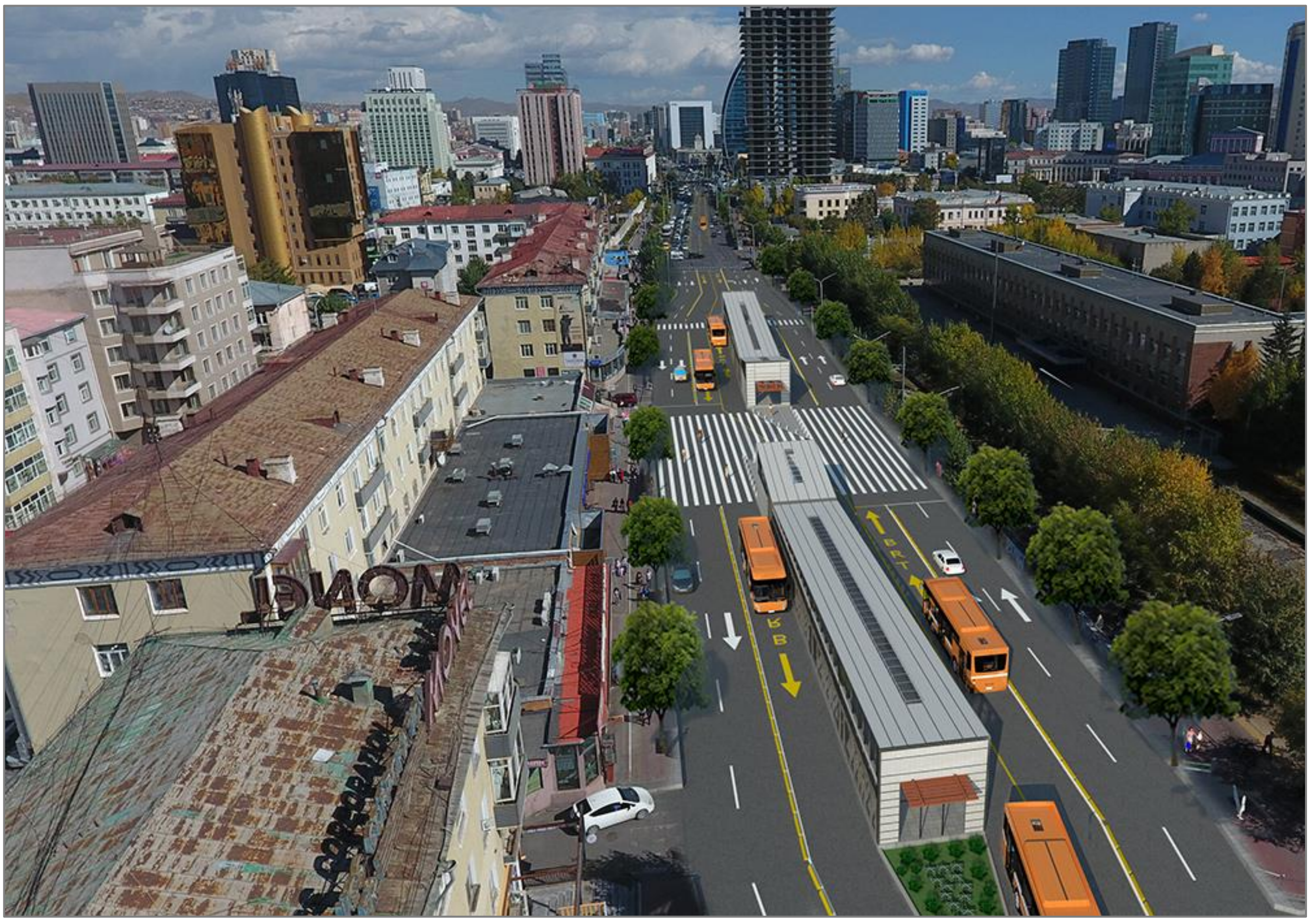
100 айл - current

100 айл – proposed – minimal option without station area improvements

100 айл – recommended – with station area improvements and bike lanes

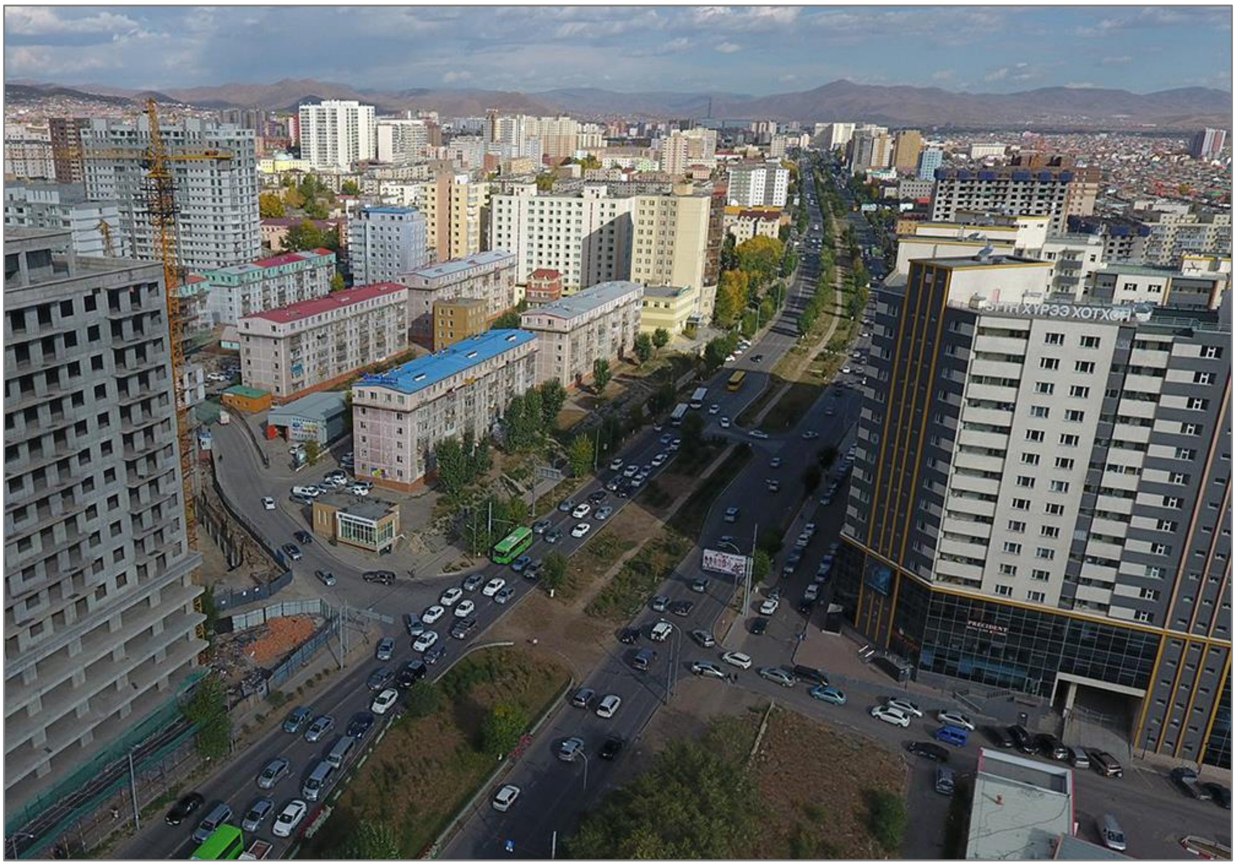
Peace Avenue (station p11 - State Department Store)

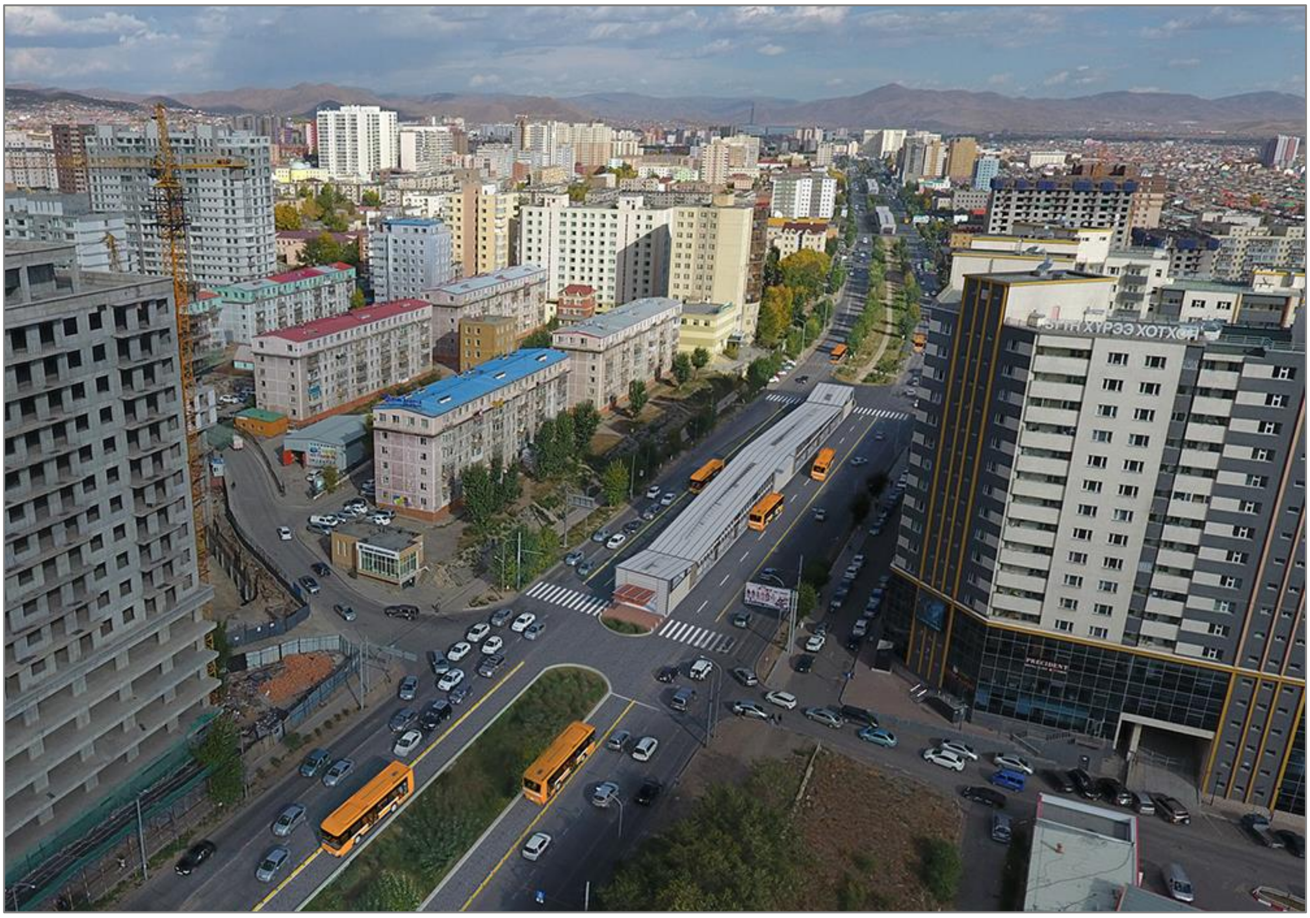




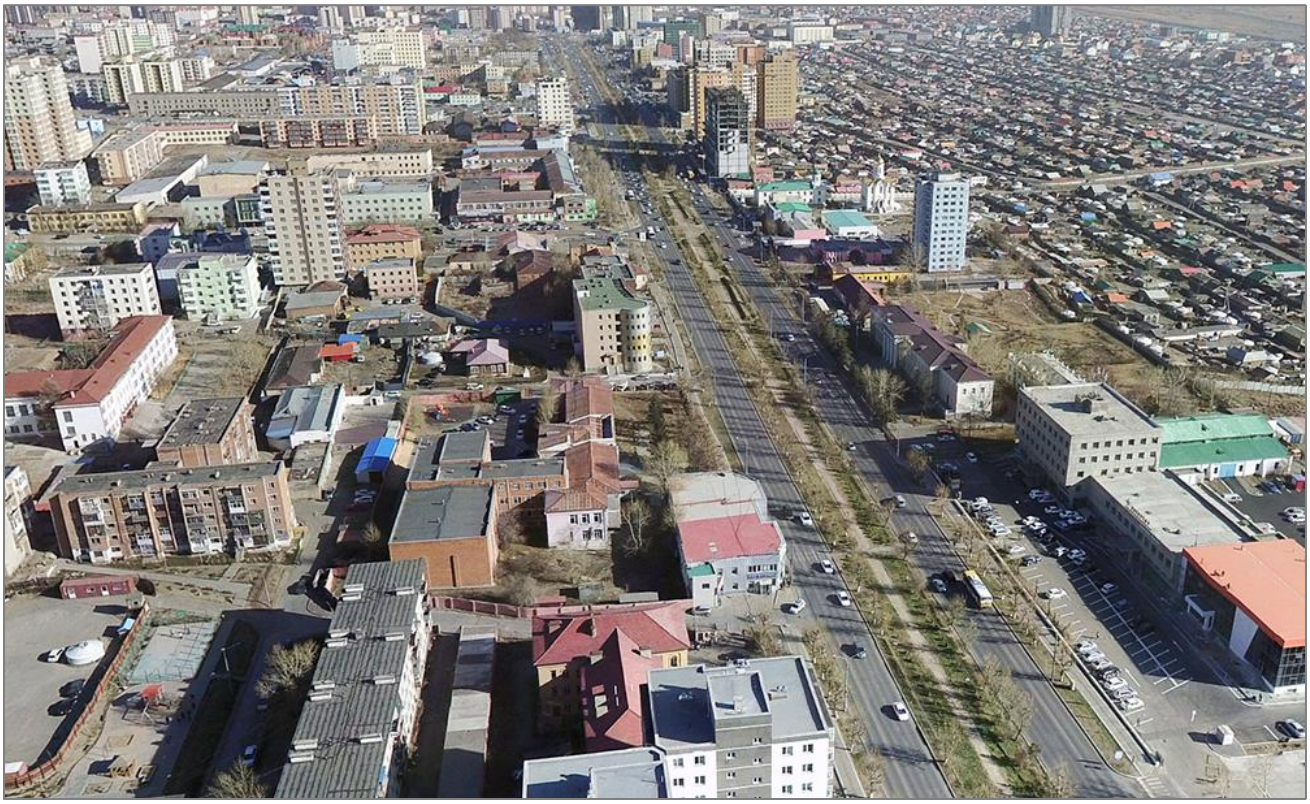
Peace Avenue (station p12 - Baga Toiruu) -- NOTE: the platform location has been changed to either side of the intersection, enabling the pedestrian tunnel to be retained.

Peace Avenue (station p13 - Чингисийн талбай)





Peace Avenue (station p16 - Зүүн 4 зам). Location will need to be adjusted if flyover built.

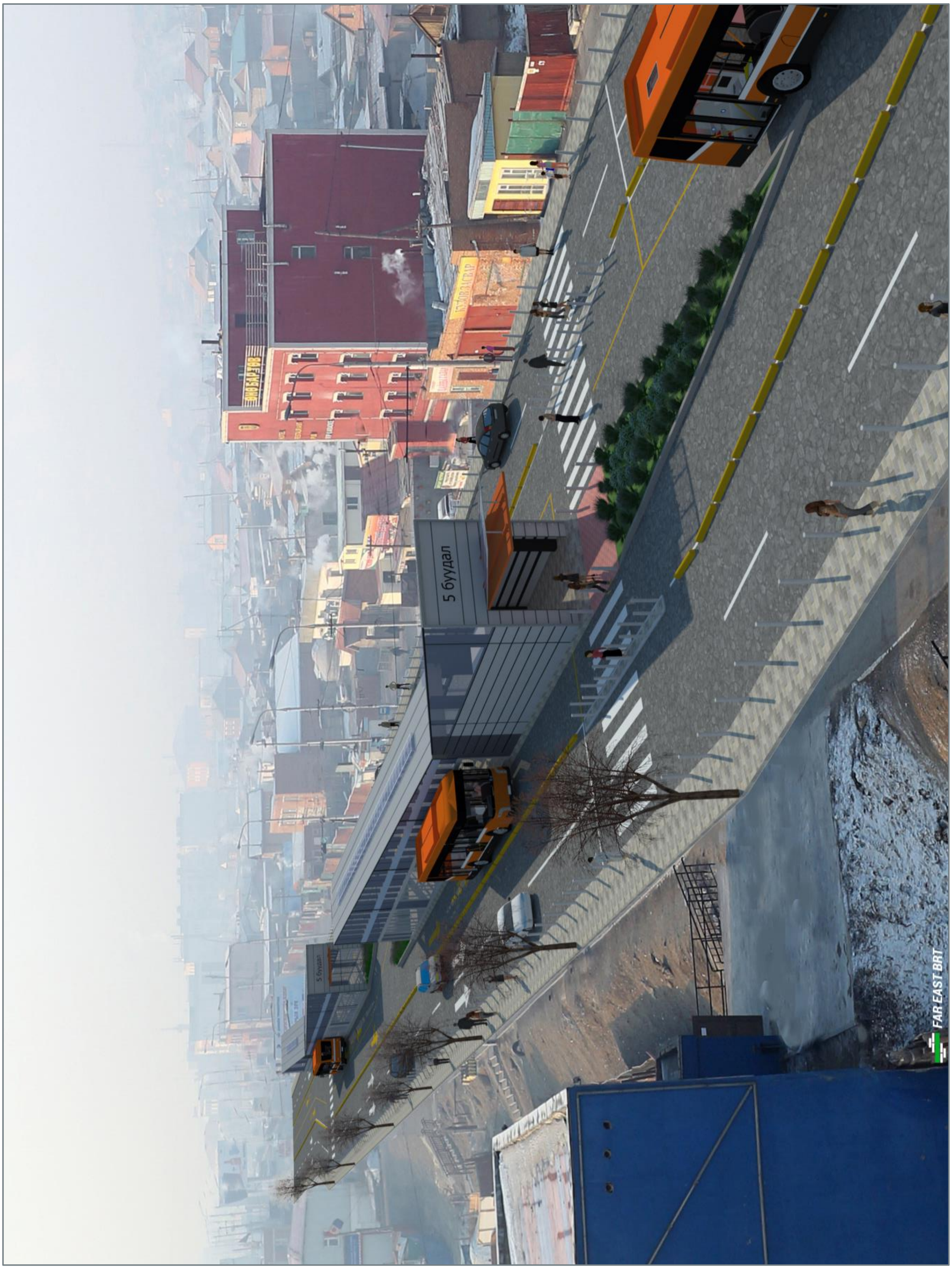


Peace Avenue (station p17 - Жуков)

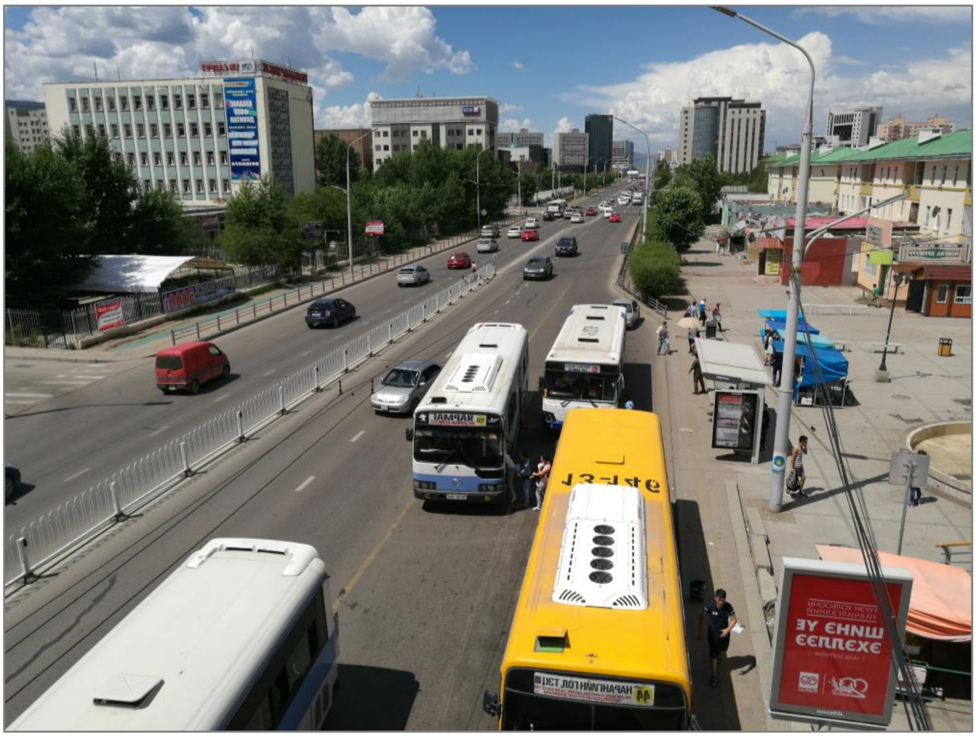
5 буудал - CURRENT

5 буудал – PROPOSED SHORT TERM – low capacity BRT with 2 mixed traffic lanes per direction

5 буудал – PROPOSED MEDIUM/LONG TERM (option 1 – high capacity BRT with no road widening, but only one mixed traffic lane at the station, on one side)



5 буудал – PROPOSED MEDIUM/LONG TERM (option 2 – High capacity BRT with road widening; 2 mixed traffic lanes on both sides, at station)



19-р хороолол - current

19-р хороолол – proposed. Note that this station location has been moved in the revised design.

19-р хороолол – between stations – current

19-р хороолол – between stations – proposed

8.8 BRT station access

8.8.1 Street level access

BRT station access relates closely to the intersection design and the final platform placement, as shown in the BRT corridor design drawings following. In general, the following approaches should be applied:

- Access should be via street level rather than bridges or tunnels.
- Directional stations can have access at the end of each platform, as well as in the middle between the two platforms.
- Island stations with two substops should have access at both ends of the platform.
- Island stations with one substop can have just one access, though in Namyan Ju these stations will require access at both ends of the platform.

Note that in the revised conceptual design of the BRT corridor along Peace Avenue provided in this report, the average station spacing is around 670m, which is more than 100m longer than in the 2011 BRT conceptual design. This longer average station spacing has many advantages in terms of reduced infrastructure cost, less difficult implementation (noting that the BRT station area is generally the most difficult place to implement BRT), and faster BRT speeds. The main drawback, however, is that passengers need to walk further to access the BRT stations.

This drawback of requiring passengers to walk further is greatly reduced and even eliminated when the station access to both sides of the platform is considered. For the directional stations, most stations have platform access at both ends of the platform, resulting in four fare collection points for the two platforms, and three pedestrian crossing points (at both ends and in the middle, between the two platforms). This will increase operating costs of the stations by requiring more personnel, and will increase the cost of the stations by requiring more fare gates, but it will result in significant walking distance reductions for passengers entering and leaving the BRT station. The walking distance savings vary by station and according to the concentration of local land uses, but many passengers will save more than 100m per station access/egress.

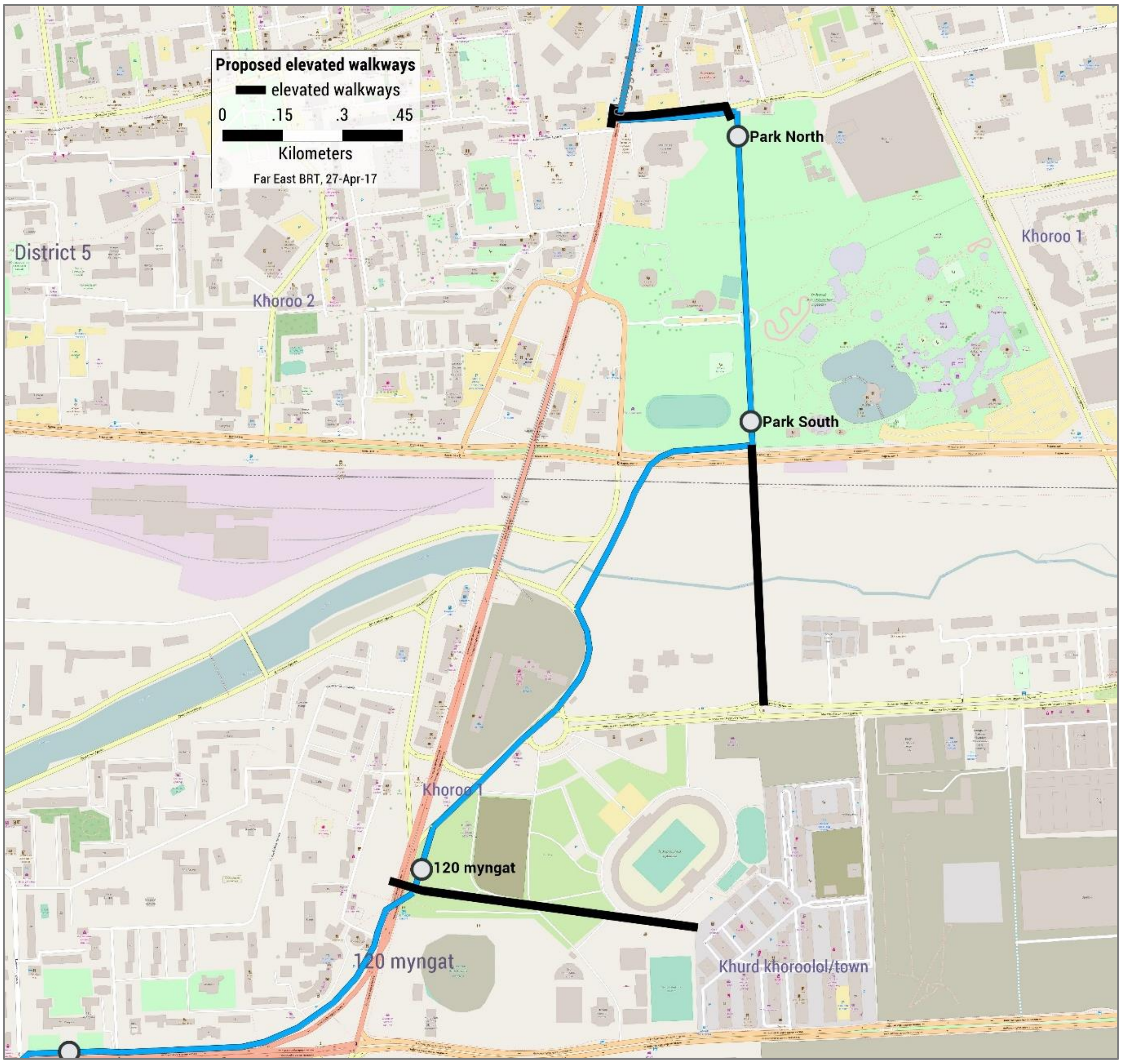
8.8.2 Elevated walkways

Elevated walkways are proposed in three locations with high pedestrian volumes or fairly long walks to BRT stations, all in the phase 2 BRT corridor.

At Bayangol, some passengers will need to walk an additional 200m to access the Park North BRT station, compared to the current bus stop in Chinggis Avenue. (Others will have a shorter walk.) An elevated, heated walkway which connects the BRT to adjacent buildings, will make this additional walking distance attractive to BRT passengers and will support transit-oriented development in the central area.

These elevated walkways should be designed taking into account the desirability of weather protection and possibly even heating in the cold season. The elevated walkways should where possible connection with nearby buildings.

The connections to buildings should be paid for by the building owner or operator, as this will benefit commercial or office activities in those buildings. Kuala Lumpur provides a good model, with the nearly 1km elevated walkway connecting KLCC (the twin towers) with the popular Bukit Bintang area. Petronas, the owner of KLCC, financed, built and operates this air-conditioned walkway. The public and BRT users benefit greatly.



Proposed elevated walkways. The Bayangol / Park North walkway should connect to adjoining buildings, and should be heated in Winter.

Excellent examples of elevated walkway networks connecting to high quality transit can be found in Brisbane (see http://www.transportphoto.net/mtc.aspx?cmtt=2900&cmtc=3), Kuala Lumpur (http://www.transportphoto.net/mtc.aspx?cmtt=2900&cmtc=14), Bangkok (http://www.transportphoto.net/mtc.aspx?cmtt=2900&cmtc=28), and Hong Kong (http://www.transportphoto.net/mtc.aspx?cmtt=2900&cmtc=11). In Kuala Lumpur and Bangkok, the elevated walkway connections to transit were funded by the private sector. In Bangkok, mall owners pay a fee to the Skytrain for the right to connect to stations, in addition to funding the infrastructure construction.

9 BRT vehicles

BRT vehicles was not a major area of analysis of this study, but should be considered in the follow-up planning. Major points regarding BRT vehicles are:

- A rough estimate is that at least 200 new 12m BRT buses with 2 doors in both sides will be required, though this varies according to the operation plan (which has not yet been prepared) and the number of island stations used in the final design. Especially if the southwest connection is used, the actual minimum number of required new BRT buses will be smaller, but a procurement of 200 BRT buses would still be recommended. Directional stations will accommodate some existing buses. Island stations require new BRT buses or retrofitted doors in the left side.
- The total BRT fleet will be a mix of new and existing buses. A very rough estimate is that the phase 1 BRT will require 300-400 buses in total, and that around half of the fleet will be new BRT buses and half will be existing buses. The deployment of existing buses in the BRT will be made based on a selection of the newer buses in better condition. A precise fleet requirement will be devised when the corridor is finalized, the demand model and operational analysis prepared, and the BRT lines optimized.
- Stations can also accommodate 18m BRT buses with 3 doors in both sides. A maximum of around 20 18m BRT buses could be used in the short term, though it is also possible to not have any 18m BRT buses. The 18m BRT buses will have at least three doors in each side of the bus. Stations are designed for 18m BRT buses where needed for capacity reasons. In the short to medium terms, 18m BRT buses will not be needed. The decision to include 18m BRT buses in the short term can be taken during the final operational design, incorporating communications (18m BRT buses can be useful for public outreach and communications purposes), maintenance, roadway conditions and cost considerations.
- A 30-35cm floor and entry height is recommended, which is convenient for both BRT station and off-corridor operation. The rear portion of the bus can have steps, but the front part should have a level floor to enable faster boarding and alighting.
- Stations do not need to be designed to accommodate trolleybuses if, as recommended, the trolleybus infrastructure along Peace Avenue is removed.
- Multiple operators are recommended, likely 3-4 operators each with a fleet of around 100-buses, including a mix of new BRT buses and existing buses, and their own depot facilities. The operators should procure the buses, rather than the government, though there will likely be a subsidy required for the initial procurement. The new BRT buses must meet system identity and other detailed specifications provided by the government. To the users, the new BRT buses will have a single common identity as part of the BRT system.
- The bus procurement should ideally draw from two manufacturers, so that there is competition but also returns to scale and efficiencies in the maintenance regimes.
- Over time, as new buses are procurement, the use of pre-existing non-BRT buses in the BRT system will be phased out, and the entire fleet in the BRT system will be BRT buses.

12m BRT buses with two doors in both sides in Yichang, in the northern part of the corridor where stations do not have overtaking lanes. Ulaanbaatar will have BRT buses with similar dimensions.

In the directional BRT stations in the main BRT corridor in Yichang, a mix of pre-existing and new BRT buses are used. The stations accommodate buses with doors in the right side only, and with doors in both sides.

10 Intersections, stations, and road layout

10.1 Intersection changes with BRT

A new BRT system always has some impact on traffic conditions. A poorly planned design can cause a negative impact on mixed traffic and non-BRT buses, while a good design can not only provide better operational conditions for the BRT buses, but also improve the mixed traffic flow. These improvements to both bus and mixed traffic flow can be achieved where:

- The BRT design does not reduce capacity beyond current capacity levels, so no adverse traffic impacts are felt along the whole corridor.
- The BRT design includes optimization of the intersections along the corridor. Changing from four phases into three or two phases, simplifying the turnings movements, shortening the cycle time and giving more green time for both BRT buses and mixed traffic on the main straight direction will generally result in more efficient intersection operation.

The most serious potential bottlenecks in any BRT corridor are usually the signalized intersections. The following tables show in general terms how different numbers of signal phases and the numbers of traffic signals will impact the BRT bus delay and speed.

BRT delay in different numbers of signal phase

	Seconds		
Phases	Cycle	Red	BRT Delay
2	60	30	7
3	90	60	20
4	120	90	34

Currently the major intersections along the phase 1 BRT corridor are four phases. Generally, the easiest and least expensive solution to fast traffic speeds along the corridor is to improve the efficiency of the intersections through eliminating the direct left turnings, reducing the traffic signals from four phases into only two phases, and using other locations to make left turns.

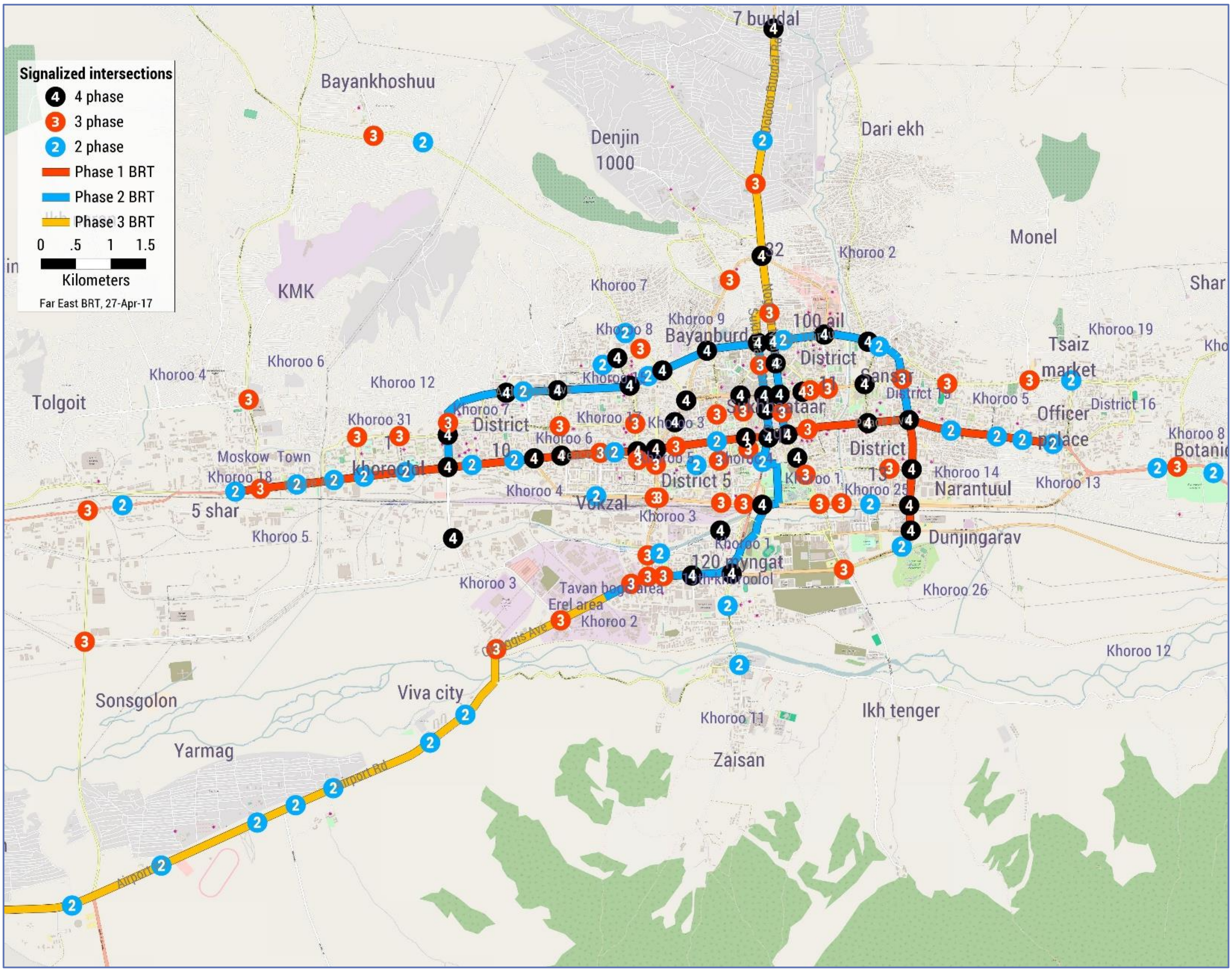
For all the intersections with four phases, we suggest reducing to two or three phases depending on the left turn volumes.

A left turn for mixed traffic is accomplished through a u-turn combined with the station alignment and pedestrian crossing which is proposed for several of the intersections along the corridors. When pedestrians are crossing the road and accessing the BRT station, the mixed traffic makes u-turn.

The current traffic signal configuration in Ulaanbaatar is extremely inefficient and is the main cause of the congestion and slow bus speeds in the city.

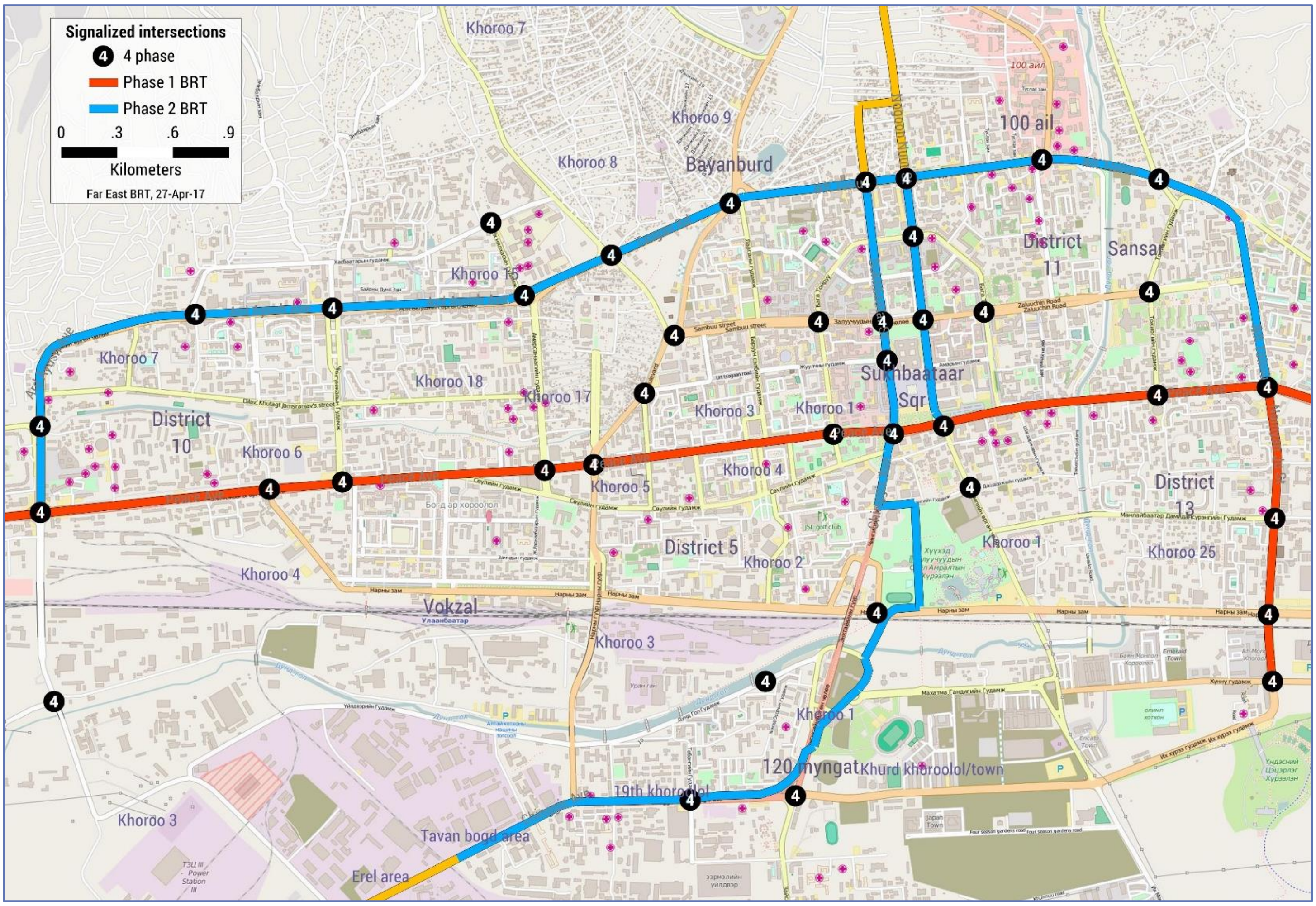
BRT is incompatible with four-phase intersections, and one of the most challenging tasks in Ulaanbaatar is to change all four-phase intersections along the BRT corridor to a maximum of three phases and preferably two phases.

These changes will improve BRT performance as well as dramatically improve conditions for mixed traffic.



Signalized intersections in Ulaanbaatar, also showing the phase 1 and phase 2 BRT corridors. Data provided by the traffic control centre in February 2016.

Detailed proposed intersection phases developed during December 2016 and January 2017 are provided below for the phase 1 BRT corridor and the central area. All four phase intersections along the BRT corridor were changed to either two or three phases.



Four-phase intersections in Ulaanbaatar in February 2016. 13 4-phase intersections along the phase 1 BRT corridor and further 10 4-phase intersections along the phase 2 corridor need to be changed.

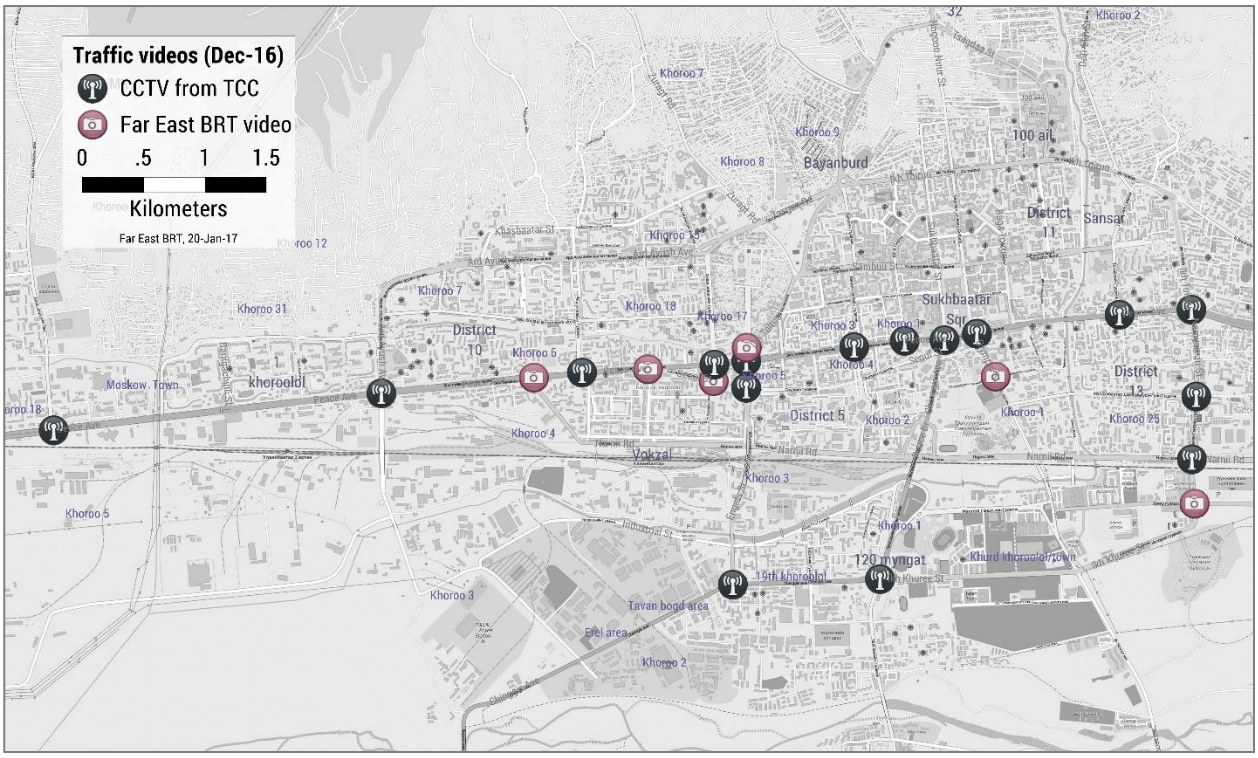
Four phase intersections along the different BRT corridors. All need to be changed.

Corridor	4-phase intersections
Peace Ave & Namyan Ju (phase 1)	13
Ikh Toiruu & 3/4 khoroolol & 120 (phase 2)	15
Doloon Buudal and Airport Rd (phase 3)	2

10.2 Data collection

Videos of intersections were carried out by the traffic control center in November and December 2016, and supplemented by videos from Far East BRT staff in December 2016, for those intersections not covered by the traffic control center videos.

The data was processed by Far East BRT in Guangzhou during December 2016. The location of the video counts is shown following.



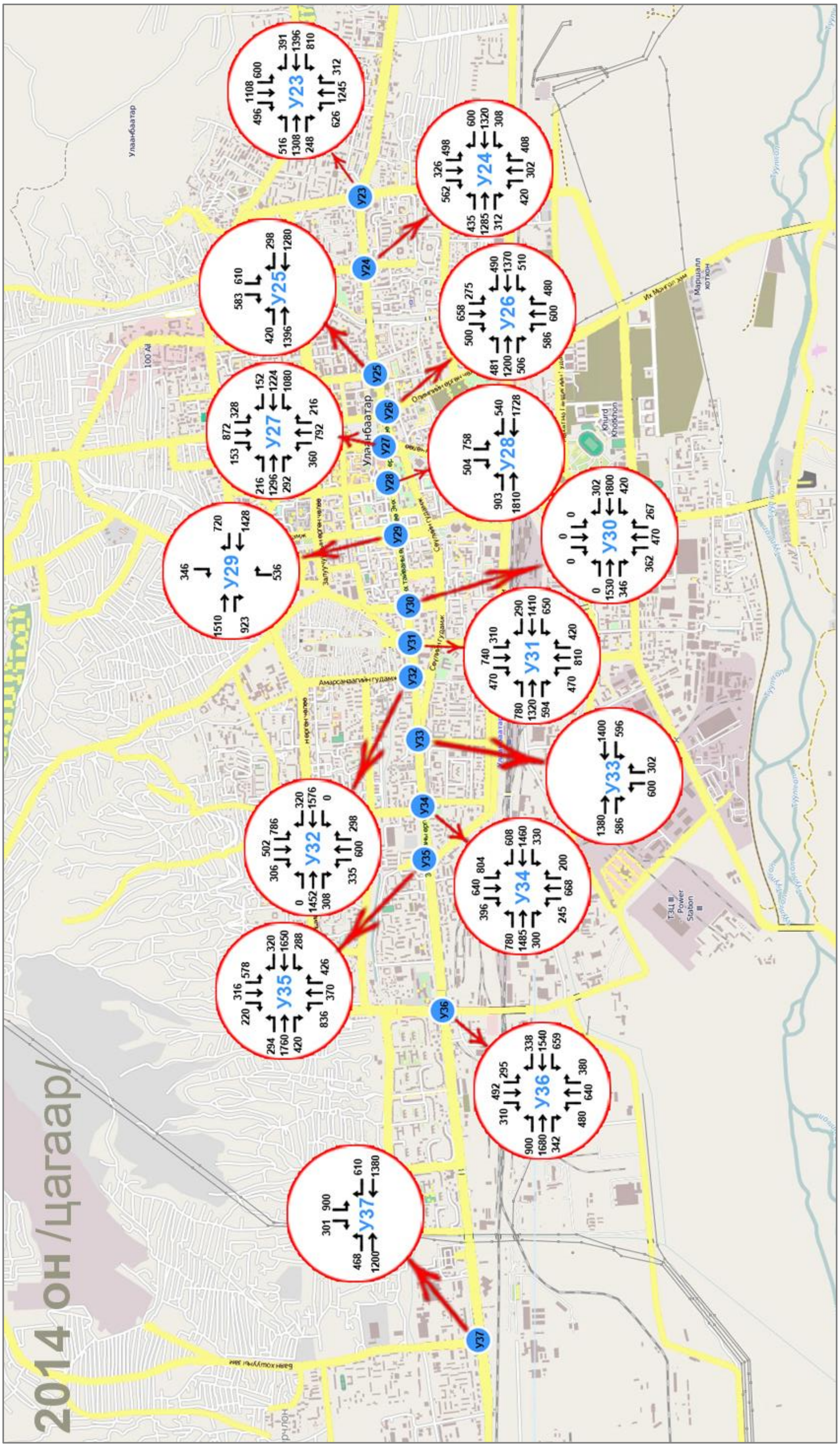
Video counts from the traffic control center (November and December 2016) and by Far East BRT personnel using handheld or tripod-based cameras (December 2016).

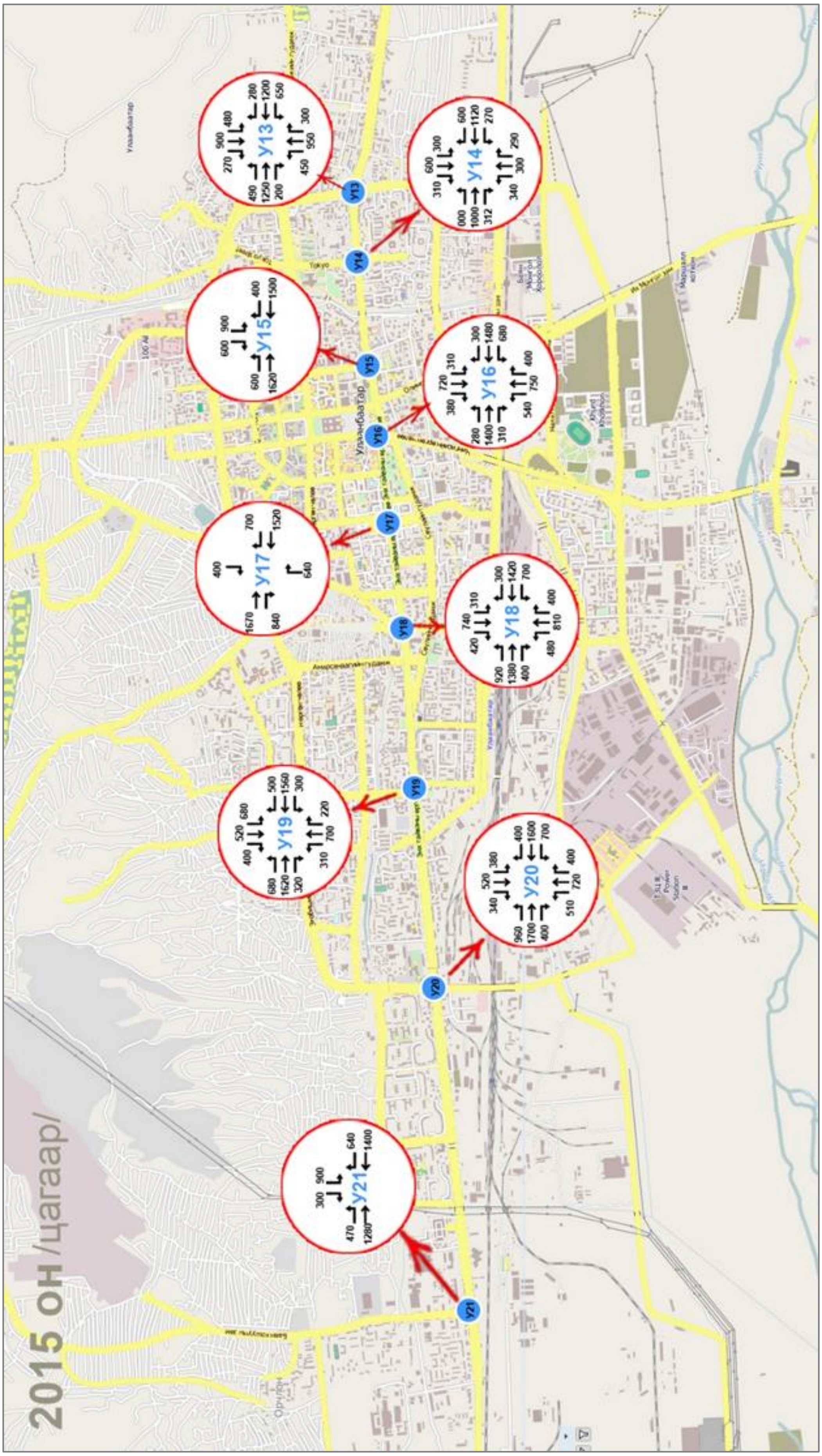
A range of different camera options were trialed prior to the Ulaanbaatar data collection, including iPhone and Android phones, digital cameras, and a Theta S 360 camera, including various combinations of lighting and tripods.

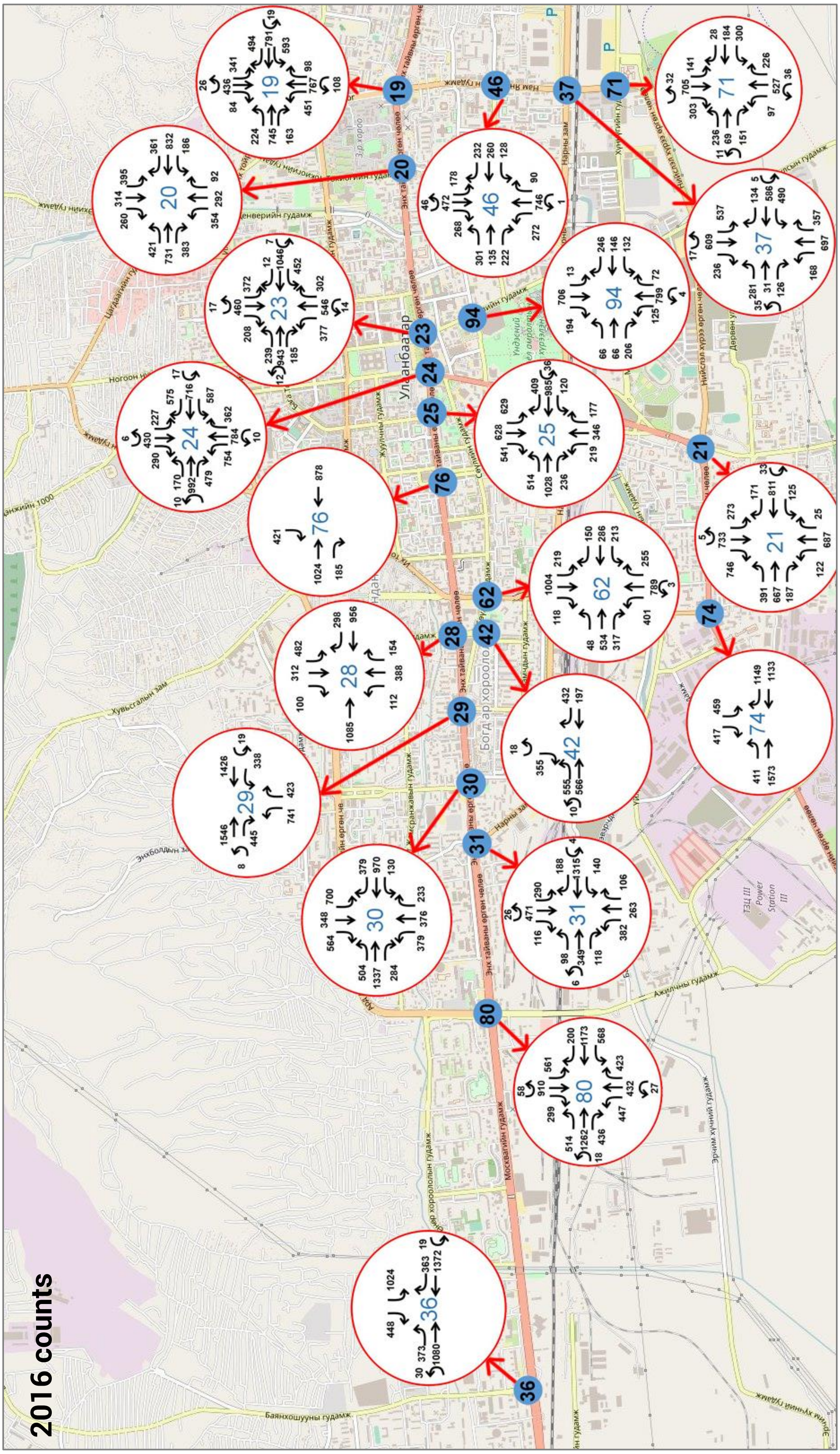
After testing and comparing all of the options, it was decided that the best option was handheld iPhone or Android photos combined with small tripods, and these were used for the Far East BRT and TA team videos identified above.

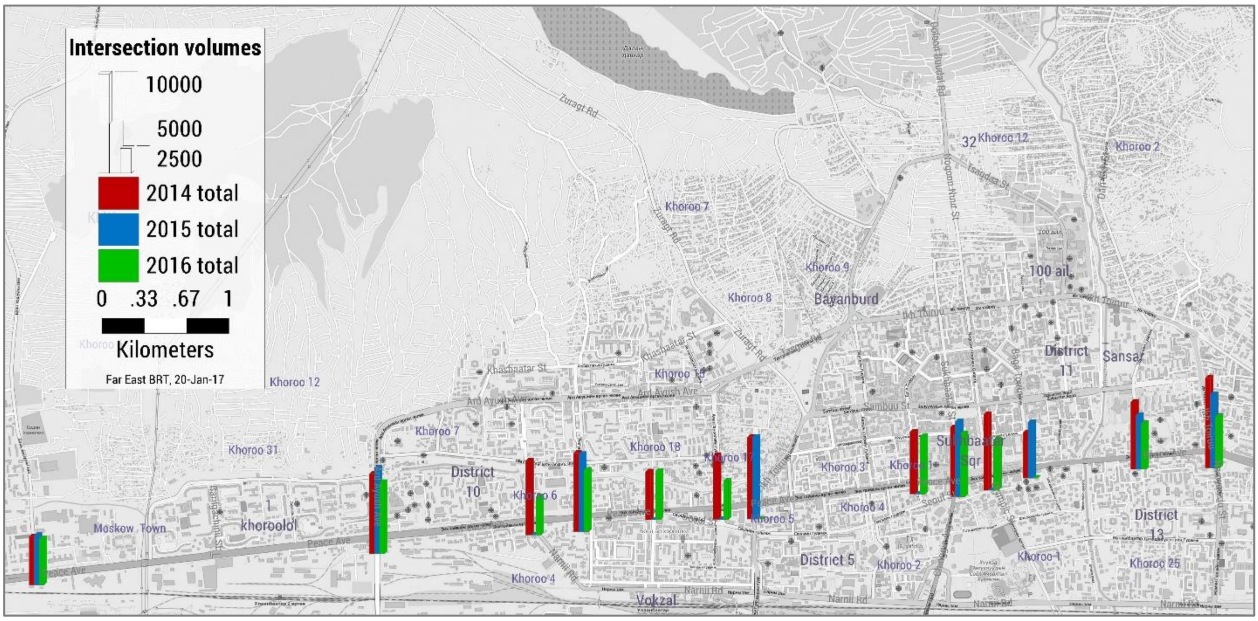
Intersection volume counts

It was found that the intersection volumes for 2016 were generally lower than for 2015 and 2014. The 2015 and 2014 data was provided by the TA office and sourced from earlier counts from the traffic control center, including all-day counts with a larger sample size than was collected in 2016. The 2014 and 2015 data for the Peace Avenue corridor is shown following, along with a comparative chart of the total intersection movements.

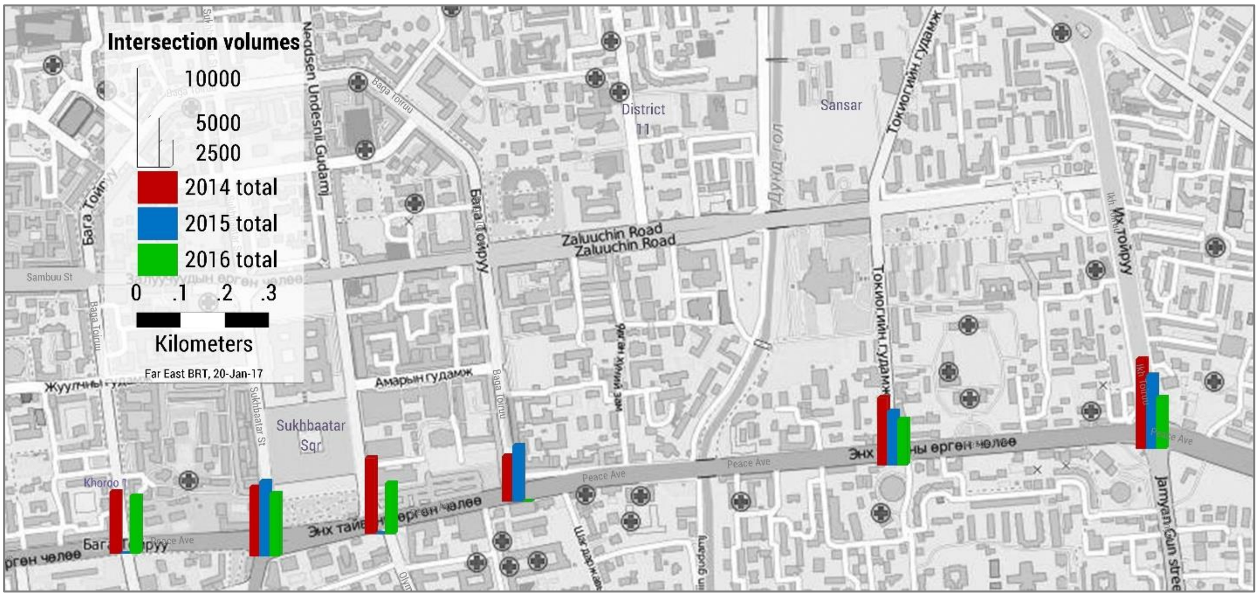

2014 он /цагаар/
У23
У24
У25
У26
У27
У28
У29
У30
У31
У32
У33
У34
У35
У36
У37


2015 ОН /цагаар/


2016 counts


Intersection volumes
10000
5000
2500
2014 total
2015 total
2016 total
0 .33 .67 1
Kilometers
Far East BRT, 20-Jan-17
Zuragt Rd
Khoroo 7
Khoroo 9
Khoroo 8
Bayanburd
Khoroo 12
Khoroo 2
100 ail
District 11
Sansar
Khoroo 31
District 10
Moskow Town
District 5
District 13
Khoroo 25
Vokzal


Intersection volumes
10000
5000
2500
2014 total
2015 total
2016 total
0 .1 .2 .3
Kilometers
Far East BRT, 20-Jan-17
Khasbaatar St
Ard Ayush Ave
Dilav Khutagt Jamsranjav's street
District 10
Khoroo 6
Khoroo 18
Khoroo 17
Khoroo 15
Peace Ave
Seoul St


Intersection volumes
10000
5000
2500
2014 total
2015 total
2016 total
0 .1 .2 .3
Kilometers
Far East BRT, 20-Jan-17
Neridsen Undesnii Gudamj
District 11
Sansar
Zaluuchin Road
Sambuu St
Sukhbaatar Sqr
Peace Ave
Jamyan Gun street

The total intersection volume figures indicate that the 2014, 2015 and 2016 intersection count varies substantially. In very broad terms, the 2014 counts are highest, followed by the 2015 data, and the 2016 data substantially lower. Possible reasons could be:

1. Errors in data collection or processing
2. Variation in the number of samples
3. Weather conditions at the time of sampling
4. Oversaturation of intersections in the peak hour, leading to artificially low flows (this is thought to be a major factor in the 2016 data)
5. A combination of all of these factors.

The most likely reason is 5, a combination of these factors. Though the weather was clear for the 2016 data, the video counts followed a two-week period of heavy snowfall and associated ice, and it is possible that this contributed to lower intersection throughput at the time of the video counts.

At the East Cross count location (Peace Ave / Namyan Ju), the 2014 data appeared to be unrealistically high, indicating a likely error in the data collection or processing. When the 2014 data for this intersection was used, it was impossible to calibrate the data such that the intersection saturation was 100% or less. The 2015 data was less than the 2014 data, though more than the 2016 data. Since this data could be calibrated, it was used for the analysis below.

In general, the highest year values were used for the intersection analysis. Where values were close, the 2015 data was preferred to the 2014 data. In only one location was the 2016 data used for analysis, P Jasray St and Peace Avenue intersection, because 2015 data was not available, and this was the only location where the 2016 data was higher than the 2014 data.

Since the focus in this study is on the comparative aspects of proposed changes in intersections, in particular whether the intersection capacity is degraded or improved by BRT implementation (rather than the absolute values), these variation factors are not considered particularly problematic. For follow-up analysis and simulations especially in the central area, more samples should be collected, including peak and off-peak periods, as part of a more detailed analysis of traffic circulation.

10.3 BRT concept design

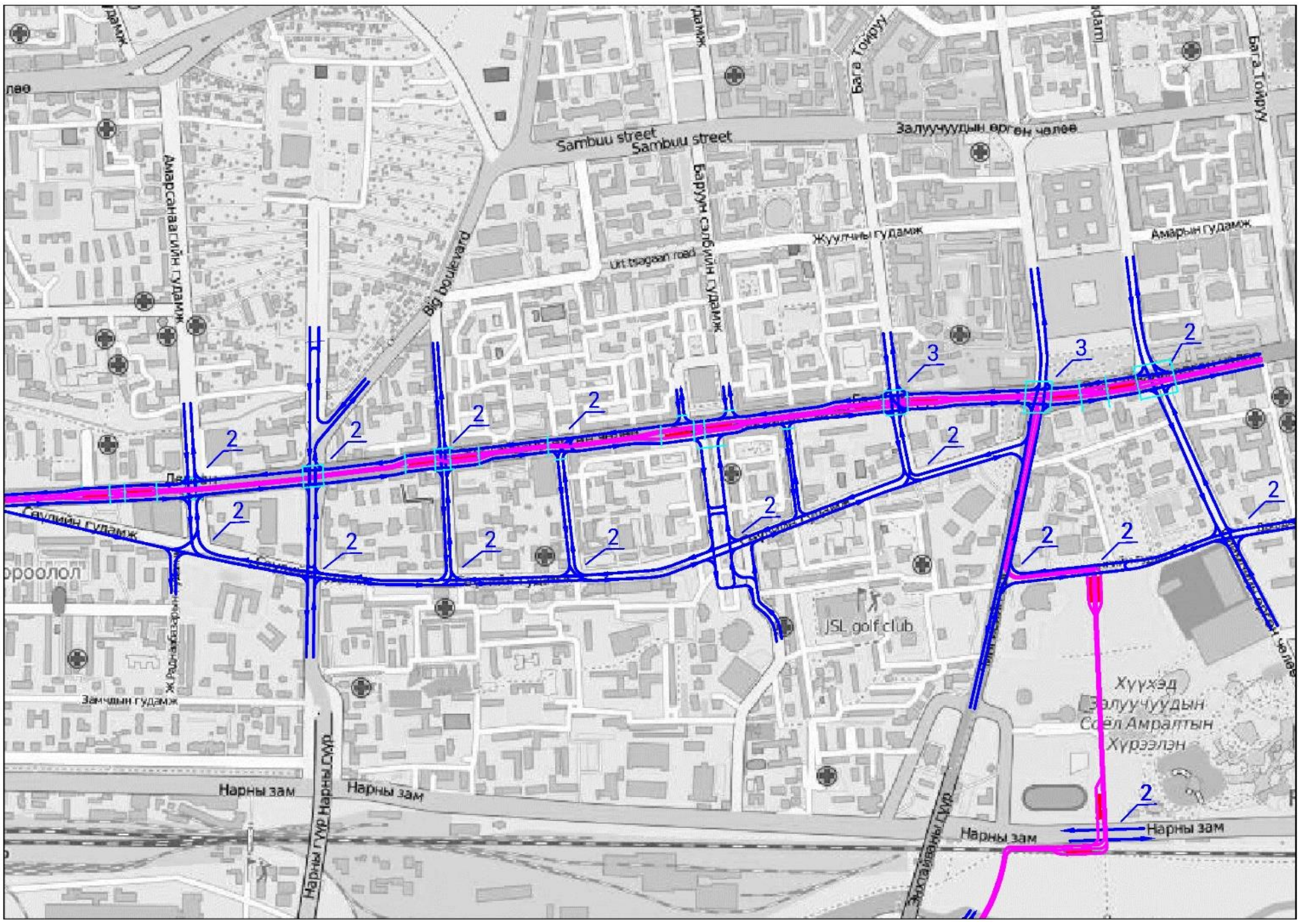
A BRT concept design including intersections, BRT stations and road layout for the entire Peace Avenue corridor is provided following. The intersections, stations, analysis and road layout proceeds from west to east along Peace Avenue covering the proposed BRT corridor along Peace Avenue.

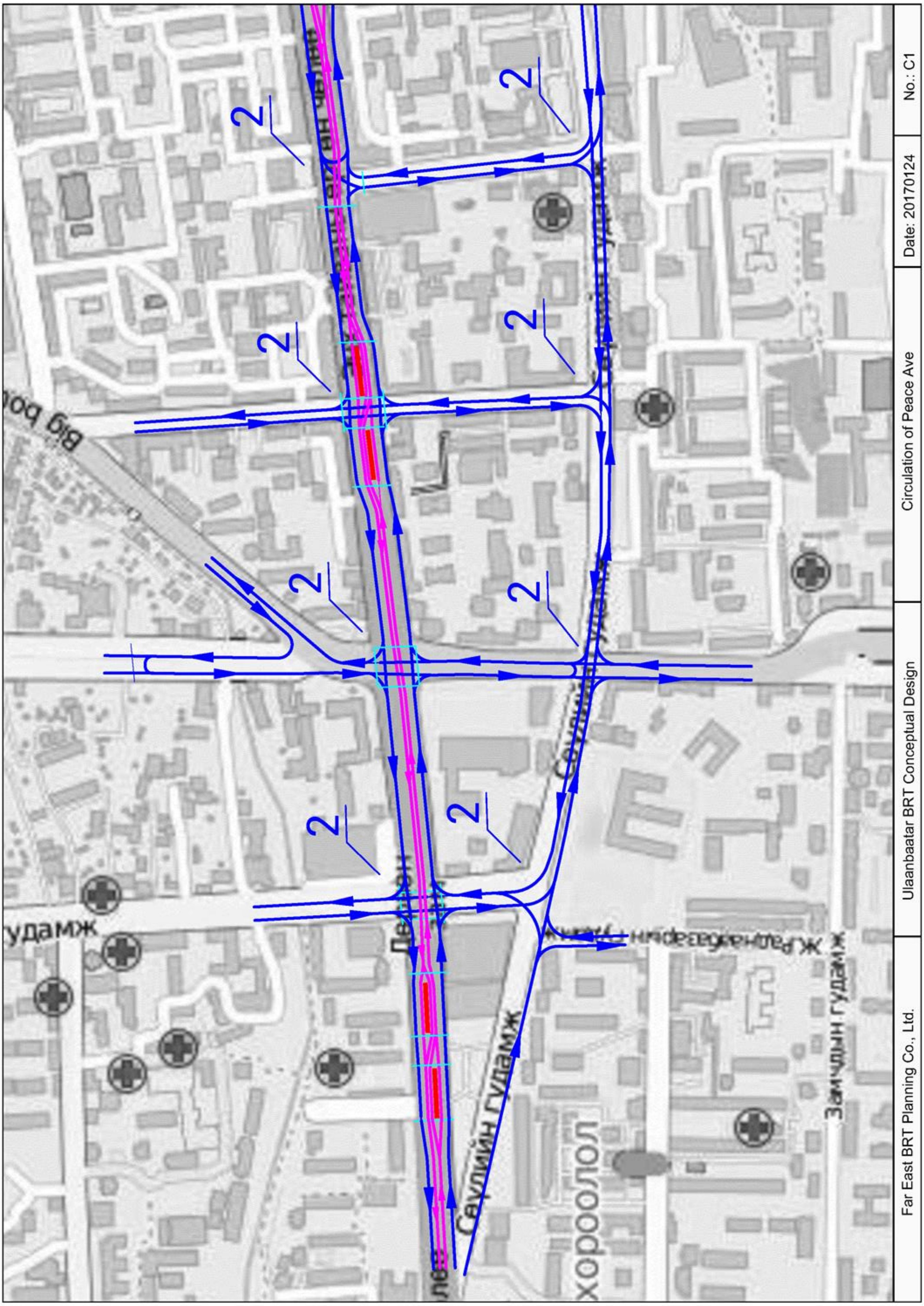
The intersections of Baga Toiruu (east) and Tokyo Street are omitted from this analysis, as more work is required to finalize the design of these two intersections and the associated BRT stations.

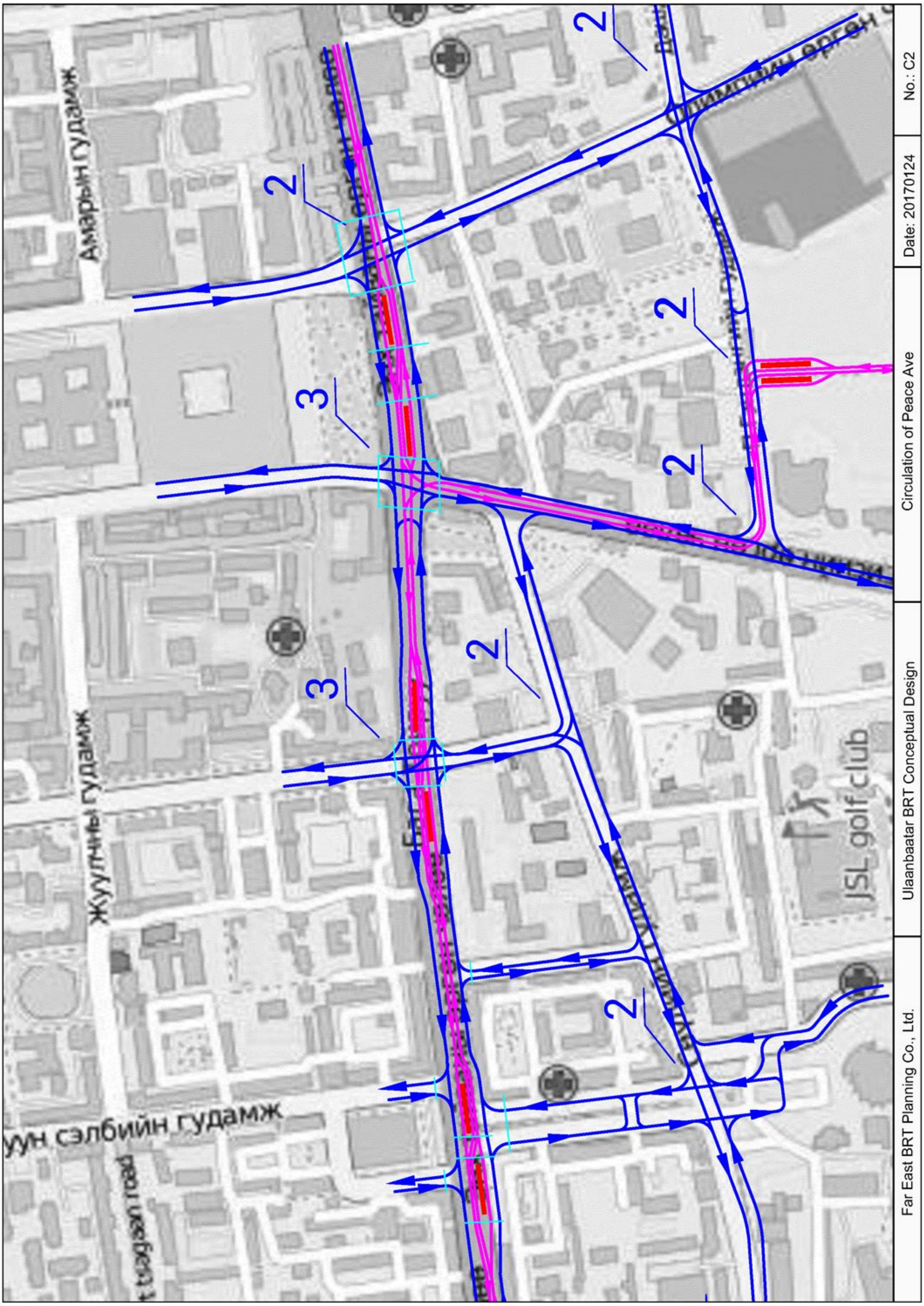
Note that in general, more design and planning work is required, as this is a preliminary concept. For example, it is highly likely that at least for some portions of Peace Avenue, especially west of West Cross intersection and east of East Cross intersection, some non-BRT buses will continue to operate in the BRT corridor, and will require bus stops. These bus stop locations are not indicated in the concept design below, but will need to be considered during the detailed design stage. Several of the intersections and stations require follow-up analysis and design work.

10.4 Traffic circulation with BRT

The proposed traffic circulation with BRT and incorporating the major proposed intersection changes is illustrated following. These circulation changes are reflected in the road, intersection and BRT station layout and access diagrams in the next section. Arrows refer to the traffic flow, and the numbers refer to the intersection phases.



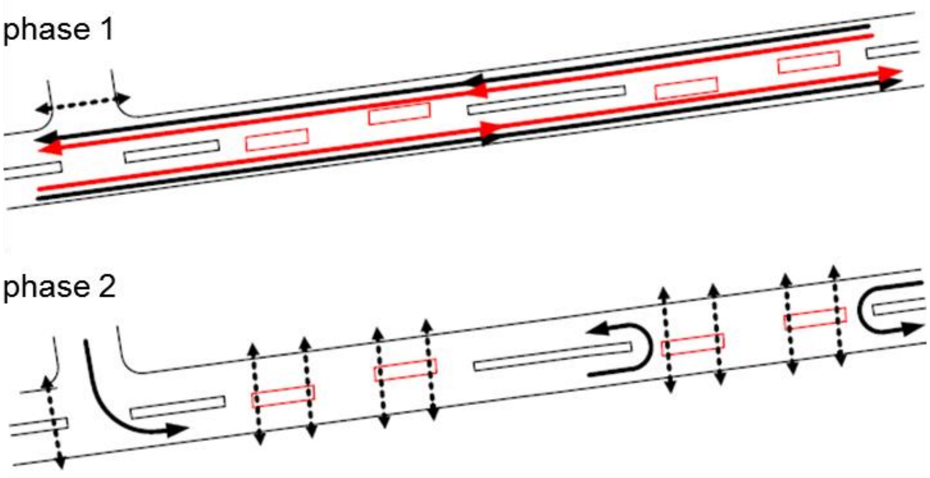

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Circulation of Peace Ave
Date: 20170124
No.: C1
Саулийн гудамж
Замчдын гудамж

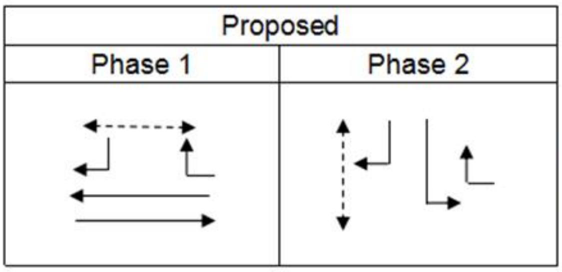

Амарын гудамж
Жуулчны гудамж
JSL golf club
Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Circulation of Peace Ave
Date: 20170124
No.: C2

10.5 Road, intersection, and BRT station layout

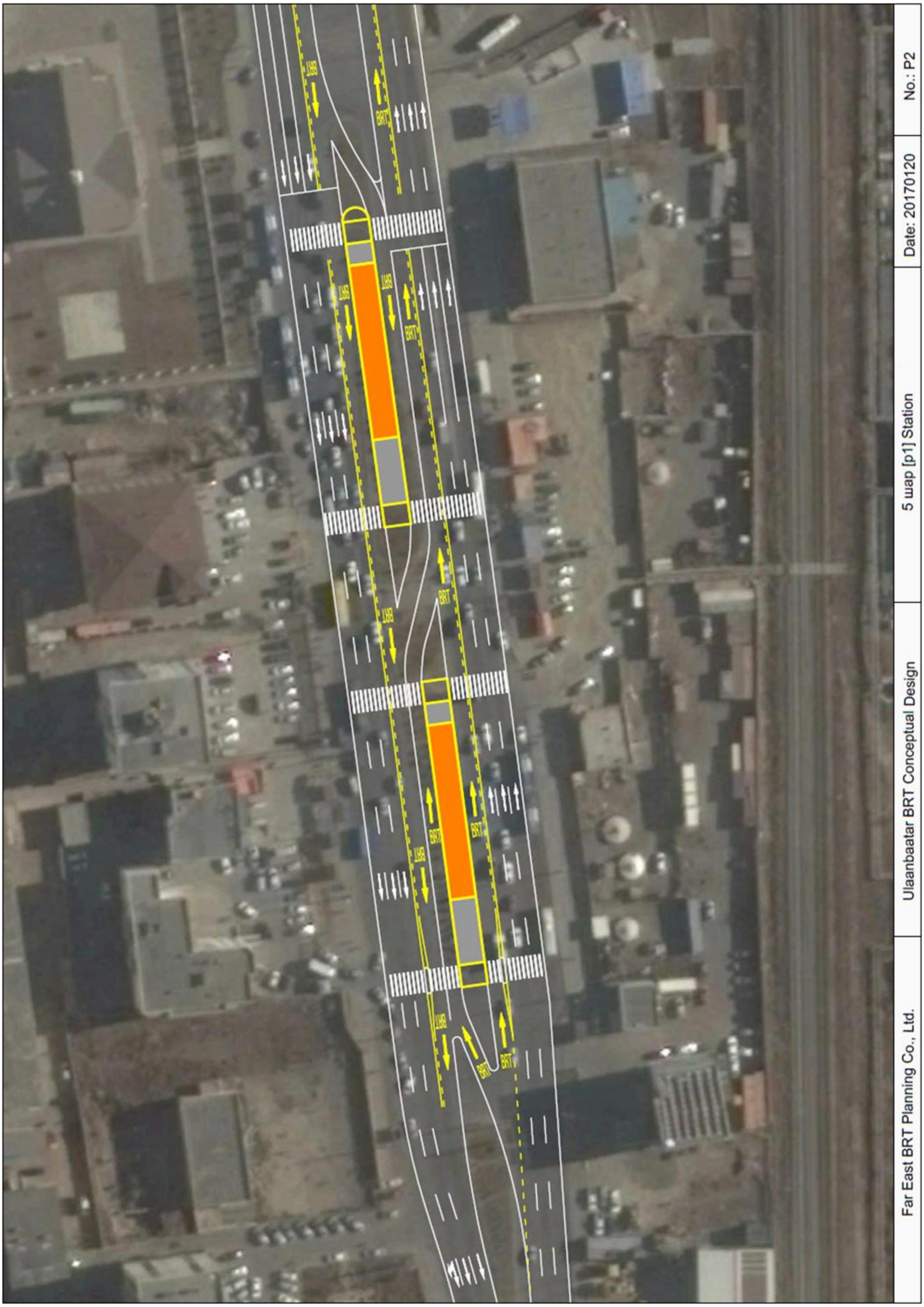
Intersection Peace Ave/ Shonnn
5 шар [p1] Station and Драгон [p2] Station

linked signals of intersection and 2 stations





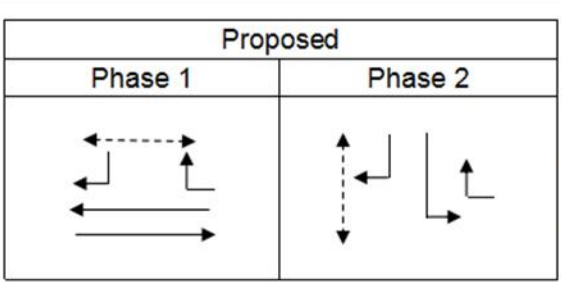

BRT
No.: P1
Date: 20170120
5 шар [p1] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.

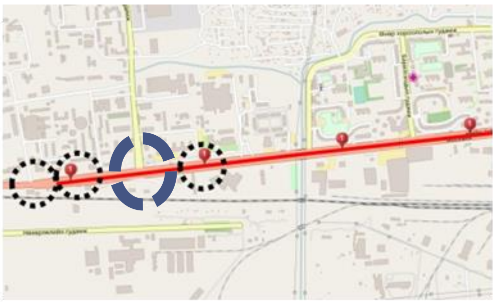

No.: P2
Date: 20170120
5 шар [p1] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

Intersection Labor Union St and Peace Avenue

The design for Labor Union St intersection with Peace Avenue was not carried out, but the same approach used in Shonnn can be used to improve the intersection performance with the BRT.

Left turns from west to north will u-turn on Peace Avenue, with the u-turn combined with BRT station access.





Current traffic volume (pcu)				
2015				
From	Left	Straight	Right	Total
North	900		300	1200
East		1400	640	2040
West	470	1280		1750
Total	**1370**	**2680**	**940**	4990

Current traffic volume - minus BRT buses				
2015				
From	Left	Straight	Right	Total
North	900		300	1200
East		1240	640	1880
West	470	1120		1590
Total	**1370**	**2360**	**940**	4670

Conclusion:

The analysis based on the traffic count data from 2015 (which for this intersection shows slightly higher overall volumes than the 2016 and 2014 data) shows that the proposed change from 3 phase to 2 phase at the intersection of Peace Avenue with Labor Union St provides significant improvements to the intersection capacity and performance.

Saturation falls from 72% (3 phases, without BRT) to 58% (2 phases, with BRT).

Present 3 phase						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	west	left	470	2	3700	13%
2	west	str	1280	2	3700	35%
	east	str	1400	3	5550	25%
	max					35%
3	north	left	900	2	3700	24%
	total					**72%**

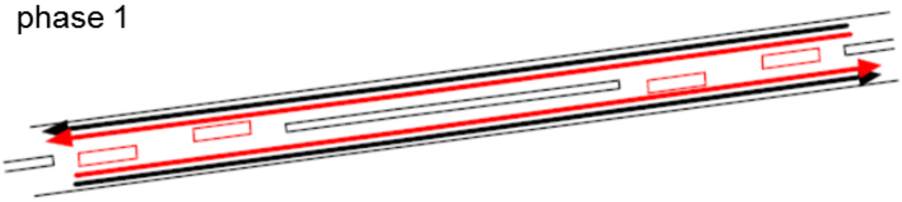
Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	west	str	1590	3	5550	29%
		brt	160	1	1850	9%
	east	str	1240	2	3700	34%
		brt	160	1	1850	9%
	max					34%
2	north	left	900	2	3700	24%
	total					**58%**


No.: P3
Date: 20170120
Драгон [p2] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

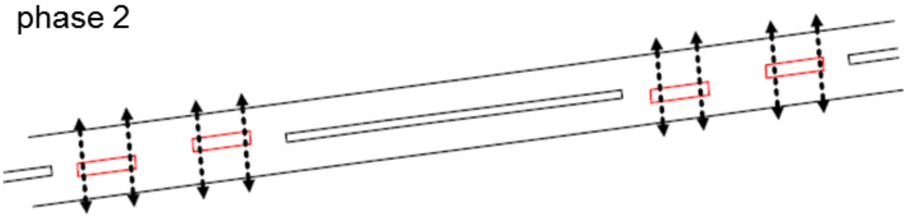
32-р байр [p3] Station and Хар хорин [p4] Station

linked signals of 2 stations

phase 1



phase 2

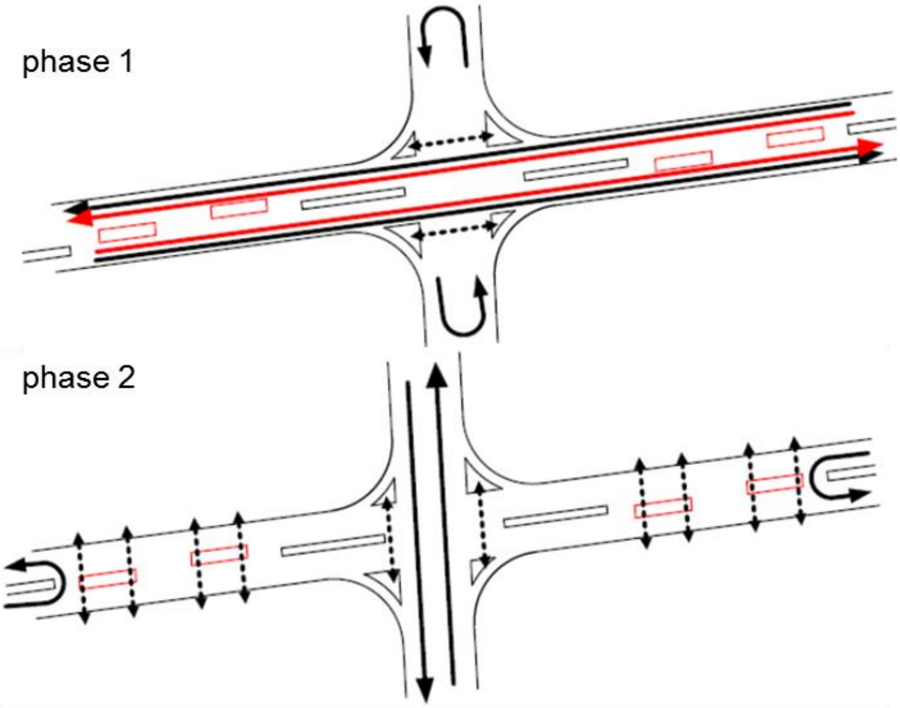


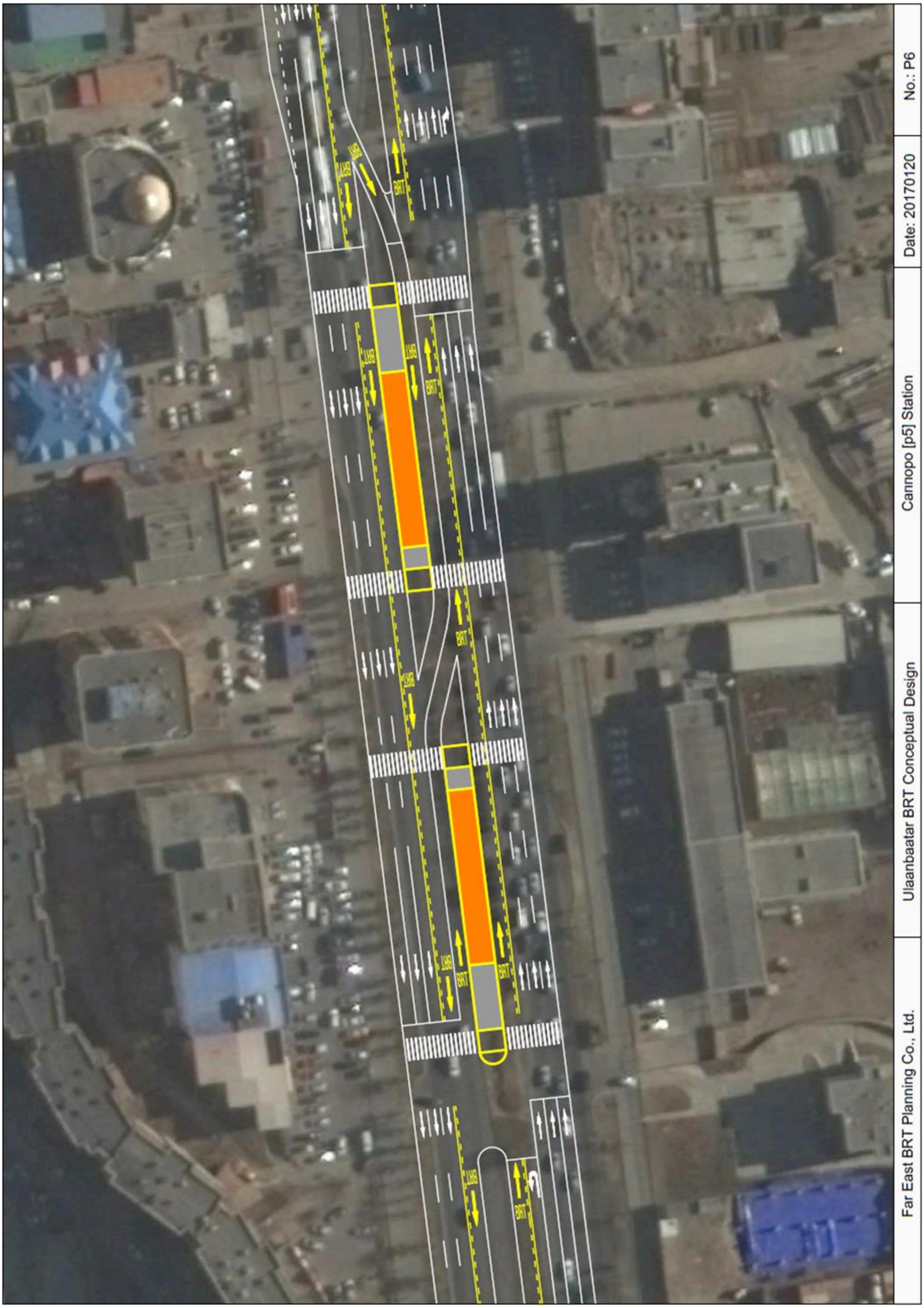

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
32-р байр [р3] Station
Date: 20170120
No.: P4
BRT

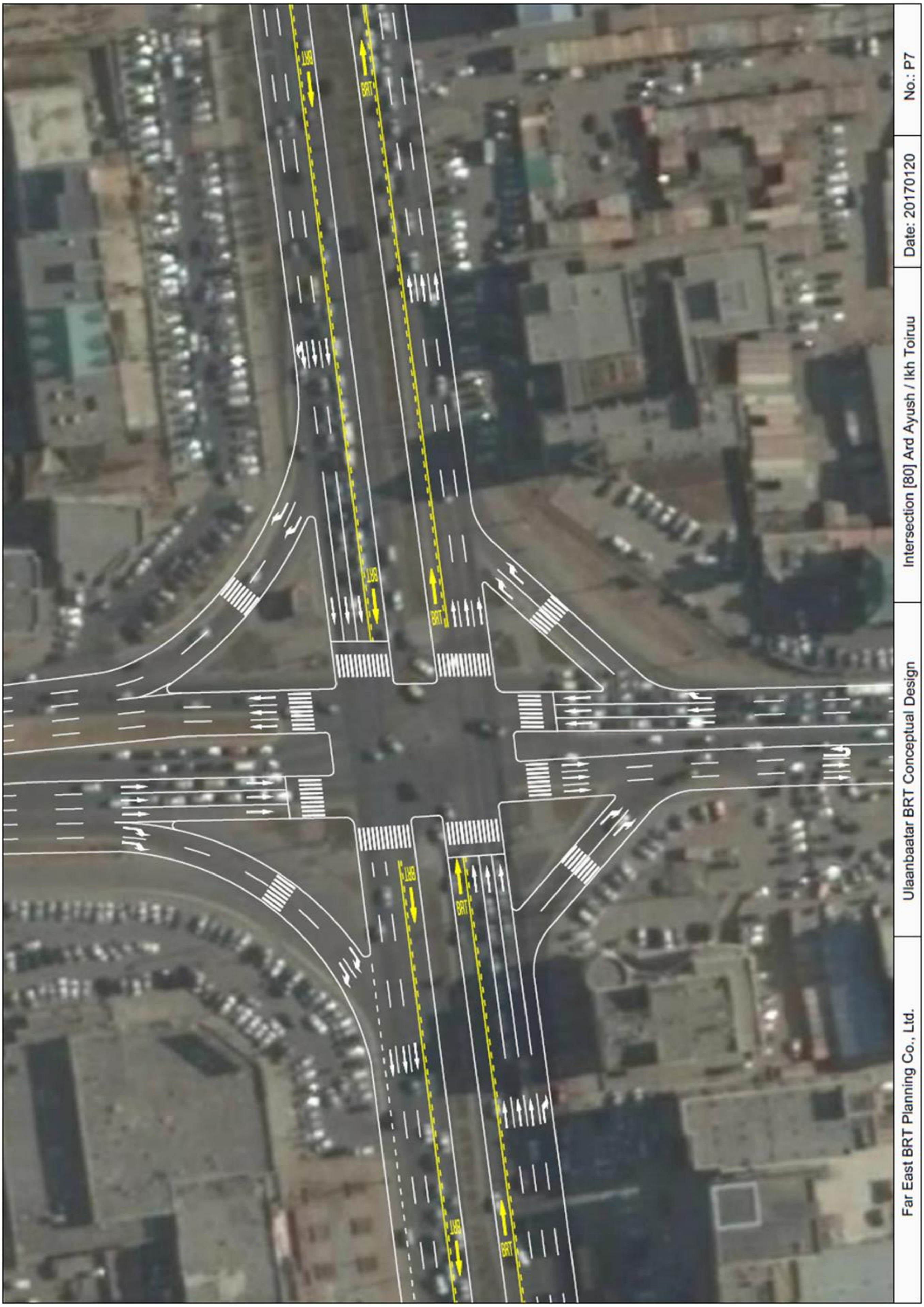

No.: P5
Date: 20170120
Хар хорин [p4] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

Intersection [80] Ard Ayush / Ikh Toiruu
Саппоро [p5] Station and 3-р эмнэлэг [p6] Station

linked signals of intersection and 2 stations




BRT
No.: P6
Date: 20170120
Cannopo [p5] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.


BRT
Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [80] Ard Ayush / Ikh Toiruu
Date: 20170120
No.: P7


N
Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [80] Ard Ayush / Ikh Toiruu
Date: 20170120
No.: B1

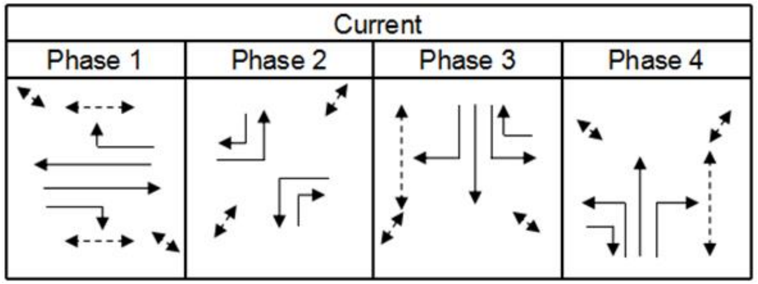
[80] Intersection Ard Ayush / Ikh Toiruu

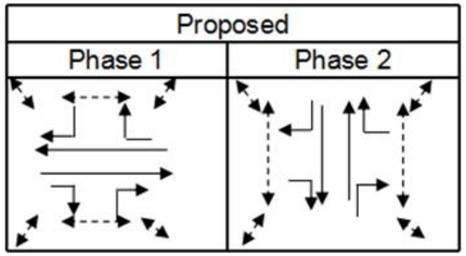
Current traffic volume (pcu)

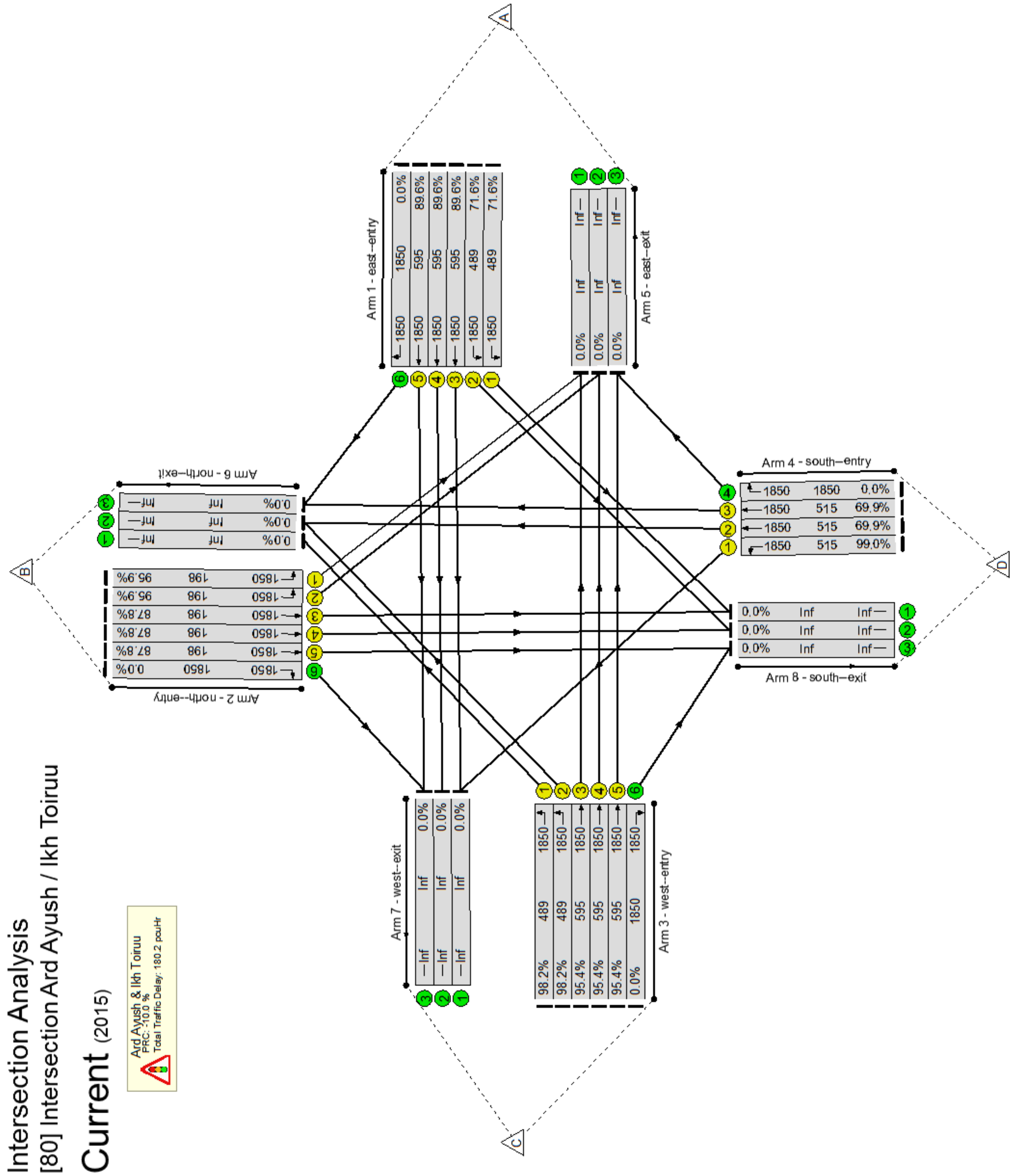
2014				
From	Left	Straight	Right	Total
North	295	492	310	1097
South	480	640	380	1500
East	659	1540	338	2537
West	900	1680	342	2922
Total	2334	4352	1370	8056

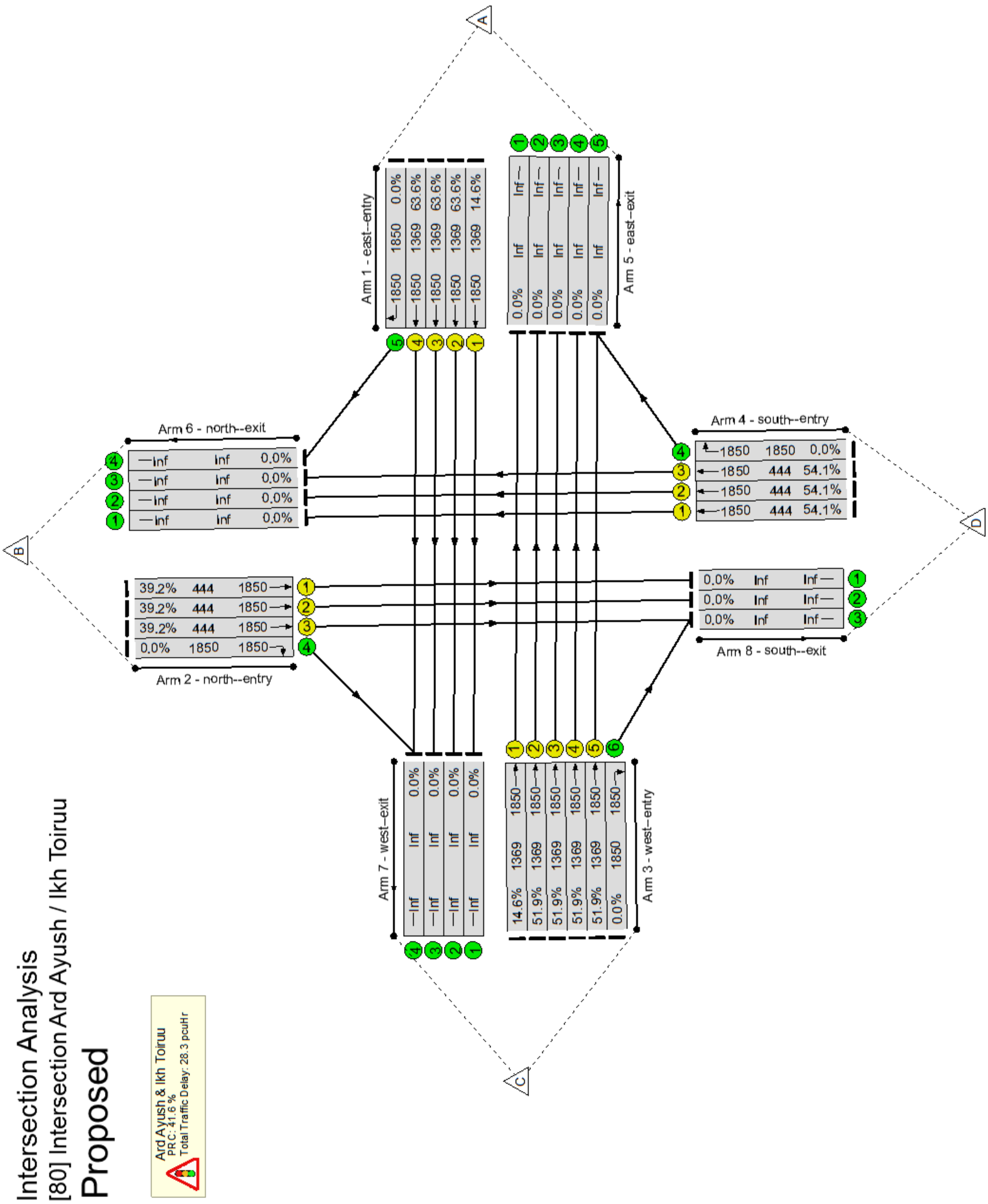
2015				
From	Left	Straight	Right	Total
North	380	520	340	1240
South	510	720	400	1630
East	700	1600	400	2700
West	960	1700	400	3060
Total	2550	4540	1540	8630

2016.12					
From	Left	Straight	Right	U-trun	Total
North	561	910	299	58	1828
South	447	432	423	27	1329
East	568	1173	200	0	1941
West	514	1262	436	18	2230
Total	2090	3777	1358	103	7328






Intersection Analysis
[80] Intersection Ard Ayush / Ikh Toiruu
Current (2015)
Ard Ayush & Ikh Toiruu
PRC: -10.0 %
Total Traffic Delay: 180.2 pcuHr
Arm 1 - east–entry
Arm 2 - north–entry
Arm 3 - west–entry
Arm 4 - south–entry
Arm 5 - east–exit
Arm 6 - north–exit
Arm 7 - west–exit
Arm 8 - south–exit
A
B
C
D

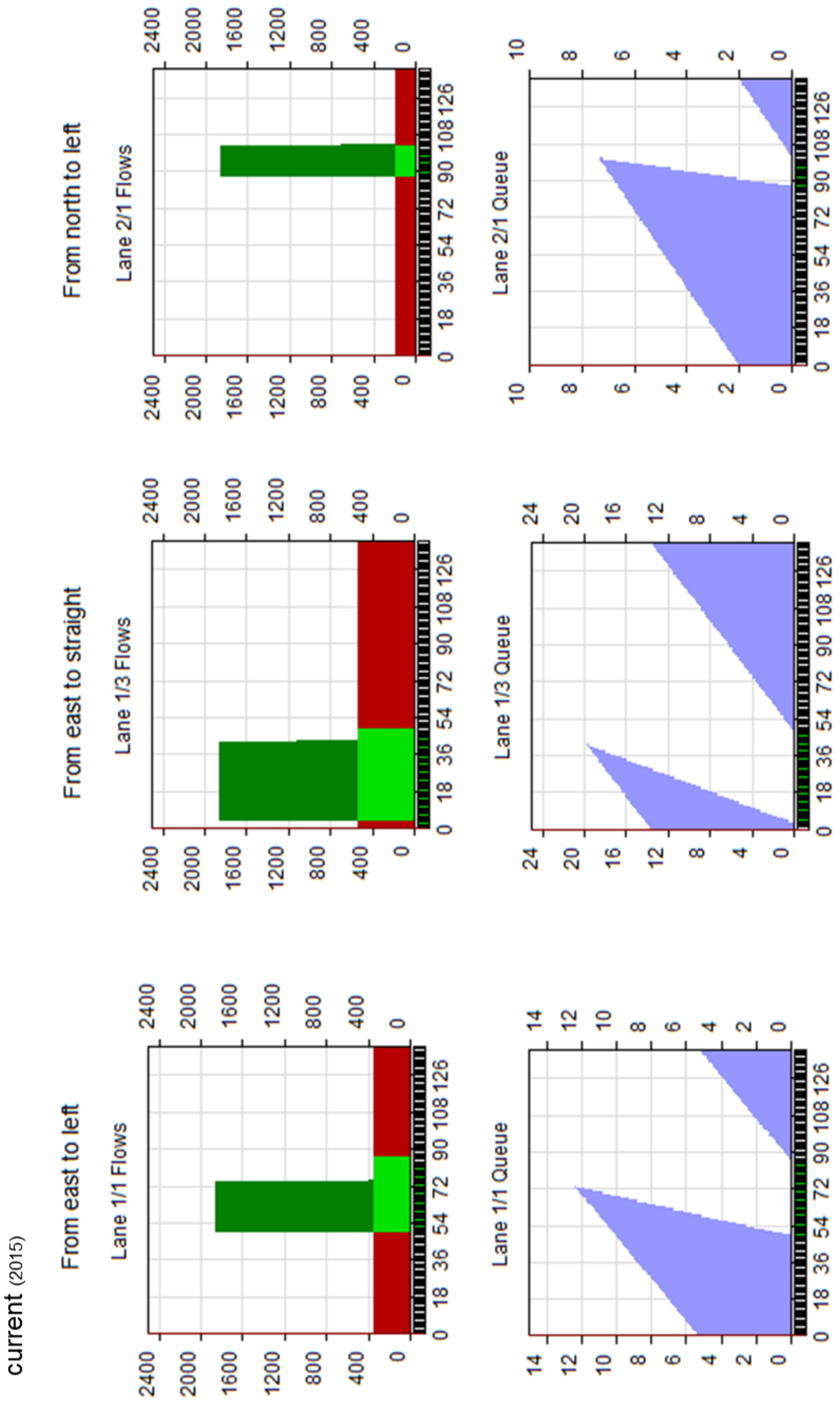

Intersection Analysis
[80] Intersection Ard Ayush / Ikh Toiruu
Proposed
Ard Ayush & Ikh Toiruu
PRC: 41.6 %
Total Traffic Delay: 28.3 pcuHr
Arm 1 - east--entry
Arm 2 - north--entry
Arm 3 - west--entry
Arm 4 - south--entry
Arm 5 - east--exit
Arm 6 - north--exit
Arm 7 - west--exit
Arm 8 - south--exit

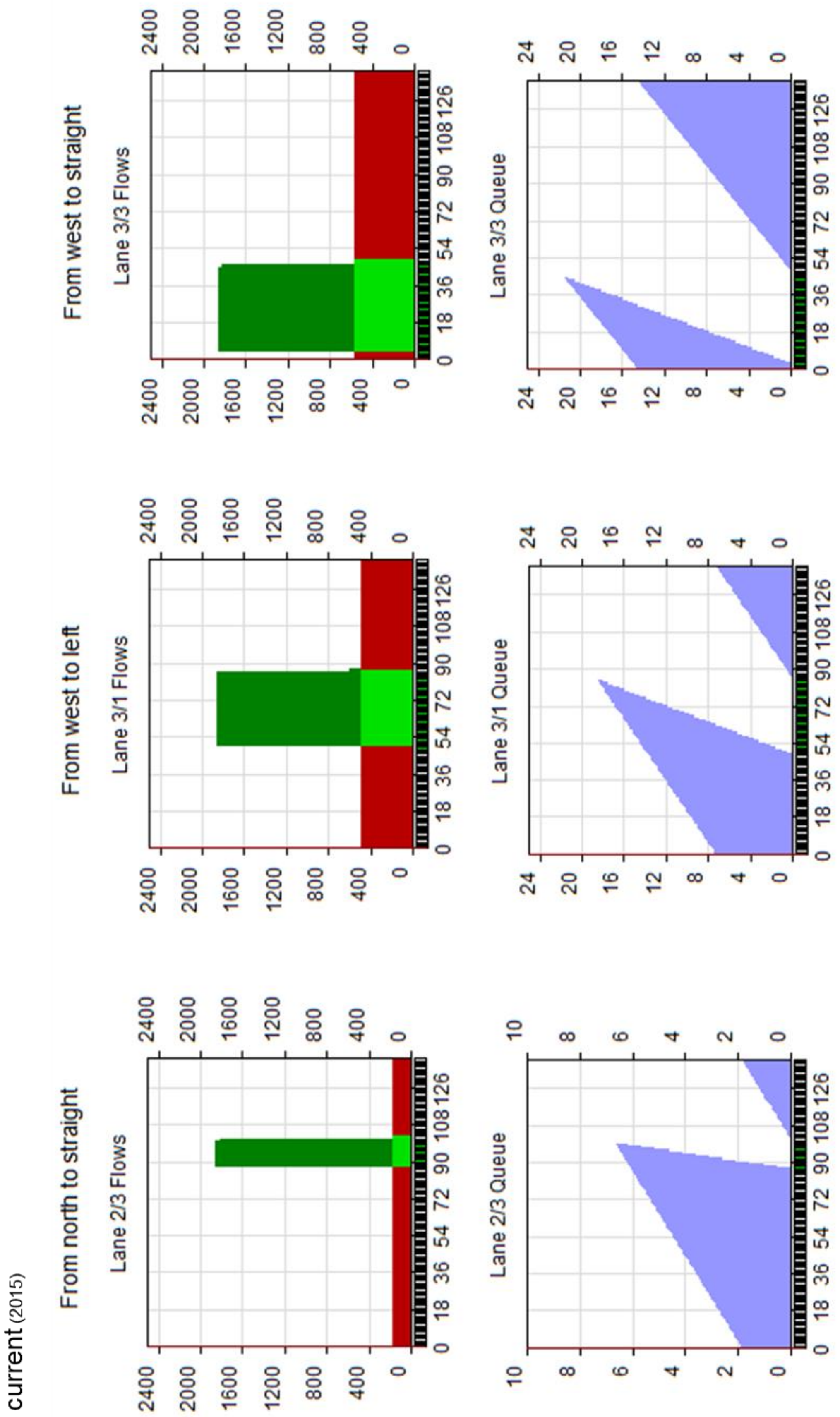
current (2015)

Item	Lane Description	Lane Type	Demand Flow (pcu)	Sat Flow (pcu/Hr)	Capacity (pcu)	Deg Sat (%)	Total Delay (pcuHr)	Av. Delay Per PCU (s/pcu)	Mean Max Queue (pcu)
Network	-	-	-	-	-	**99.0%**	**180.2**	-	-
1/1	east--entry Left	U	350	1850	489	71.6%	5.8	59.5	13.6
1/2	east--entry Left	U	350	1850	489	71.6%	5.8	59.5	13.6
1/3	east--entry Ahead	U	533	1850	595	89.6%	10.5	71.2	23.5
1/4	east--entry Ahead	U	533	1850	595	89.6%	10.5	71.2	23.5
1/5	east--entry Ahead	U	533	1850	595	89.6%	10.5	71.2	23.5
1/6	east--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
2/1	north--entry Left	U	190	1850	198	95.9%	8.4	159.5	12.5
2/2	north--entry Left	U	190	1850	198	95.9%	8.4	159.5	12.5
2/3	north--entry Ahead	U	174	1850	198	87.8%	5.9	121.6	9.5
2/4	north--entry Ahead	U	174	1850	198	87.8%	5.9	121.6	9.5
2/5	north--entry Ahead	U	174	1850	198	87.8%	5.9	121.6	9.5
2/6	north--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
3/1	west--entry Left	U	480	1850	489	98.2%	15.8	118.3	27.5
3/2	west--entry Left	U	480	1850	489	98.2%	15.8	118.3	27.5
3/3	west--entry Ahead	U	567	1850	595	95.4%	14.2	90.0	28.3
3/4	west--entry Ahead	U	567	1850	595	95.4%	14.2	90.0	28.3
3/5	west--entry Ahead	U	567	1850	595	95.4%	14.2	90.0	28.3
3/6	west--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
4/1	south--entry Left	U	510	1850	515	99.0%	17.2	121.1	29.7
4/2	south--entry Ahead	U	360	1850	515	69.9%	5.7	56.7	13.6
4/3	south--entry Ahead	U	360	1850	515	69.9%	5.7	56.7	13.6
4/4	south--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0

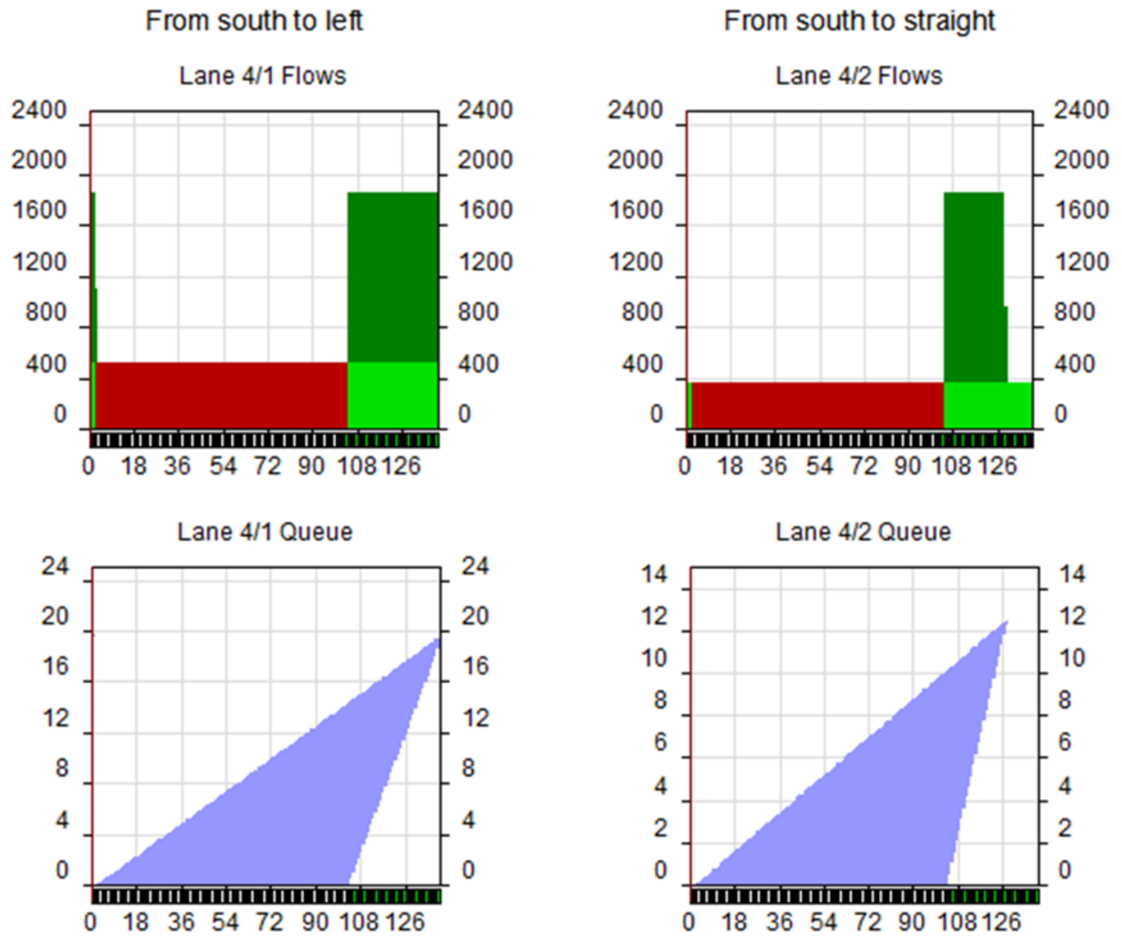
proposed

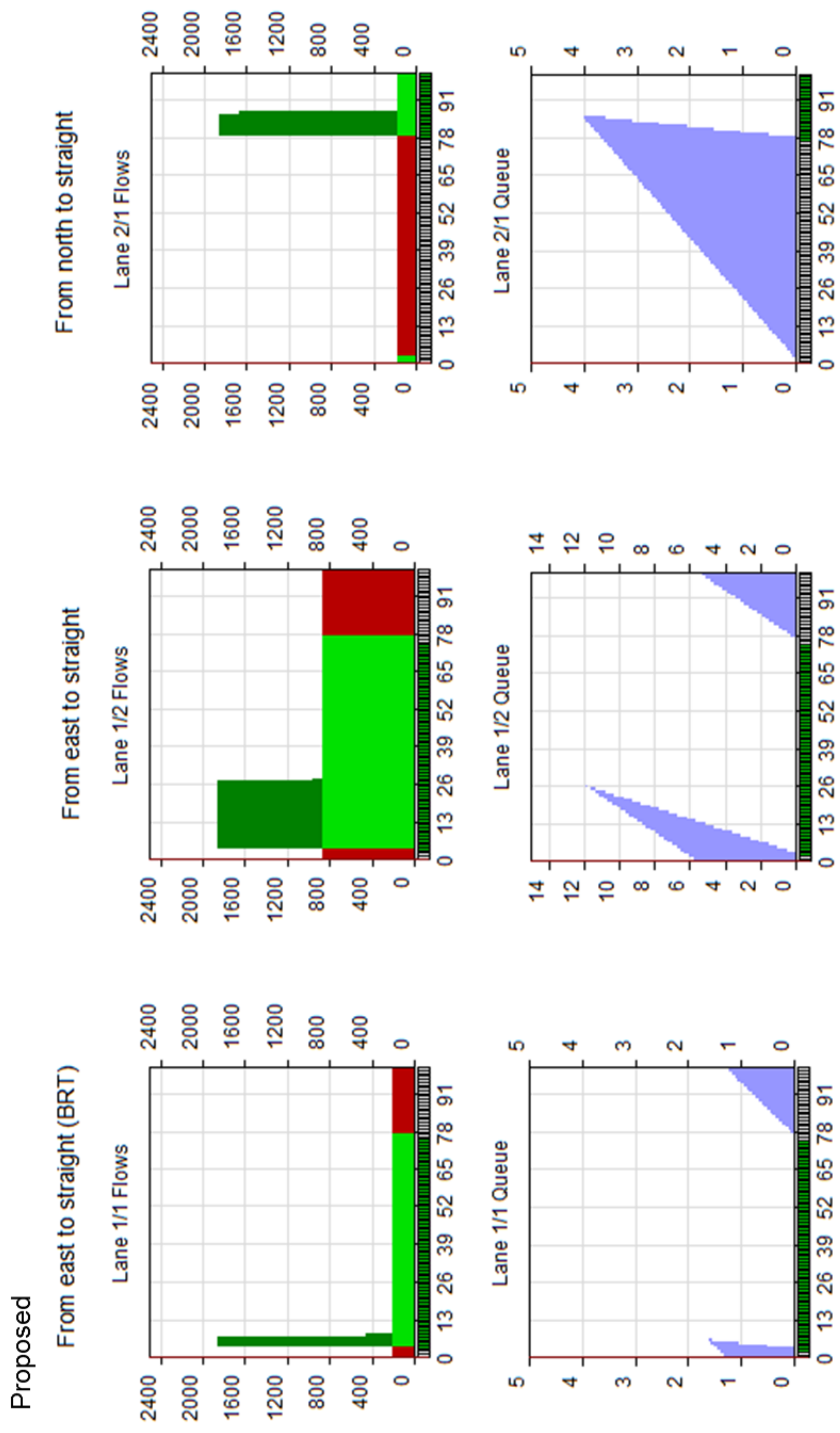
Item	Lane Description	Lane Type	Demand Flow (pcu)	Sat Flow (pcu/Hr)	Capacity (pcu)	Deg Sat (%)	Total Delay (pcuHr)	Av. Delay Per PCU (s/pcu)	Mean Max Queue (pcu)
Network	-	-	-	-	-	**63.6%**	**28.3**	-	-
1/1	east--entry Ahead	U	200	1850	1369	14.6%	0.3	5.3	1.7
1/2	east--entry Ahead	U	870	1850	1369	63.6%	2.4	10.0	12.7
1/3	east--entry Ahead	U	870	1850	1369	63.6%	2.4	10.0	12.7
1/4	east--entry Ahead	U	870	1850	1369	63.6%	2.4	10.0	12.7
1/5	east--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
2/1	north--entry Ahead	U	174	1850	444	39.2%	1.9	38.5	4.3
2/2	north--entry Ahead	U	174	1850	444	39.2%	1.9	38.5	4.3
2/3	north--entry Ahead	U	174	1850	444	39.2%	1.9	38.5	4.3
2/4	north--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
3/1	west--entry Ahead	U	200	1850	1369	14.6%	0.3	5.3	1.7
3/2	west--entry Ahead	U	710	1850	1369	51.9%	1.6	8.2	8.8
3/3	west--entry Ahead	U	710	1850	1369	51.9%	1.6	8.2	8.8
3/4	west--entry Ahead	U	710	1850	1369	51.9%	1.6	8.2	8.8
3/5	west--entry Ahead	U	710	1850	1369	51.9%	1.6	8.2	8.8
3/6	west--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0
4/1	south--entry Ahead	U	240	1850	444	54.1%	2.8	42.0	6.4
4/2	south--entry Ahead	U	240	1850	444	54.1%	2.8	42.0	6.4
4/3	south--entry Ahead	U	240	1850	444	54.1%	2.8	42.0	6.4
4/4	south--entry Right	U	0	1850	1850	0.0%	0.0	0.0	0.0


current (2015)
From east to left
Lane 1/1 Flows
Lane 1/1 Queue
From east to straight
Lane 1/3 Flows
Lane 1/3 Queue
From north to left
Lane 2/1 Flows
Lane 2/1 Queue

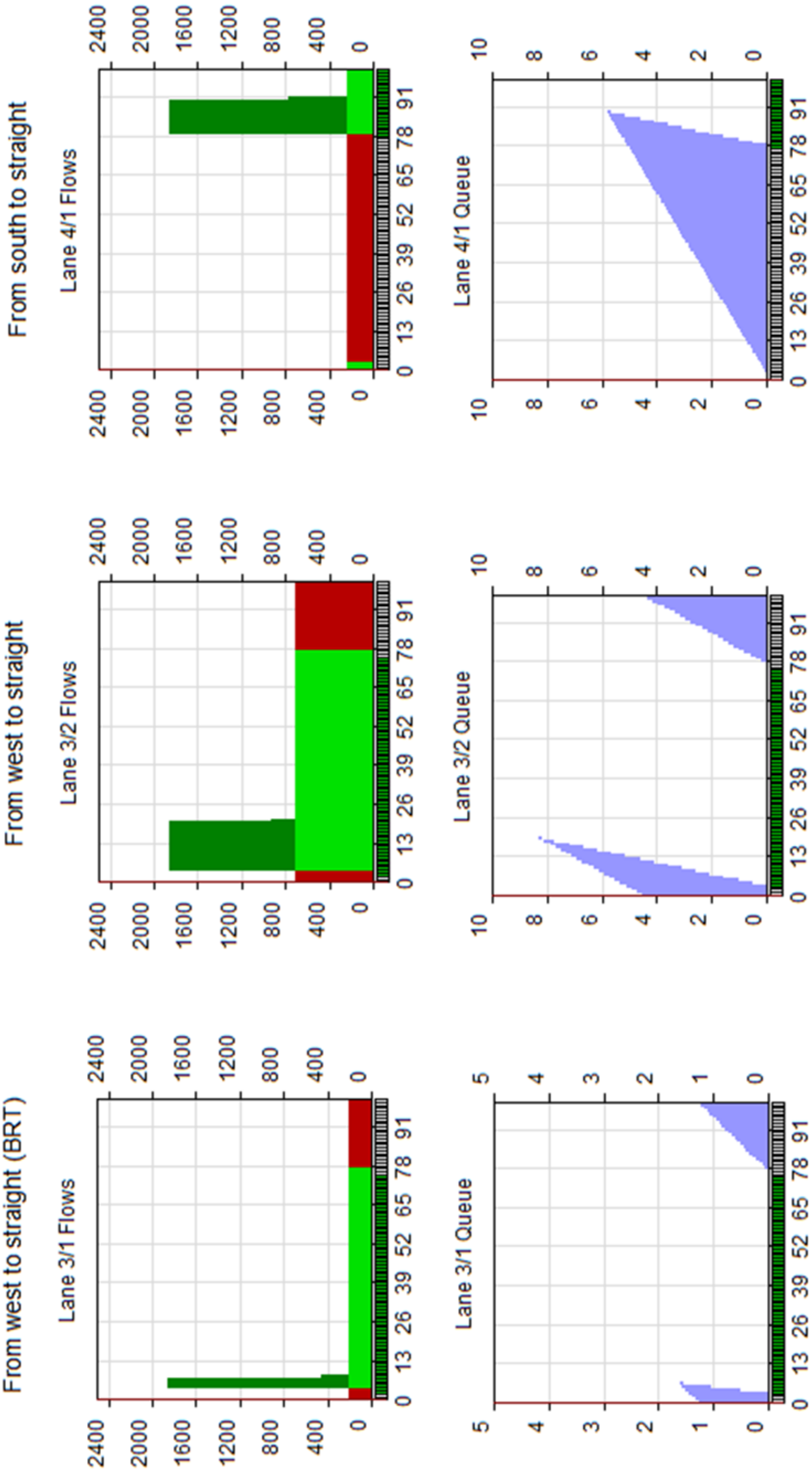

current (2015)
From north to straight
Lane 2/3 Flows
Lane 2/3 Queue
From west to left
Lane 3/1 Flows
Lane 3/1 Queue
From west to straight
Lane 3/3 Flows
Lane 3/3 Queue

current (2015)




Proposed
From east to straight (BRT)
Lane 1/1 Flows
Lane 1/1 Queue
From east to straight
Lane 1/2 Flows
Lane 1/2 Queue
From north to straight
Lane 2/1 Flows
Lane 2/1 Queue

Proposed


From west to straight (BRT)
Lane 3/1 Flows
Lane 3/1 Queue
From west to straight
Lane 3/2 Flows
Lane 3/2 Queue
From south to straight
Lane 4/1 Flows
Lane 4/1 Queue

Conclusion:

The analysis based on the traffic count data from 2015 shows that the proposed change from 4 phase to 2 phase at the intersection of Peace Avenue with Ard Ayush / Ikh Toiruu provides major improvements to the intersection capacity and performance by all measures.

Saturation falls from 99% to 63%.

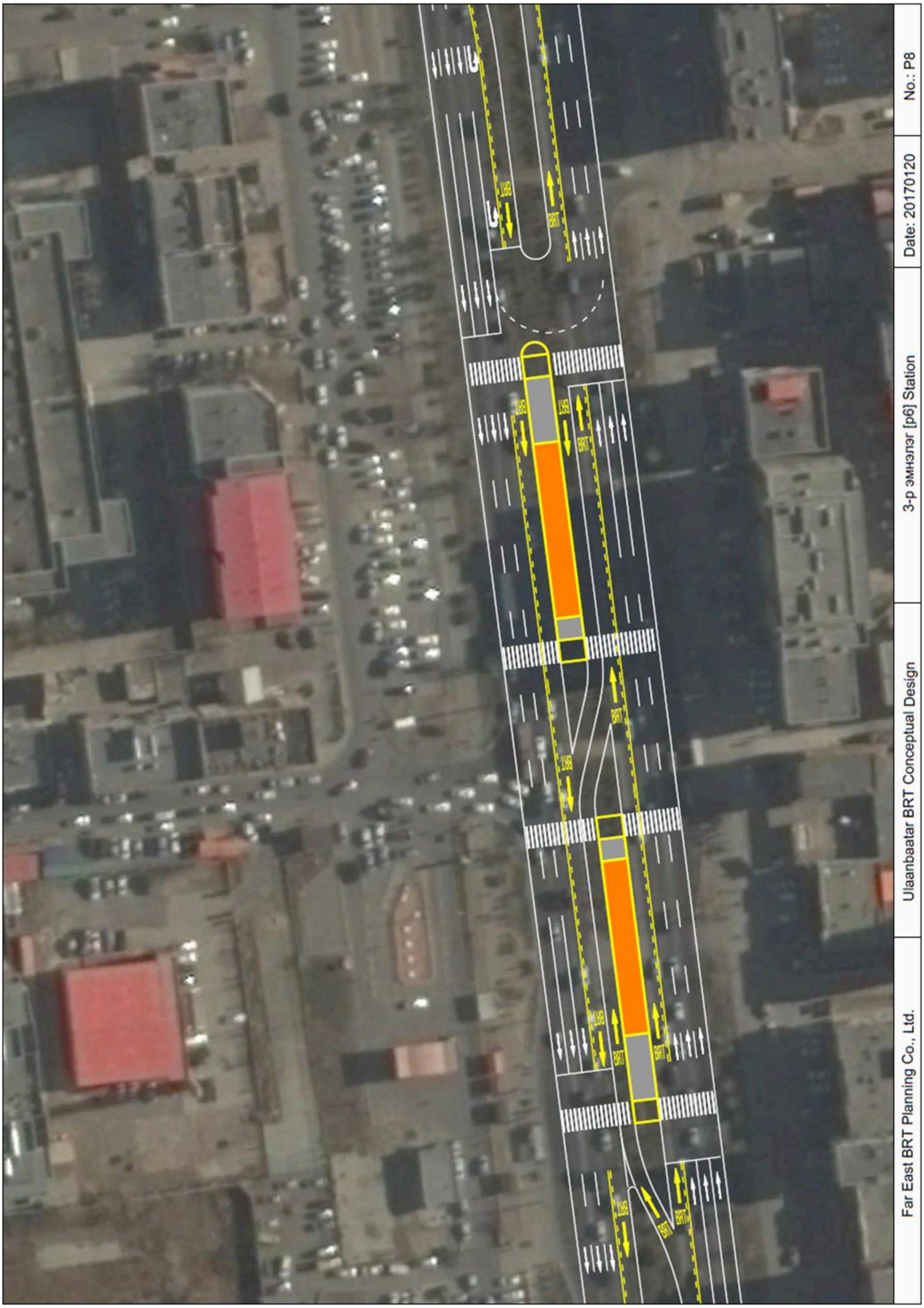
Total delay falls from 180 PCU hours to 28 PCU hours.

Queue length is dramatically reduced on all approaches. In the main east-west direction, queue lengths fall from around 20 PCU to 12 PCU (east straight) and 9 PCU (west straight).

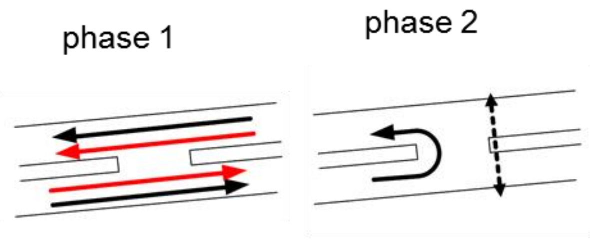
The results of this analysis are confirmed by a separate analysis of the intersection saturation using Excel without dedicated intersection analysis software, as follows. The results are almost identical to the analysis above. **Saturation falls from the current 98% with four phases, to 60% with two phases plus BRT.**

Present 4 phase						
phase	side	to	volume	lanes	capacity (pcu/h)	saturation
1	east	str	1600	3	5550	29%
	west	str	1700	3	5550	31%
	max					31%
2	east	left	700	2	3700	19%
	west	left	960	2	3700	26%
	max					26%
3	north	str	520	2	3700	14%
		lef	380	2	3700	10%
	max					14%
4	south	str	720	2	3700	19%
		lef	510	1	1850	28%
	max					28%
	total					**98%**

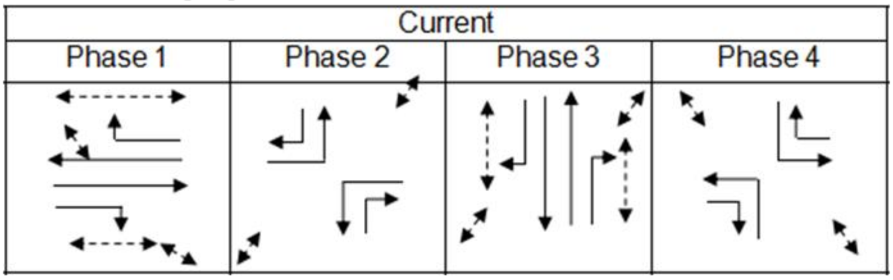
Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	capacity (pcu/h)	saturation
1	east	str	2610	3	5550	47%
		brt	200	1	1850	11%
	west	str	2840	4	7400	38%
		brt	200	1	1850	11%
	max					47%
2	south	str	720	3	5550	13%
	north	str	520	3	5550	9%
	max					13%
	total					**60%**


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
3-р эмнэлэг [p6] Station
Date: 20170120
No.: P8

10-р хороолол [p7] Station and Intersection [31] Peace Ave / Narnii Rd



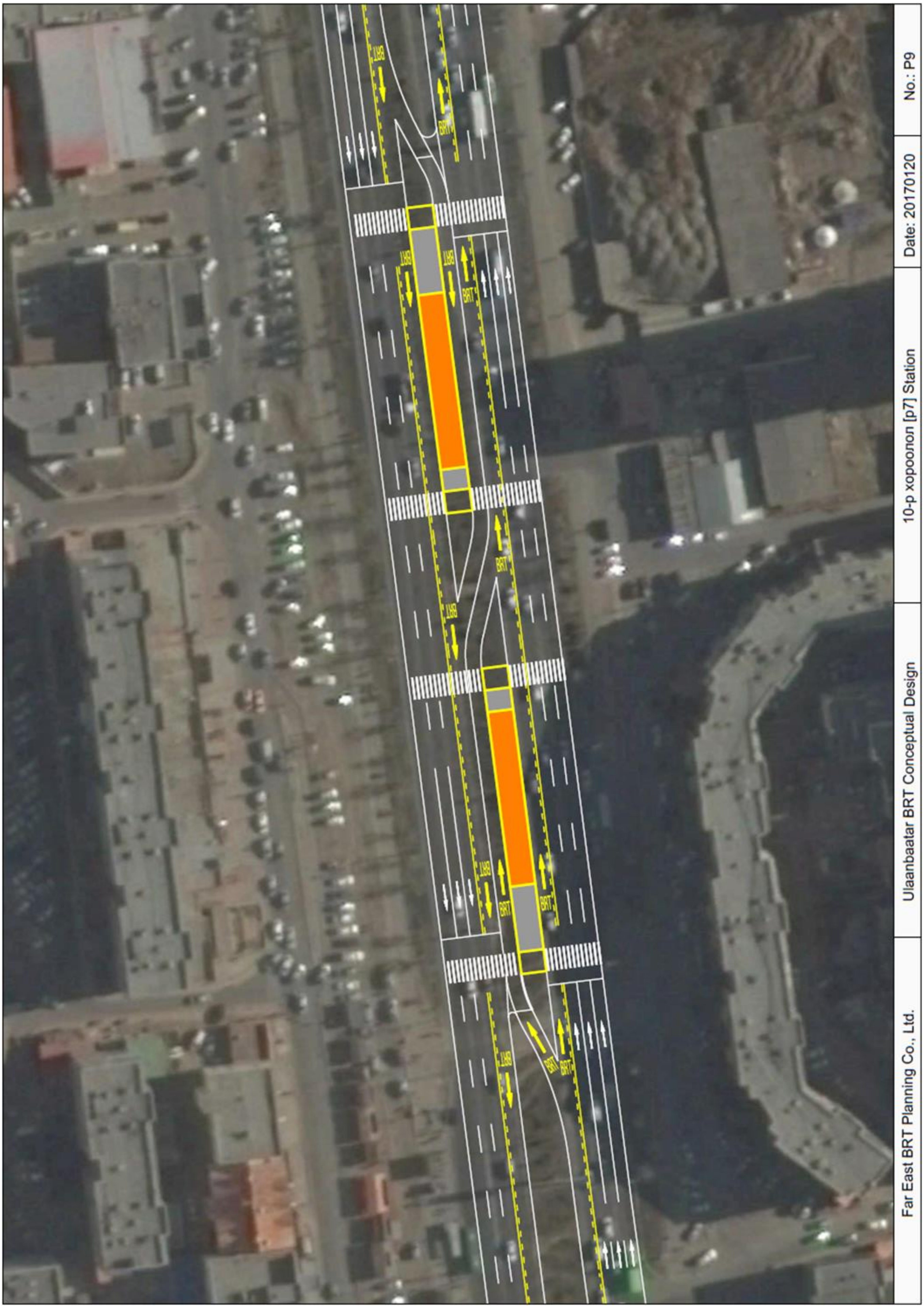
Intersection [31] Peace Ave / Narnii Rd



Proposed: no signal

Current traffic volume (pcu)

2016.12					
From	Left	Straight	Right	U-trun	Total
North	290	471	116	26	903
South	382	263	106	0	751
East	140	1315	188	4	1647
West	98	349	118	6	571
Total	910	2398	528	36	3872

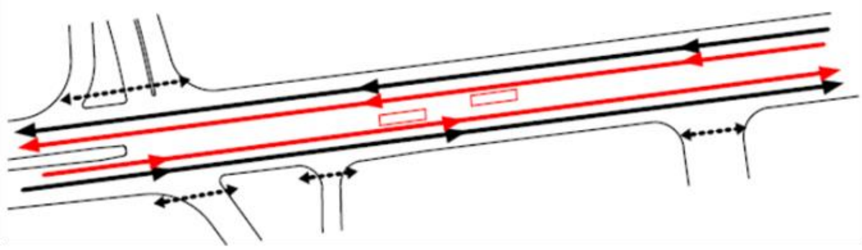

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
10-р хороолол [p7] Station
Date: 20170120
No.: P9


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [31] Peace Ave / Narnii Rd
Date: 20170120
No.: P10
BRT

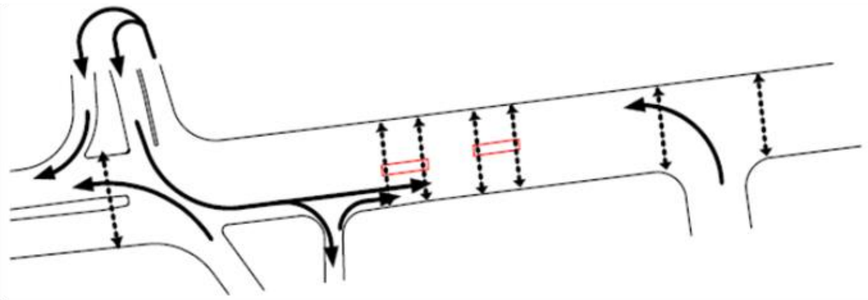
Intersection [30] Peace Ave / Chingunjav St, 25-р эмийн сан [p8] Station and Intersection [29] Peace Ave / P Jasray St

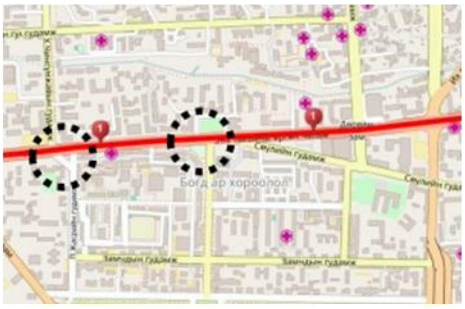
linked signals of 2 intersections and station

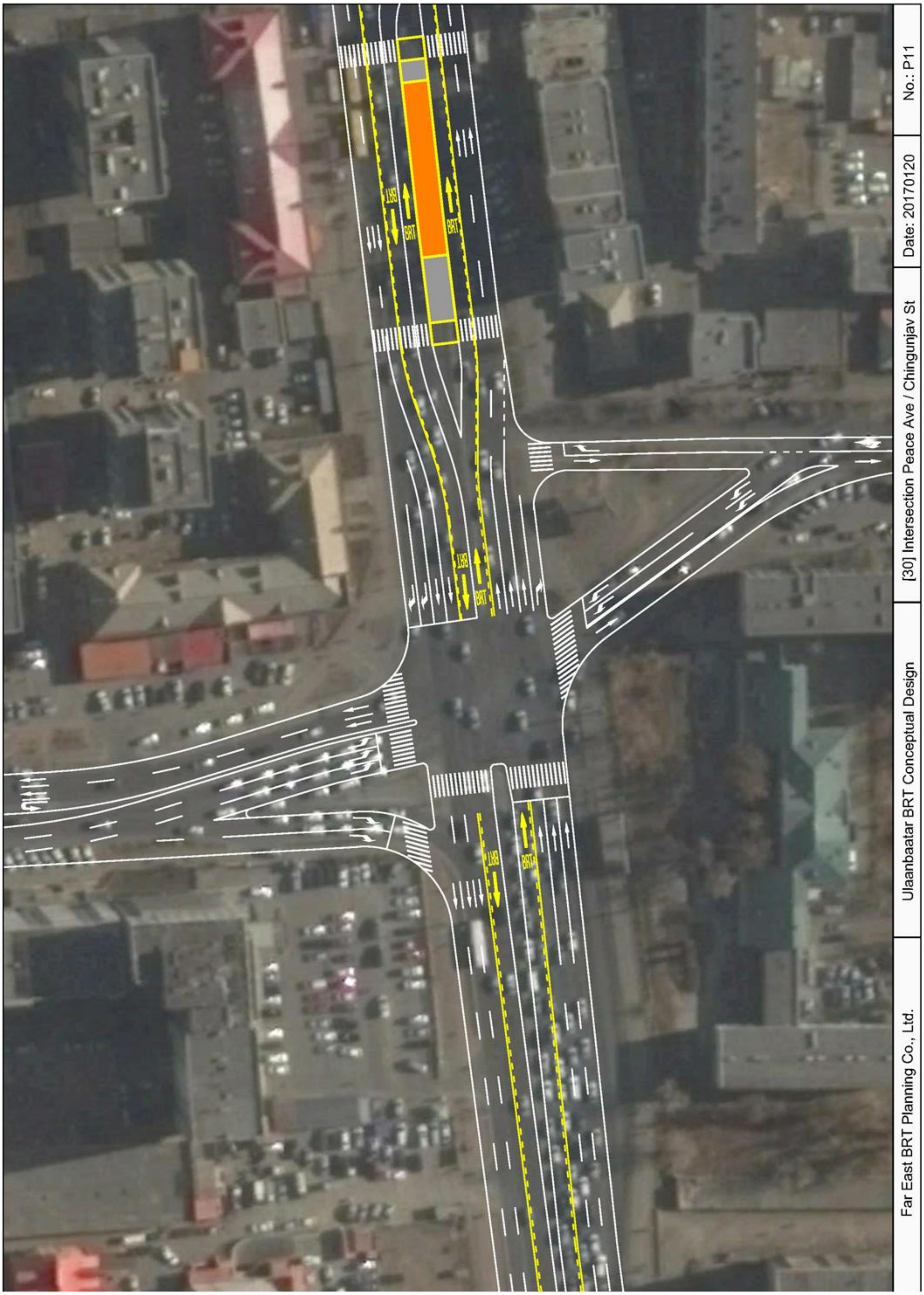
phase 1



phase 2






Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
[30] Intersection Peace Ave / Chingunjav St
Date: 20170120
No.: P11


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
[30] Intersection Peace Ave / Chingunjav St
Date: 20170120
No.: B2

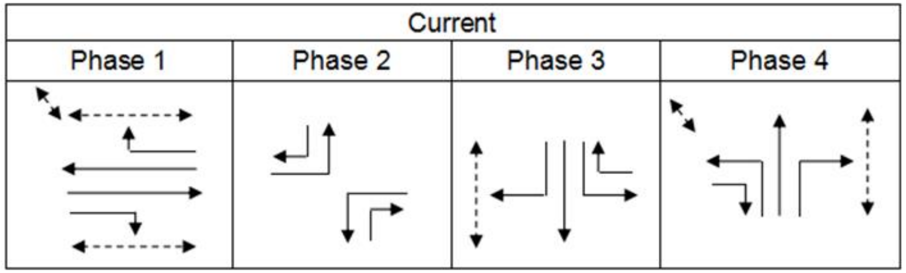
[30] Intersection Peace Ave / Chingunjav St

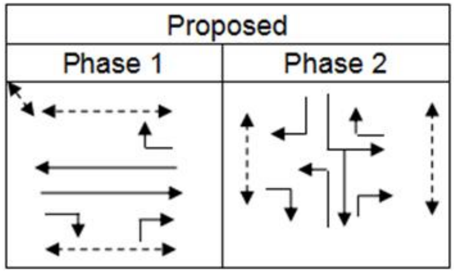
Current traffic volume (pcu)

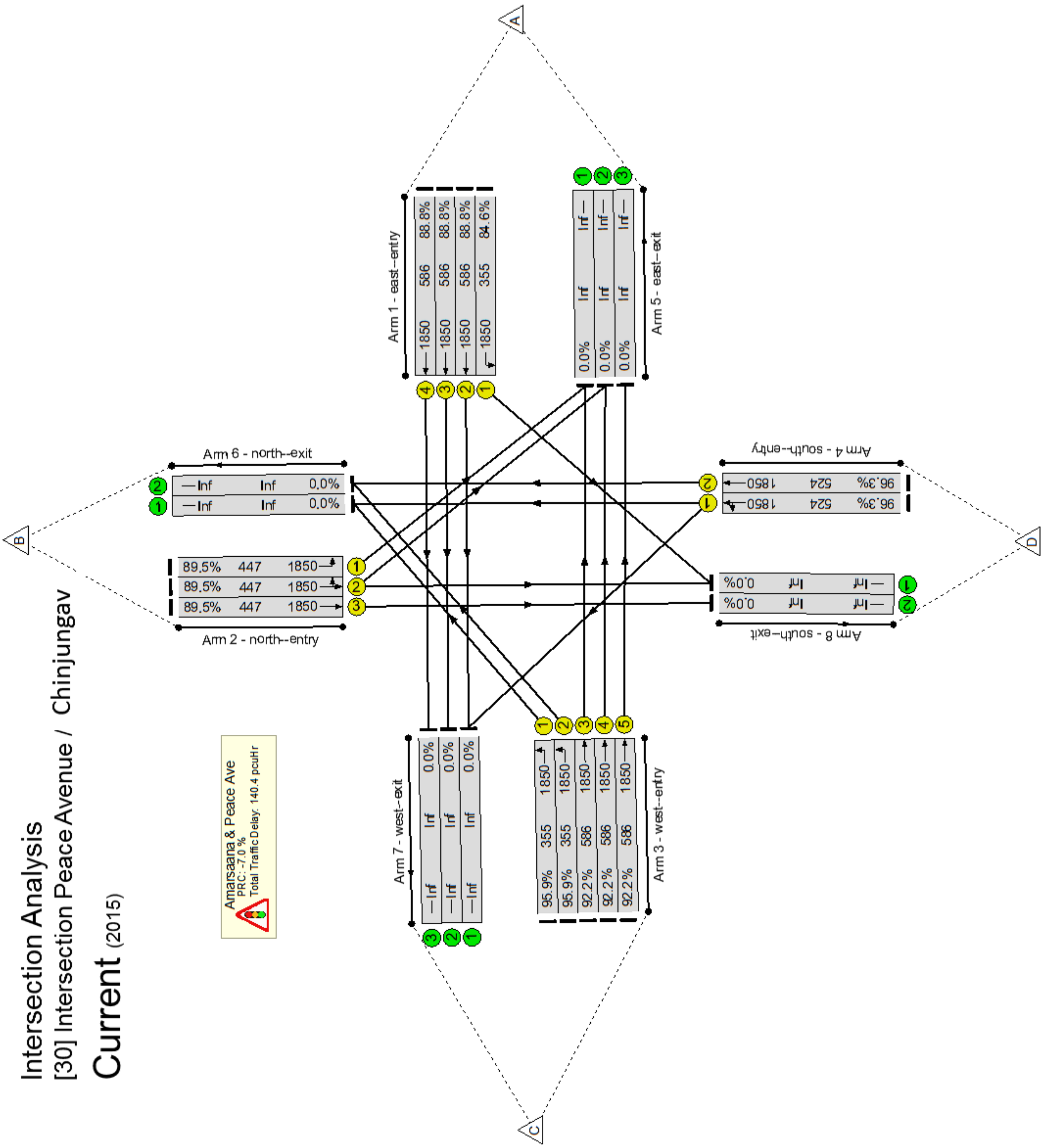
2014				
From	Left	Straight	Right	Total
North	804	640	396	1840
South	245	668	200	1113
East	330	1460	608	2398
West	780	1485	300	2565
Total	2159	4253	1504	7916

2015				
From	Left	Straight	Right	Total
North	680	520	400	1600
South	310	700	220	1230
East	300	1560	500	2360
West	680	1620	320	2620
Total	1970	4400	1440	7810

2016.12				
From	Left	Straight	Right	Total
North	700	348	564	1612
South	379	376	233	988
East	130	970	379	1479
West	504	1337	284	2125
Total	1713	3031	1460	6204






Intersection Analysis
[30] Intersection Peace Avenue / Chinjungav
Current (2015)
Amarsaana & Peace Ave
PRC: -7.0 %
Total Traffic Delay: 140.4 pcuHr
Arm 1 - east-entry
Arm 2 - north-entry
Arm 3 - west-entry
Arm 4 - south-entry
Arm 5 - east-exit
Arm 6 - north-exit
Arm 7 - west-exit
Arm 8 - south-exit
A
B
C
D

current (2015)

Item	Lane Description	Lane Type	Demand Flow (pcu)	Sat Flow (pcu/Hr)	Capacity (pcu)	Deg Sat (%)	Total Delay (pcuHr)	Av. Delay Per PCU (s/pcu)	Mean Max Queue (pcu)
Network	-	-	-	-	-	**96.3%**	**140.4**	-	-
1/1	east--entry Left	U	300	1850	355	84.6%	6.4	77.0	12.1
1/2	east--entry Ahead	U	520	1850	586	88.8%	9.2	63.6	20.0
1/3	east--entry Ahead	U	520	1850	586	88.8%	9.2	63.6	20.0
1/4	east--entry Ahead	U	520	1850	586	88.8%	9.2	63.6	20.0
2/1	north--entry Left	U	400	1850	447	89.5%	8.6	77.1	16.6
2/2	north--entry Left Ahead	U	400	1850	447	89.5%	8.6	77.1	16.6
2/3	north--entry Ahead	U	400	1850	447	89.5%	8.6	77.1	16.6
3/1	west--entry Left	U	340	1850	355	95.9%	10.8	114.4	17.4
3/2	west--entry Left	U	340	1850	355	95.9%	10.8	114.4	17.4
3/3	west--entry Ahead	U	540	1850	586	92.2%	10.8	72.0	22.1
3/4	west--entry Ahead	U	540	1850	586	92.2%	10.8	72.0	22.1
3/5	west--entry Ahead	U	540	1850	586	92.2%	10.8	72.0	22.1
4/1	south--entry Ahead Left	U	505	1850	524	96.3%	13.4	95.3	24.0
4/2	south--entry Ahead	U	505	1850	524	96.3%	13.4	95.3	24.0

Conclusion:

The analysis based on the traffic count data from 2015 shows that the proposed change from 4 phase to 2 phase at the intersection of Peace Avenue with Chinjungav St provides major improvements to the intersection capacity and performance.

Saturation falls from 96% to 56%.

Following is a separate analysis of the intersection saturation, using Excel without dedicated intersection analysis software, as follows. The results calibrate well with the analysis above regarding the intersection saturation. **Saturation falls from the current 96% with four phases, to 56% with two phases plus BRT.**

Present 4 phase						
phase	side	to	volume	lanes	capacity (pcu/h)	saturation
1	east	str	1560	3	5550	28%
	west	str	1620	3	5550	29%
	max					29%
2	east	left	300	1	1850	16%
	west	left	680	2	3700	18%
	max					18%
3	north	str, left	1200	3	5550	22%
4	south	str, left	1010	2	3700	27%
	total					**96%**

Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	capacity (pcu/h)	saturation
1	east	str	1360	2	3700	37%
		brt	200	1	1850	11%
	west	str	2100	3	5550	38%
		brt	200	1	1850	11%
	max					38%
2	north	left	680	2	3700	18%
	south	left	310	2	3700	8%
	max					18%
	total					**56%**

Note regarding this intersection that as with the other intersections, for analysis purposes the right turns were not considered. In the Peace Avenue / Chinjungav intersection the right turn volume from the east, however, will increase significantly. The south straight traffic (700 PCU), east left turn traffic (300 PCU), east right turn traffic (500 PCU) plus the east left turn traffic from P Jasray St intersection (338 PCU) will all use the east right turn. The east right turn volume (which is not included in the analysis above) is therefore 1,838 PCU. To accommodate this high volume, two right-turn lanes are provided in the design from east to north along Peace Avenue.

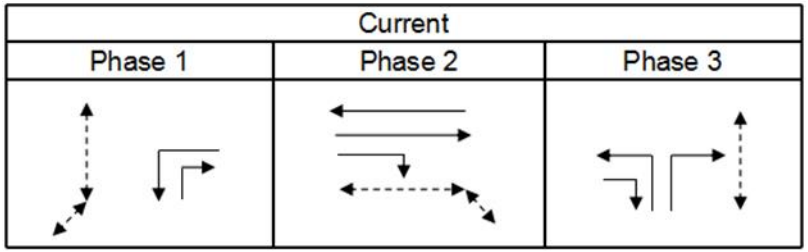

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
25-р эмийн сан [p8] Station
Date: 20170120
No.: P12
BRT


No.: P13
Date: 20170120
[29] Intersection Peace Ave / P Jasray St
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

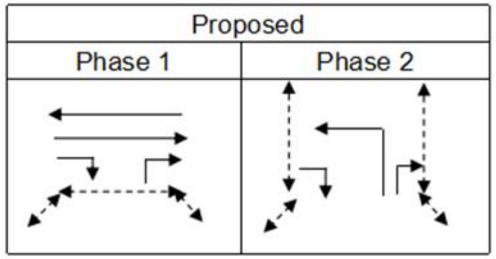
[29] Intersection Peace Ave / P Jasray St

Current traffic volume (pcu)

2014				
From	Left	Straight	Right	Total
North	0	0	0	0
South	600	0	302	902
East	596	1400	0	1996
West	0	1380	586	1966
Total	1196	2780	888	4864



2016					
From	Left	Straight	Right	U-trun	Total
North	0	0	0	0	0
South	741	0	423	0	1164
East	338	1426	0	19	1783
West	0	1546	445	8	1999
Total	1079	2972	868	27	4946



Conclusion:

The analysis based on the traffic count data from 2016 (since there was no data from 2015, and the 2016 data was higher than the 2014 data for the P Jasray intersection) shows that the proposed change from 3 phases to 2 phase at the intersection of Peace Avenue with Jasray St provides a significant improvement to the intersection capacity and performance.

Saturation falls from the current 77% (3 phase, without BRT) to 63% (2 phase, with BRT).

Current traffic volume (pcu)				
2016				
From	Left	Straight	Right	Total
South	741		423	1164
East	338	1426		1764
West		1546	445	1991
Total	**1079**	**2972**	**868**	**4919**

Present 3 phase						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	east	left	338	1	1850	18%
2	east	str	1426	2	3700	39%
	west	str	1546	3	5550	28%
	max					39%
3	south	left	741	2	3700	20%
	total					**77%**

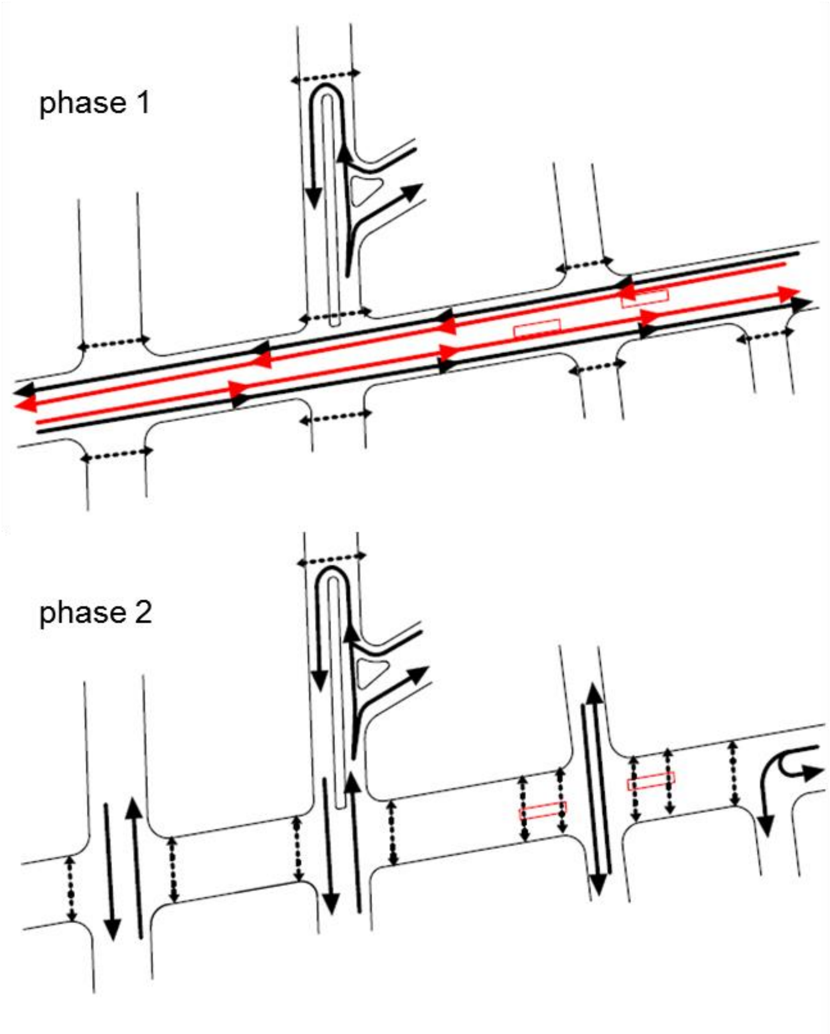
Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	east	str	1604	2	3700	43%
		brt	160	1	1850	9%
	west	str	1386	2	3700	37%
		brt	160	1	1850	9%
	max					43%
2	south	left	741	2	3700	20%
	total					**63%**

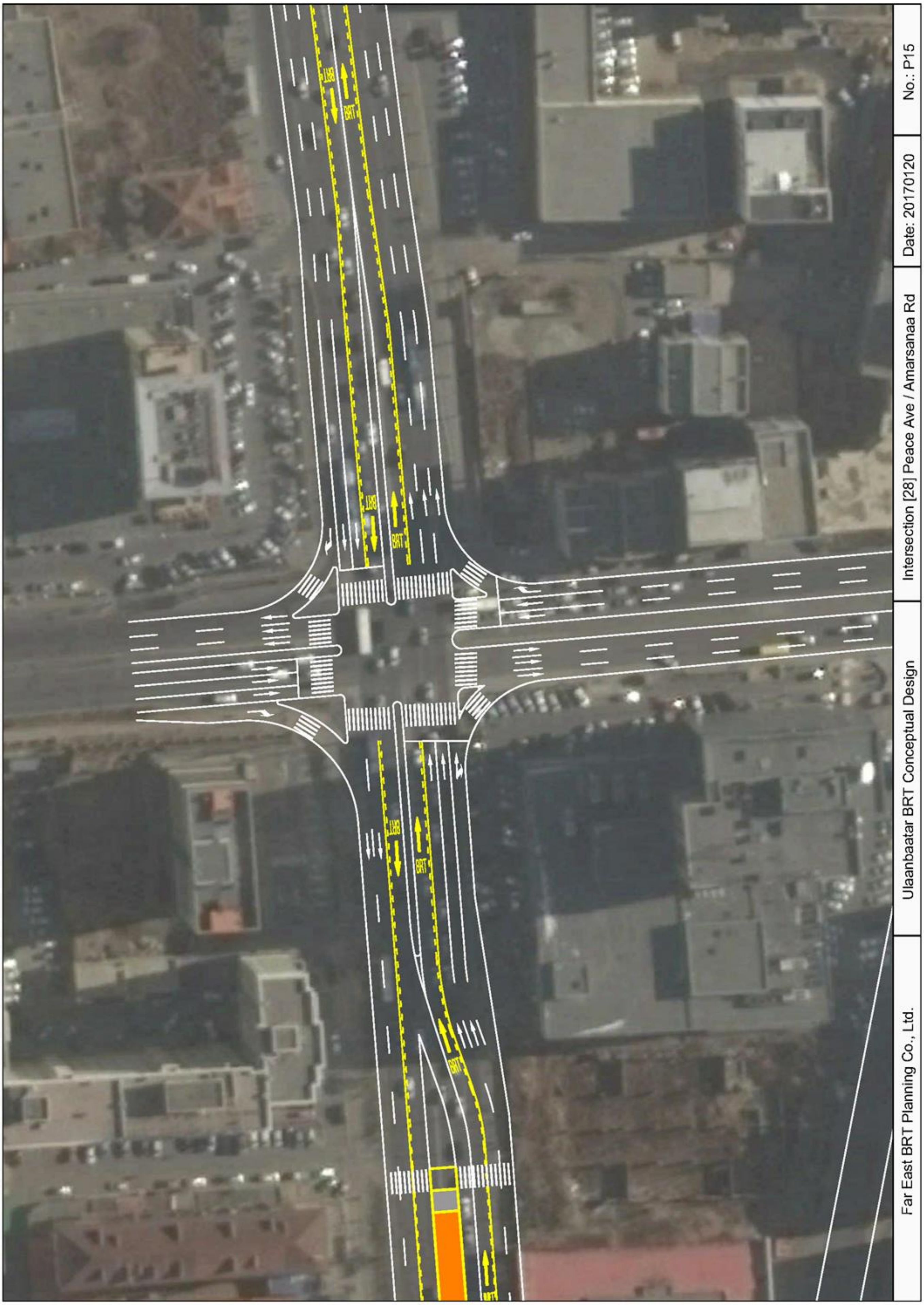
ТБД андууд [p9] Station


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
ТБД андууд [р9] Station
Date: 20170120
No.: P14
BRT

Intersection [28] Peace Ave / Amarsanaa Rd, Intersection [27] West cross road , Intersection [26] Peace Ave / Partizan Rd, Intersection Peace and Friendship Palace, and Баруун 4 зам [p10] Station

linked signals of 4 intersections and station



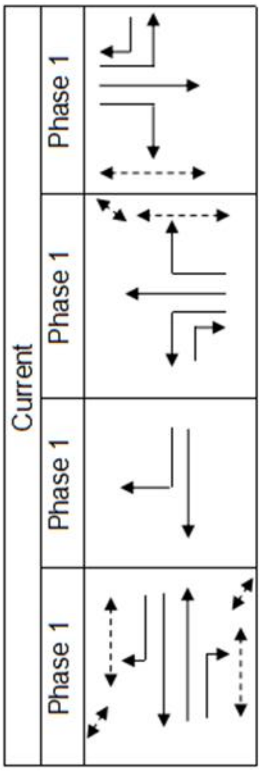

No.: P15
Date: 20170120
Intersection [28] Peace Ave / Amarsanaa Rd
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

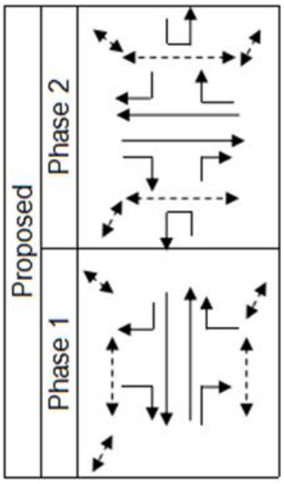
[28] Intersection Peace Ave / Amarsanaa Rd

Current traffic volume (pcu)

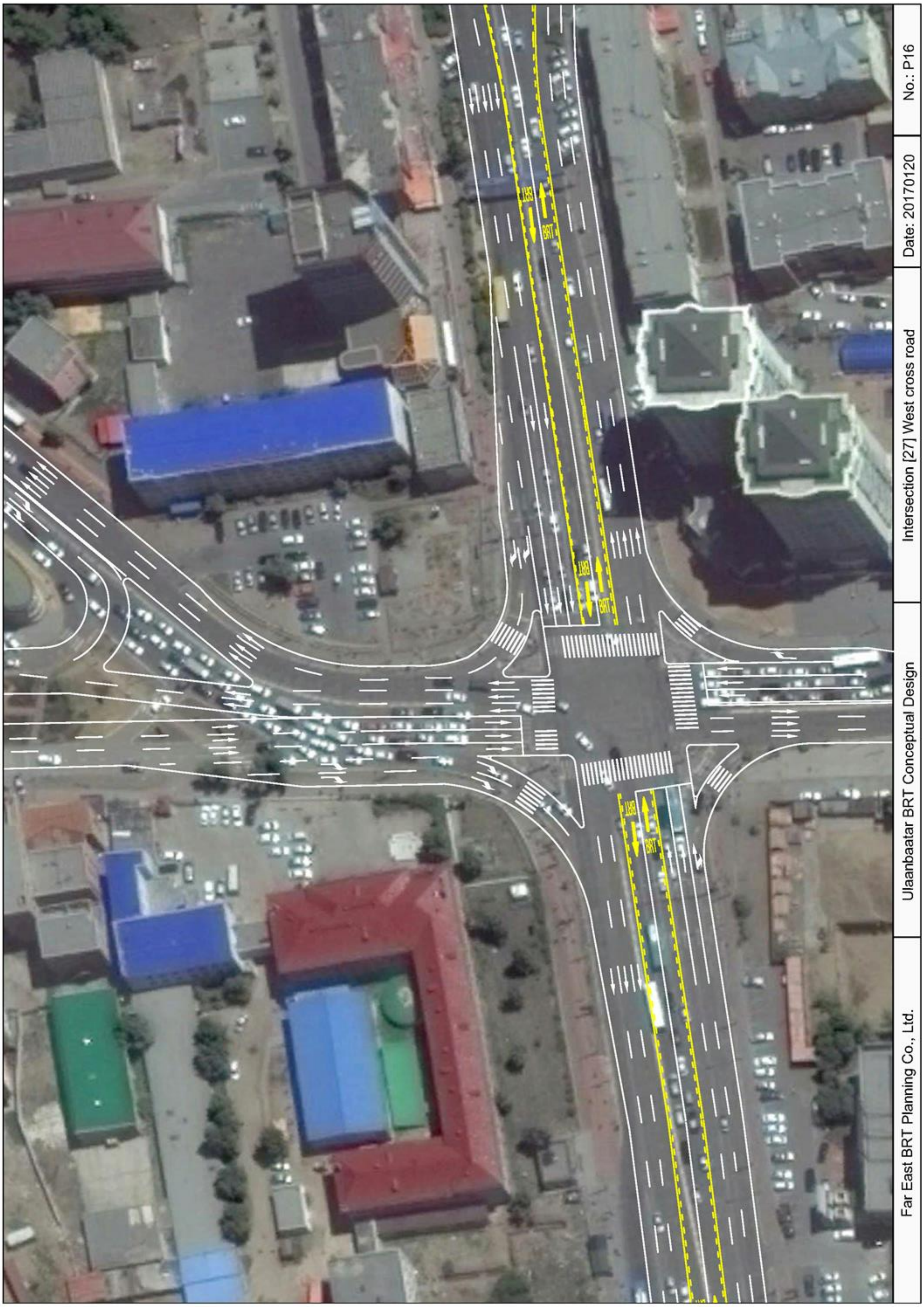
2014				
From	Left	Straight	Right	Total
North	786	502	306	1594
South	335	600	298	1233
East	0	1576	320	1896
West	0	1542	308	1850
Total	1121	4220	1232	6573

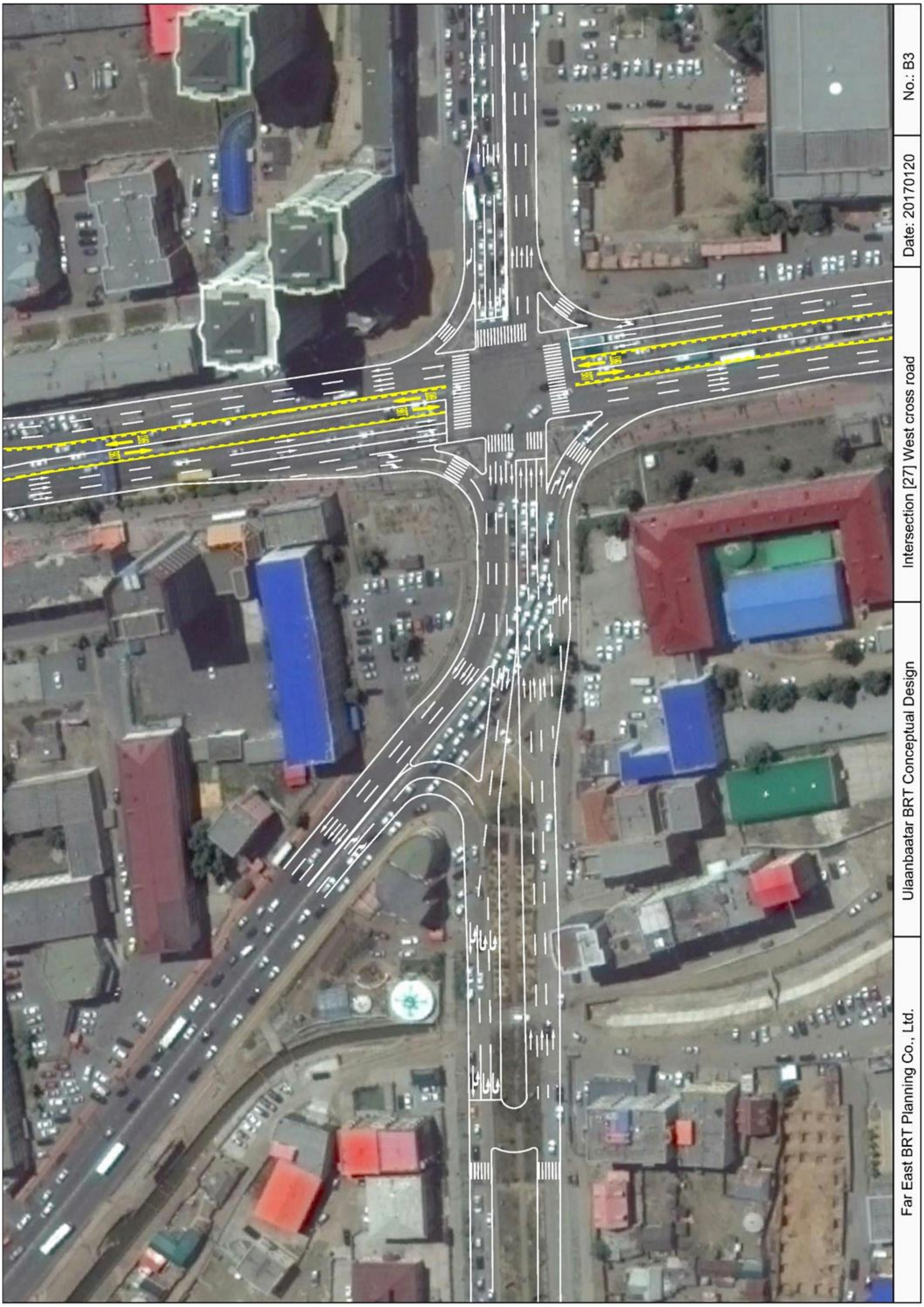
2016.12				
From	Left	Straight	Right	Total
North	482	312	100	894
South	112	388	154	654
East	0	956	298	1254
West	0	1085	0	1085
Total	594	2741	552	3887





Proposed intersection improvements and traffic circulation changes in this area show that major improvements can be achieved with the implementation of BRT and without the need for flyovers at the West Cross intersection.

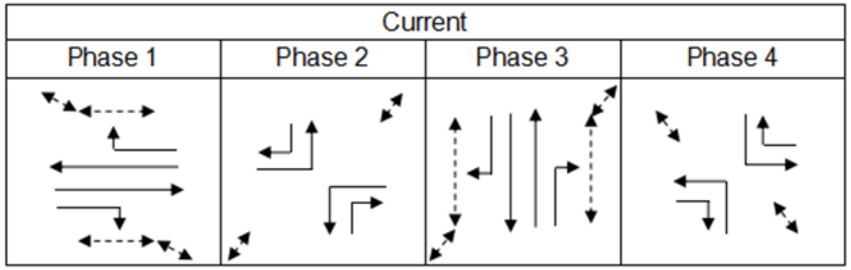

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [27] West cross road
Date: 20170120
No.: P16


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [27] West cross road
Date: 20170120
No.: B3

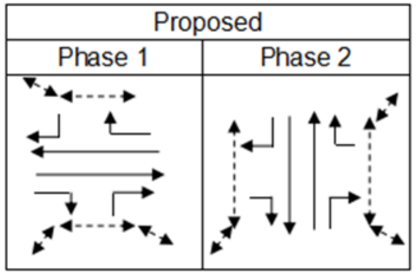
[27] Intersection West cross road

Current traffic volume (pcu)

2014				
From	Left	Straight	Right	Total
North	310	740	470	1520
South	470	810	420	1700
East	650	1410	290	2350
West	780	1320	594	2694
Total	2210	4280	1774	8264



2015				
From	Left	Straight	Right	Total
North	310	740	420	1470
South	480	810	400	1690
East	700	1420	300	2420
West	920	1380	400	2700
Total	2410	4350	1520	8280



Conclusion:

The analysis based on the traffic count data from 2015 shows that the proposed change from 4 phases to 2 phase at the intersection of Peace Avenue with West Cross, together with BRT, provides major improvements to the intersection capacity and performance.

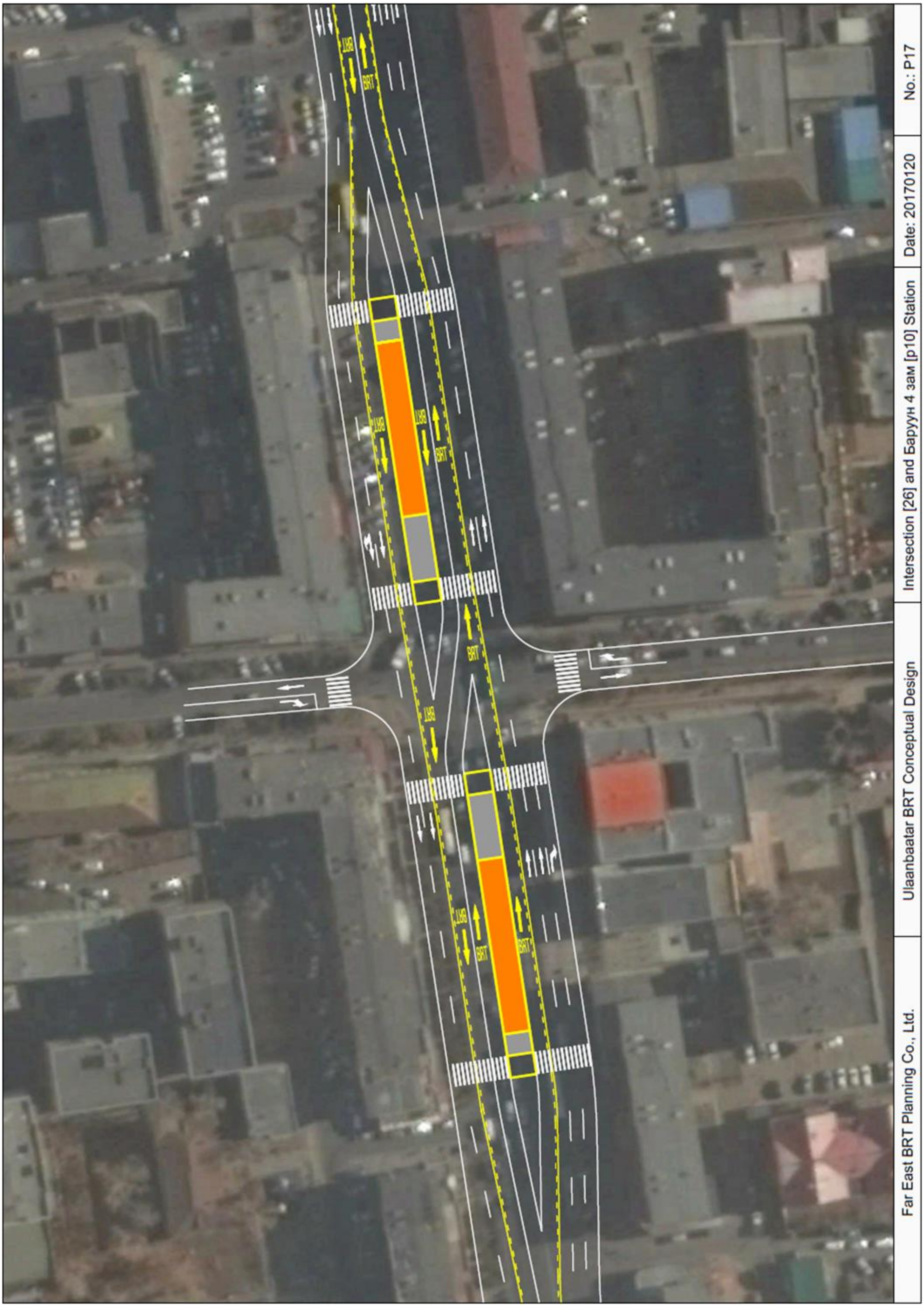
Saturation falls from the current 98% (4 phases, without) BRT to 63% (2 phases, with BRT).

Present 4 phase						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	north	str	740	2	3700	20%
	south	str	810	2	3700	22%
	max					22%
2	south	left	480	1	1850	26%
	north	left	310	1	1850	17%
	max					26%
3	east	str	1420	3	5550	26%
	west	str	1380	3	5550	25%
	max					26%
4	east	left	700	2	3700	19%
	west	left	920	2	3700	25%
	max					25%
	total					**98%**

Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	east	str	1260	3	5550	23%
		brt	160	1	1850	9%
	west	str	1220	3	5550	22%
		brt	160	1	1850	9%
	max					23%
2	south	str	2210	3	5550	40%
	north	str	1750	3	5550	32%
	max					40%
	total					**63%**

Some notes regarding the West Cross intersection proposal:

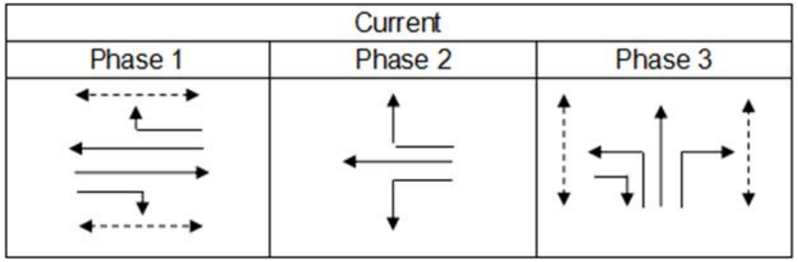
- These improvements can be achieved without the proposed flyover along Peace Avenue.
- Left turns from the west along Peace Avenue will first use Seoul Street.
- Some widening or reconfiguration of the north and south approaches may be needed to ensure 6 lanes on both the north and south sides of the intersection.

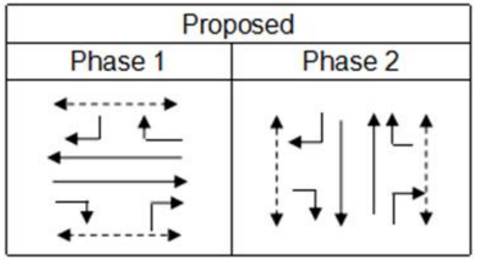

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [26] and Баруун 4 зам [p10] Station
Date: 20170120
No.: P17
BRT

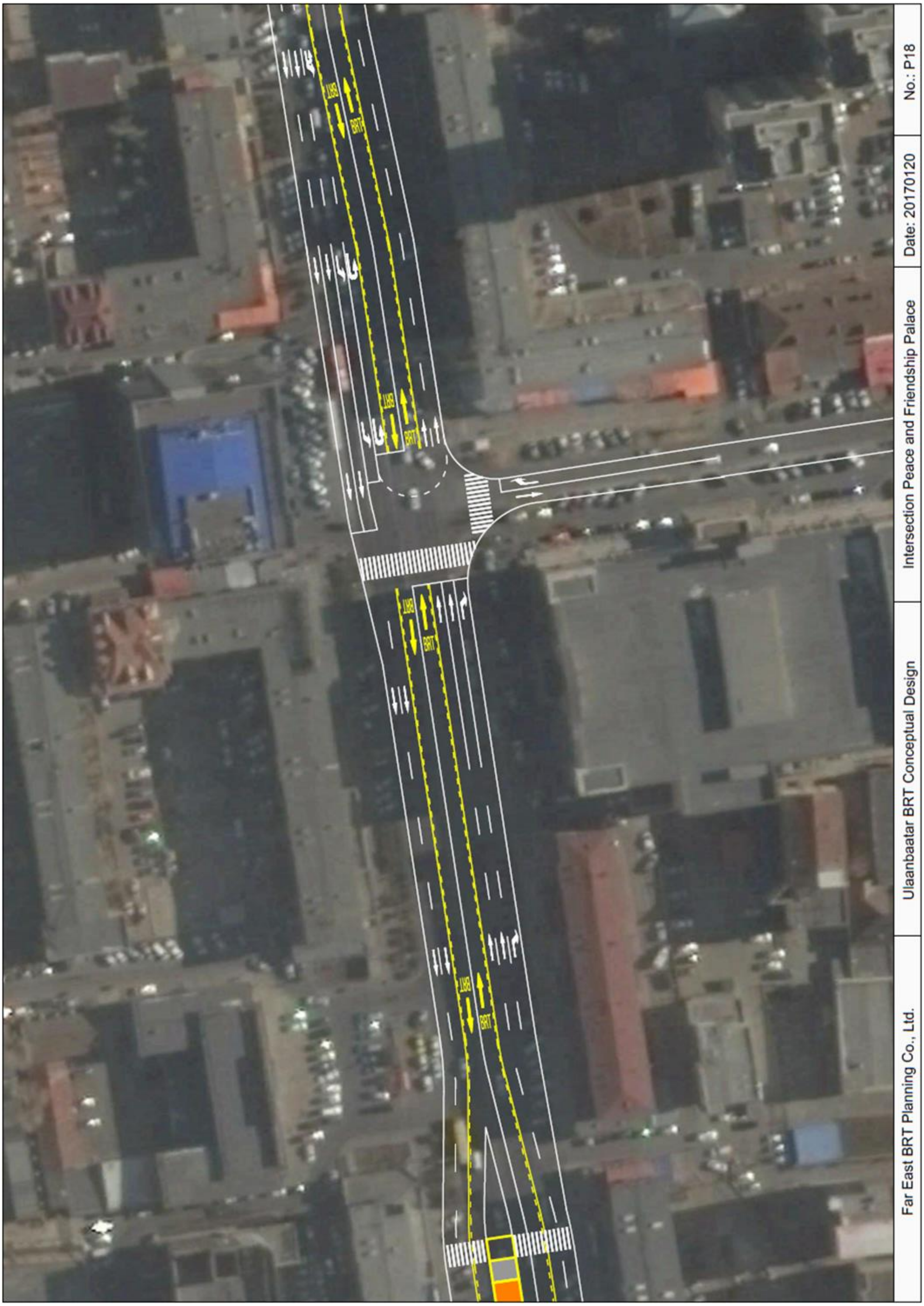
[26] Intersection Peace Ave / Partizan Rd

Current traffic volume (pcu)

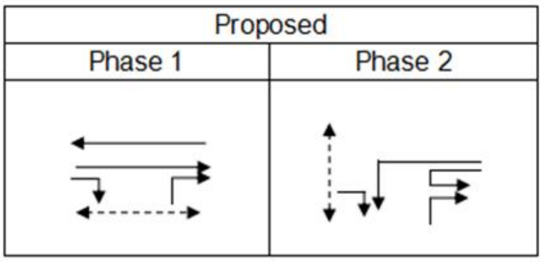
2014				
From	Left	Straight	Right	Total
North	0	0	0	0
South	362	470	267	1099
East	420	1800	302	2522
West	0	1530	346	1876
Total	782	3800	915	5497

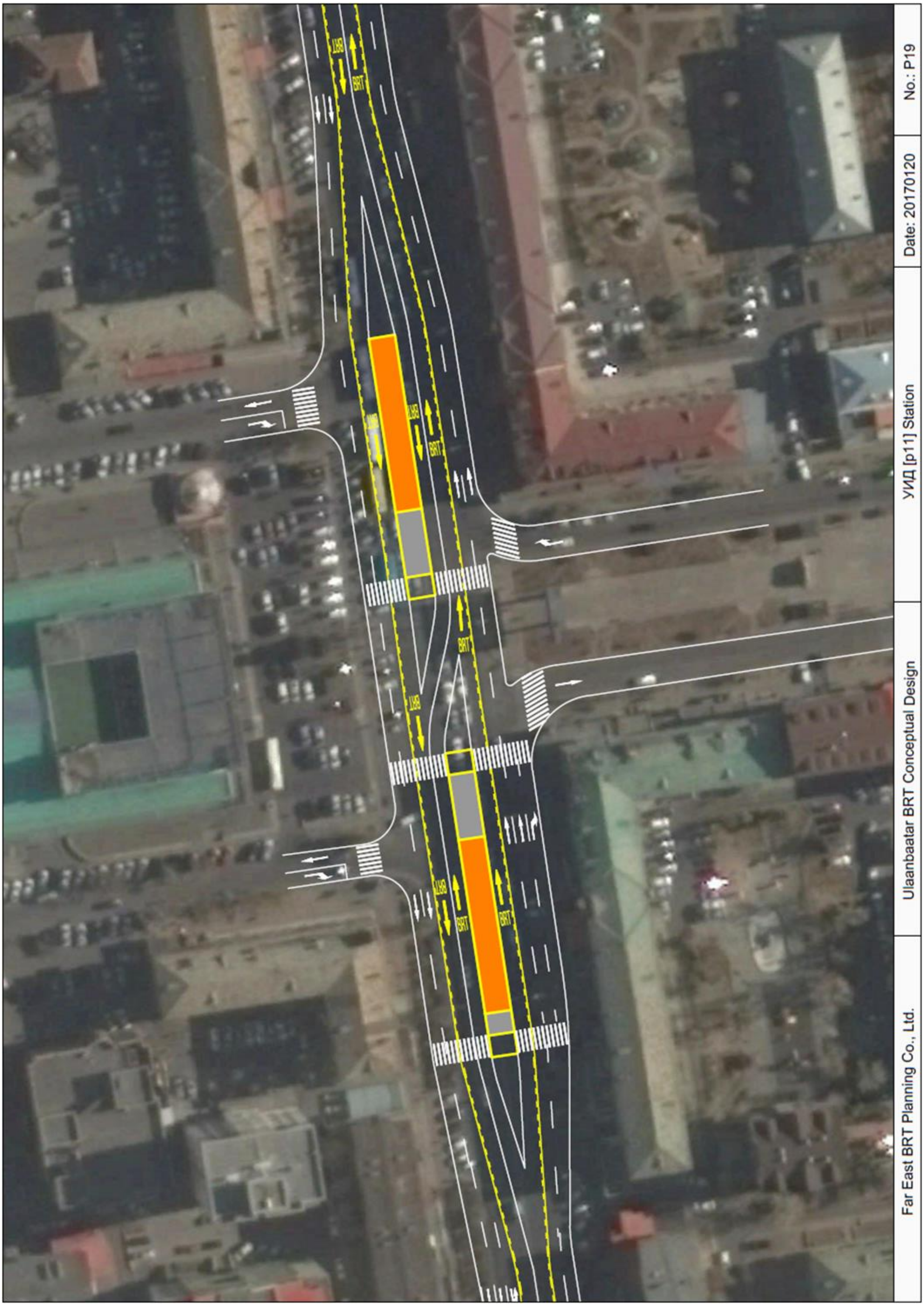





Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection Peace and Friendship Palace
Date: 20170120
No.: P18
BRT

Intersection Peace and Friendship Palace

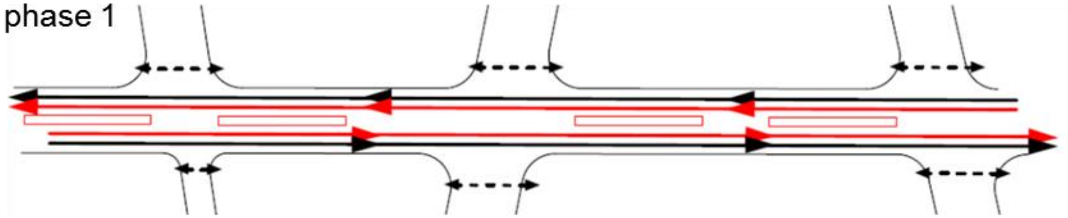



No.: P19
Date: 20170120
УИД [p11] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

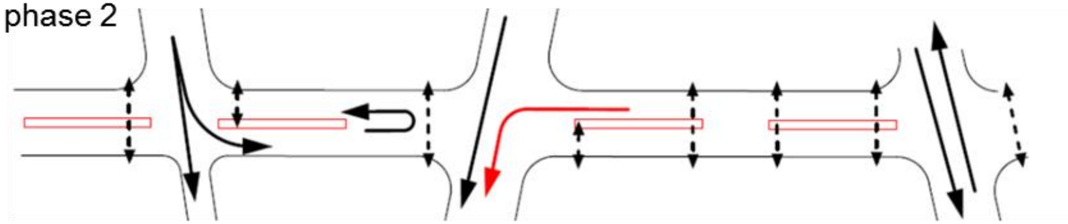
Intersection [25] Tsetseg tuv, Intersection [24] Central post office and Intersection [23] Ministry of Foreign Affairs
Мөнгөн завъяа [p12] Station and Чингисийн талбай [p13] Station

linked signals of 3 intersections and 2 stations

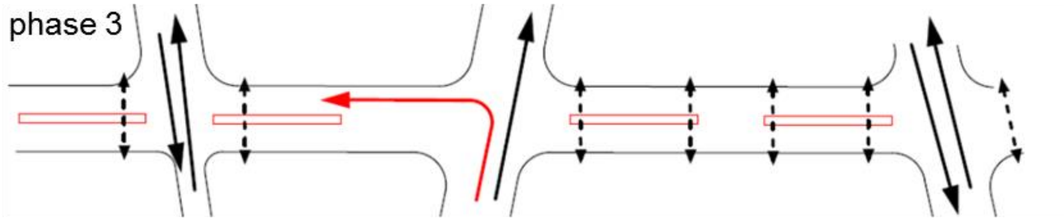
phase 1



phase 2



phase 3

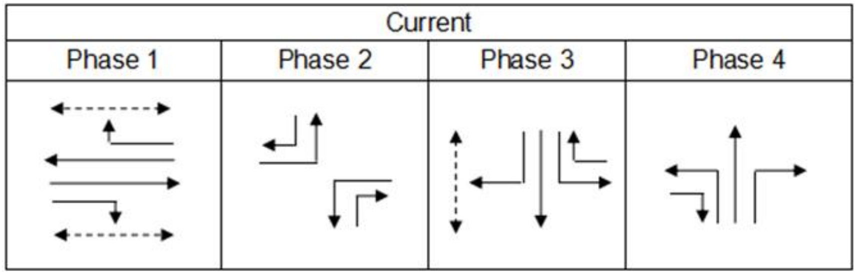



No.: P20
Date: 20170120
Intersection [25] and Мөнгөн завъяа [p12] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

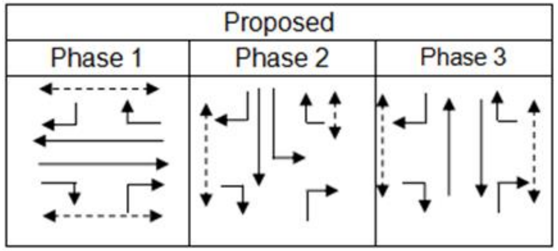
[25] Intersection Tsetseg tuv

Current traffic volume (pcu)

2014				
From	Left	Straight	Right	Total
North	758	0	504	1262
South	0	0	0	0
East	0	1728	540	2268
West	903	1810	0	2713
Total	1661	3538	1044	6243



2016.12					
From	Left	Straight	Right	U-trun	Total
North	629	628	541	0	1798
South	219	346	177	0	742
East	120	985	409	36	1550
West	514	1028	236	0	1778
Total	1482	2987	1363	36	5868




Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [24] Central post office
Date: 20170120
No.: P21

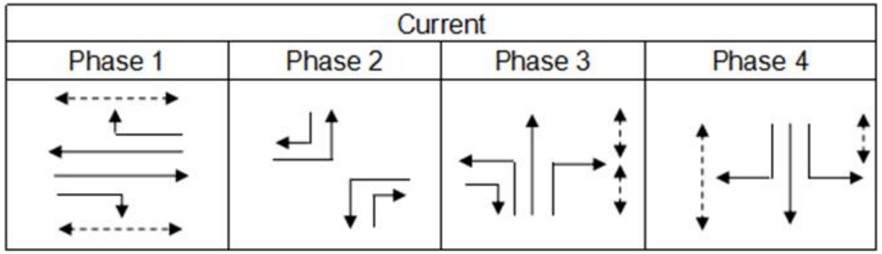
[24] Intersection Central post office

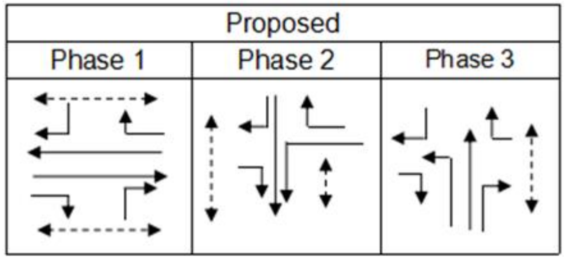
Current traffic volume (pcu)

2014				
From	Left	Straight	Right	Total
North	328	872	153	1353
South	360	792	216	1368
East	1080	1224	152	2456
West	216	1296	292	1804
Total	1984	4184	813	6981

2015				
From	Left	Straight	Right	Total
North	310	720	380	1410
South	540	750	400	1690
East	680	1480	300	2460
West	280	1400	310	1990
Total	1810	4350	1390	7550

2016.12					
From	Left	Straight	Right	U-turn	Total
North	227	430	290	6	953
South	754	784	362	10	1910
East	587	716	575	17	1895
West	170	992	479	10	1651
Total	1738	2922	1706	43	6409



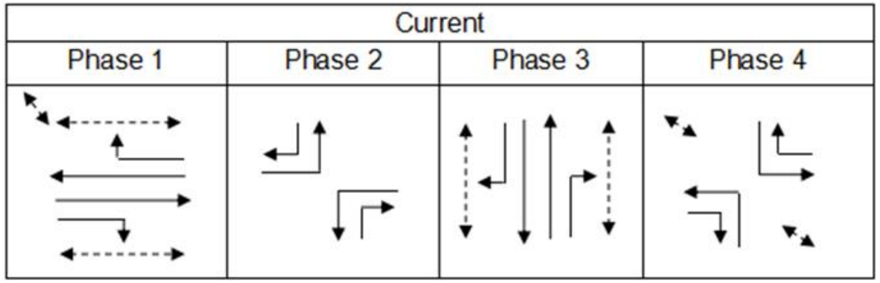



No.: P22
Date: 20170120
Intersection [23] and Чингисийн талбай [p13] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

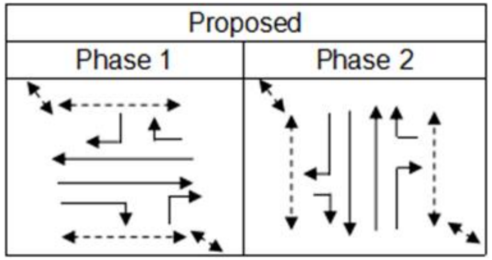
[23] Intersection Ministry of Foreign Affairs

Current traffic volume (pcu)

2014				
From	Left	Straight	Right	Total
North	275	658	500	1433
South	586	600	480	1666
East	510	1370	490	2370
West	481	1200	506	2187
Total	1852	3828	1976	7656

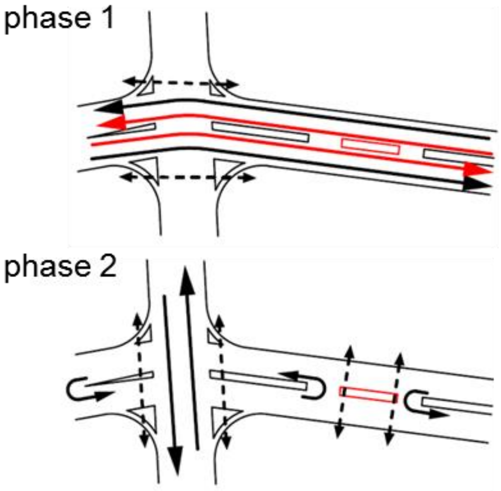


2016.12					
From	Left	Straight	Right	U-turn	Total
North	372	460	208	17	1057
South	377	546	302	14	1239
East	452	1046	12	7	1517
West	239	943	185	12	1379
Total	1440	2995	707	50	5192

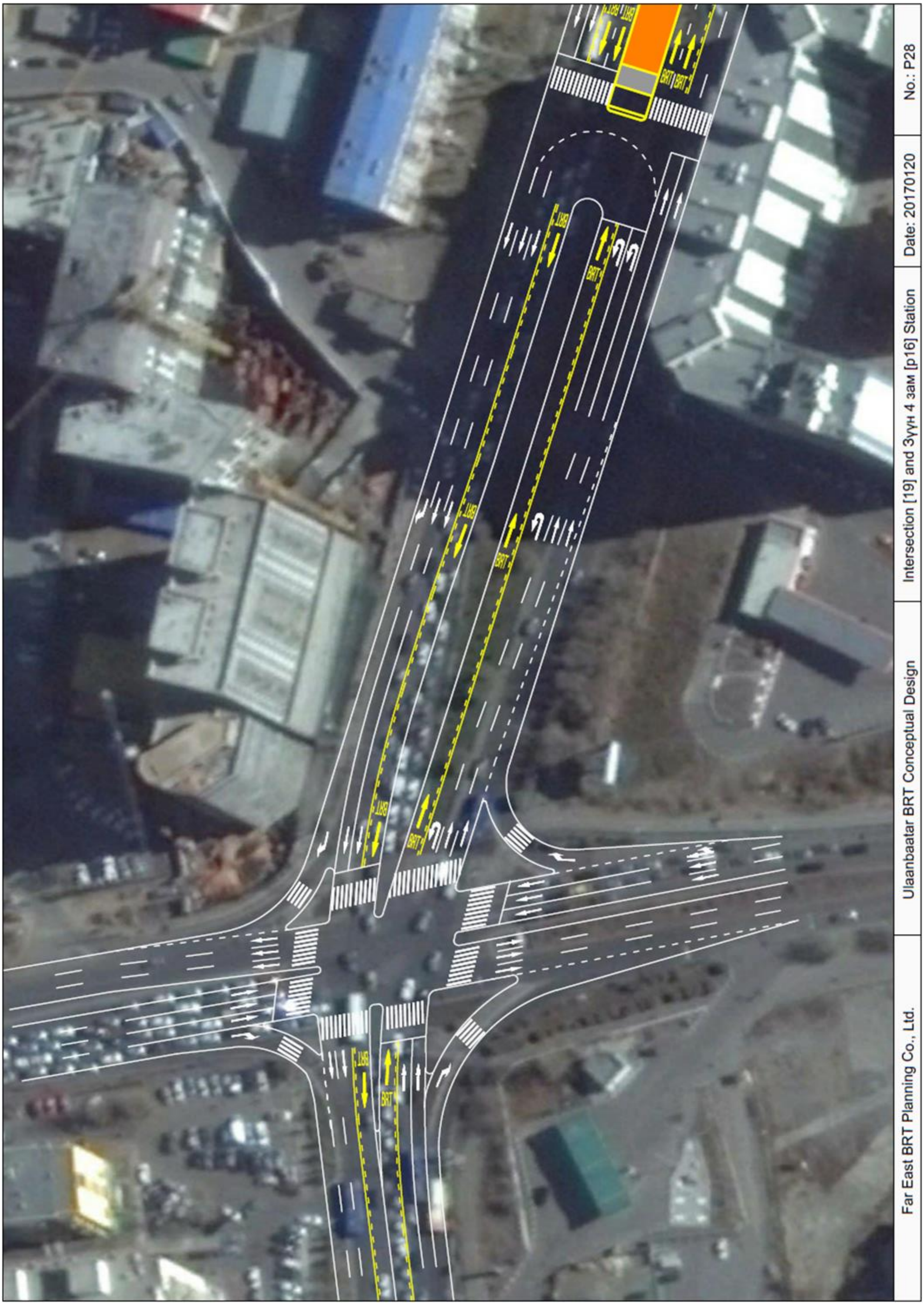


Intersection [19] East cross and Зүүн 4 зам [p16] Station

linked signals of intersection and station




Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [19] and Зүүн 4 зам [p16] Station
Date: 20170120
No.: P27

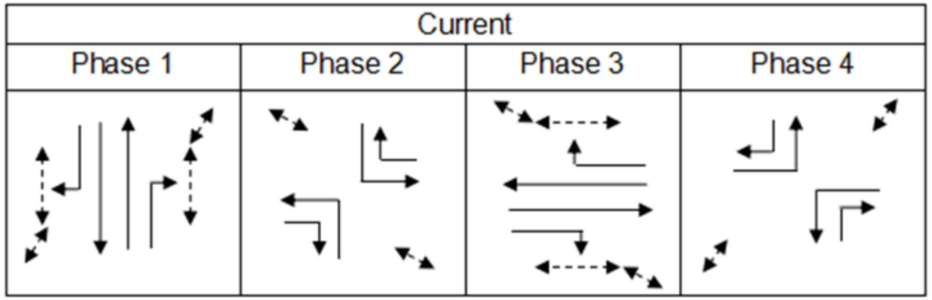

Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Intersection [19] and Зүүн 4 зам [p16] Station
Date: 20170120
No.: P28
BRT


No.: P29
Date: 20170120
Зүүн 4 зам [p16] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT

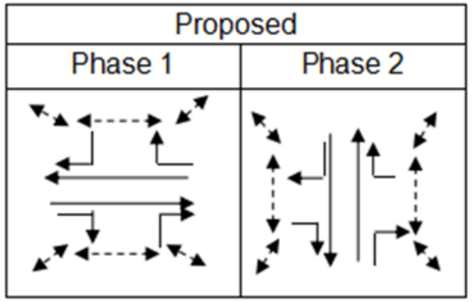
[19] Intersection East Cross (Peace Avenue & Namyan Ju)

Current traffic volume (pcu)

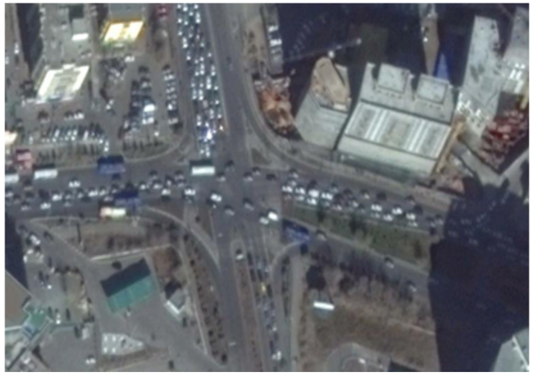
2014				
From	Left	Straight	Right	Total
North	600	1108	496	2204
South	626	1245	312	2183
East	810	1396	391	2597
West	516	1308	248	2072
Total	2552	5057	1447	9056

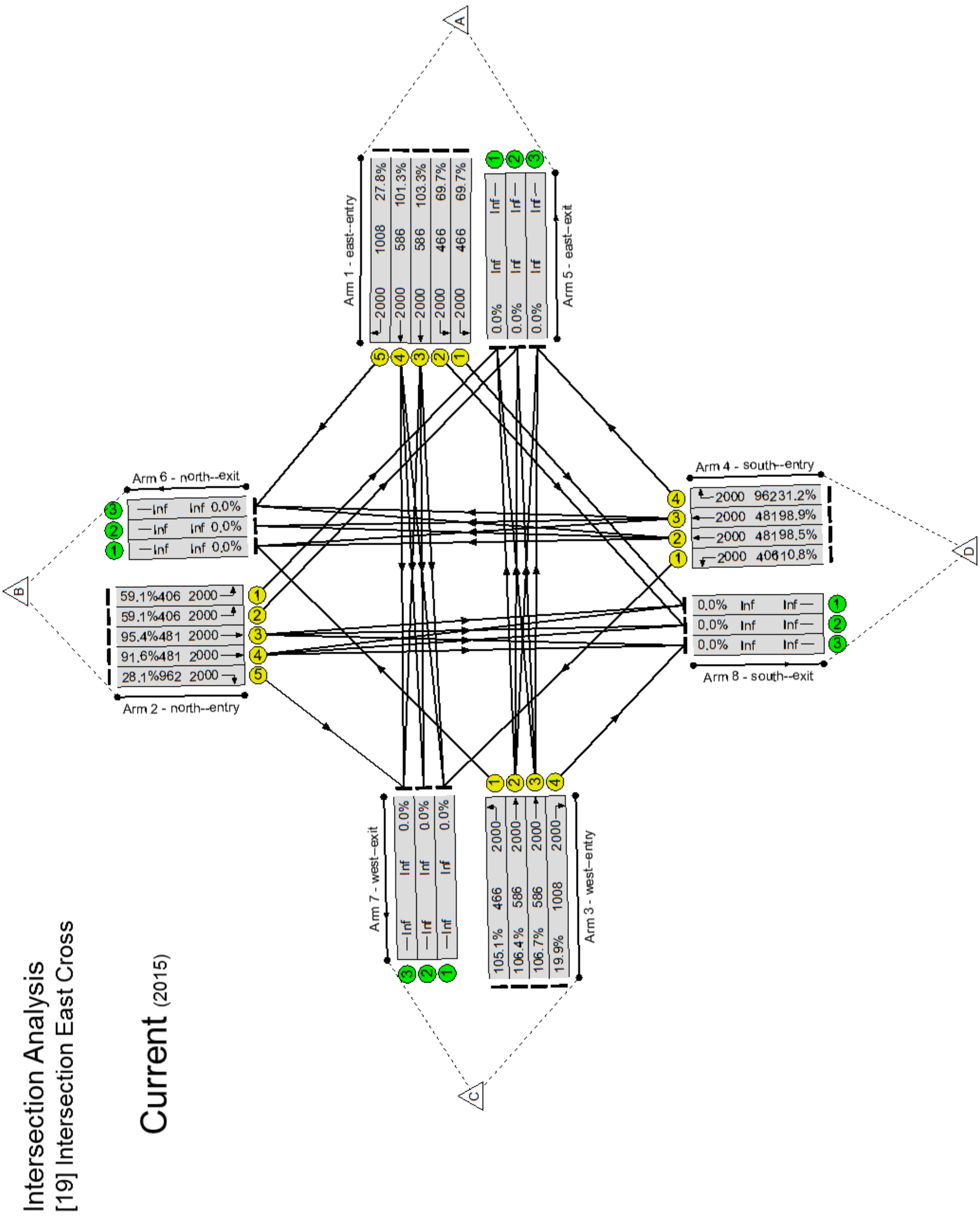


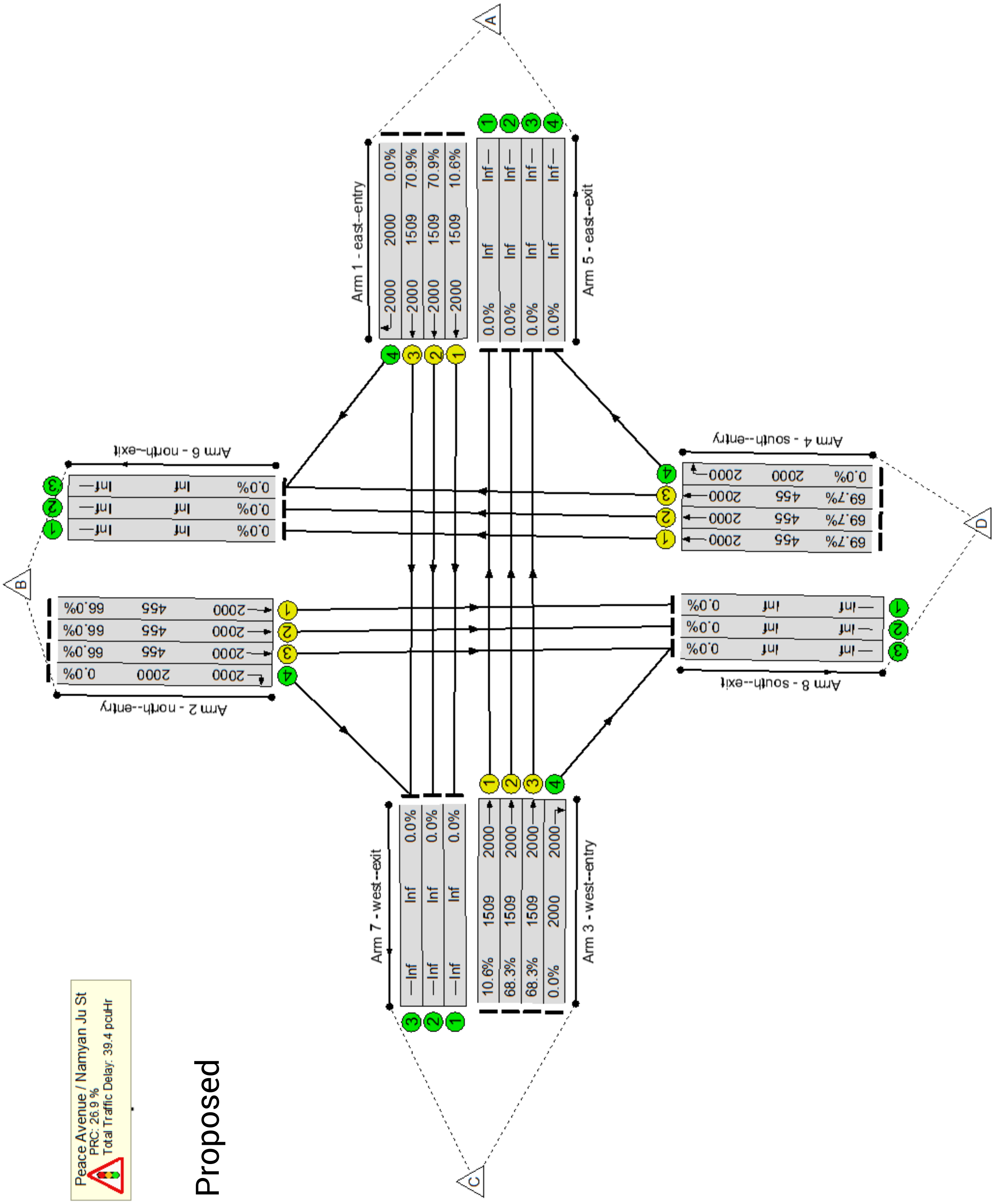
2015				
From	Left	Straight	Right	Total
North	480	900	270	1650
South	450	950	300	1700
East	650	1200	280	2130
West	490	1250	200	1940
Total	2070	4300	1050	7420



2016.12					
From	Left	Straight	Right	U-turn	Total
North	341	436	84	26	887
South	451	767	98	108	1424
East	593	791	494	19	1897
West	224	745	163	0	1132
Total	1609	2739	839	153	5340




Intersection Analysis
[19] Intersection East Cross
Current (2015)
Arm 1 - east--entry
Arm 2 - north--entry
Arm 3 - west--entry
Arm 4 - south--entry
Arm 5 - east--exit
Arm 6 - north--exit
Arm 7 - west--exit
Arm 8 - south--exit
A
B
C
D

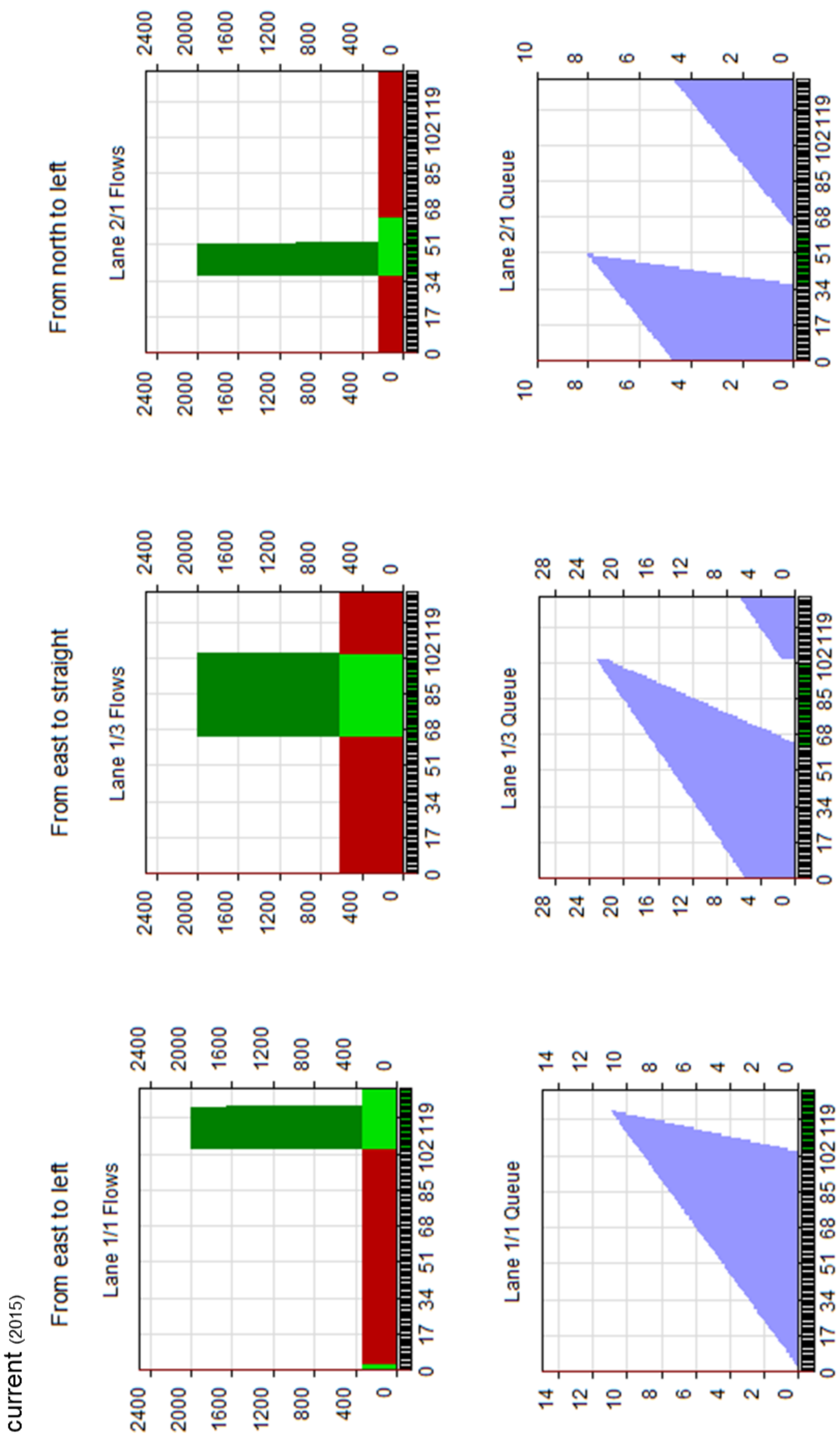

Arm 1 - east--entry
Arm 5 - east--exit
Arm 4 - south--entry
Arm 8 - south--exit
Arm 2 - north--entry
Arm 6 - north--exit
Arm 7 - west--exit
Arm 3 - west--entry
A
B
C
D
Peace Avenue / Namyan Ju St
PRC: 26.9 %
Total Traffic Delay: 39.4 pcuHr
Proposed

current (2015)

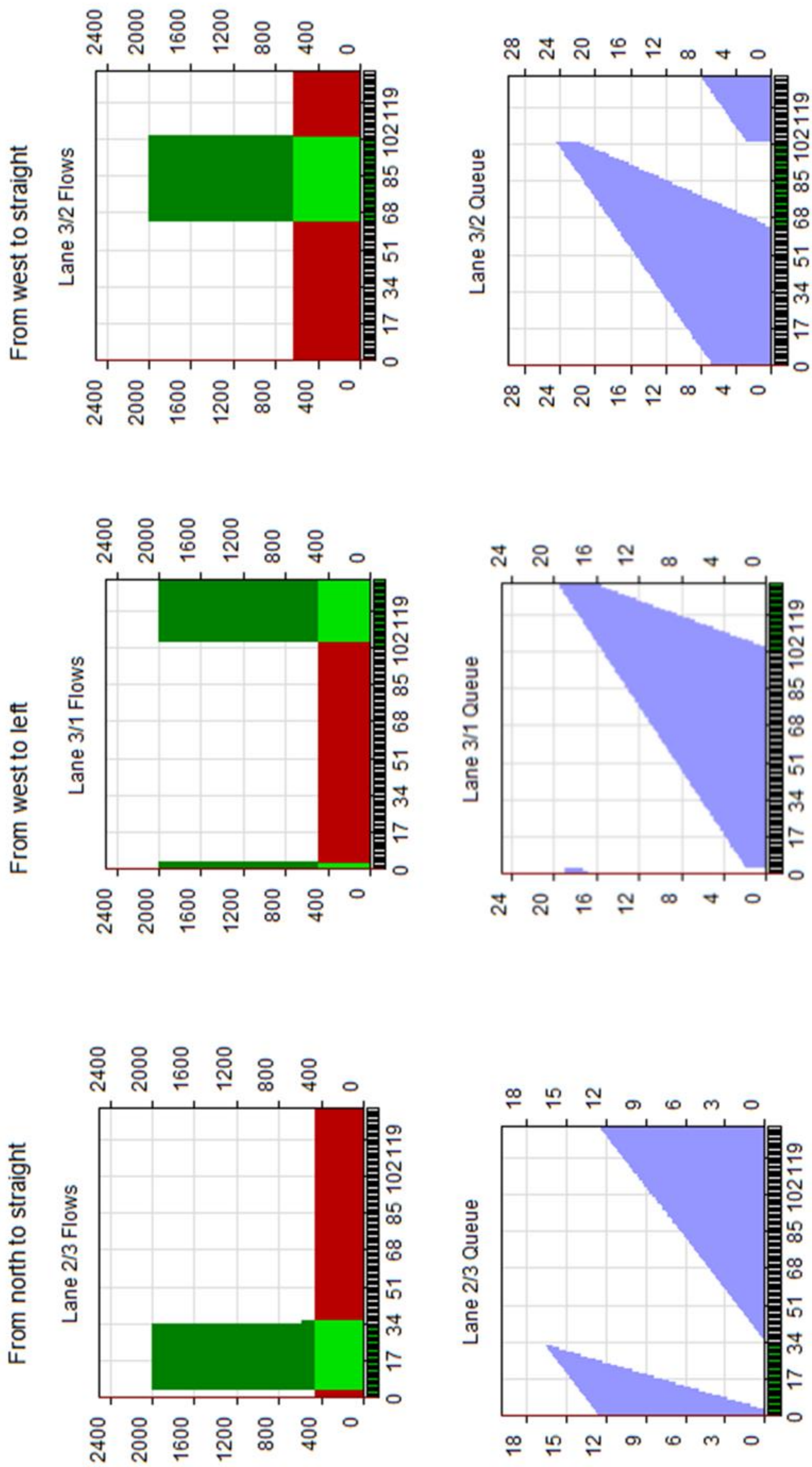
Item	Lane Description	Lane Type	Demand Flow (pcu)	Sat Flow (pcu/Hr)	Capacity (pcu)	Deg Sat (%)	Total Delay (pcuHr)	Av. Delay Per PCU (s/pcu)	Mean Max Queue (pcu)
Network	-	-	-	-	-	**110.8%**	**263.9**	-	-
1/1	east--entry Left	U	325	2000	466	69.7%	5.3	59.3	12.1
1/2	east--entry Left	U	325	2000	466	69.7%	5.3	59.3	12.1
1/3	east--entry Ahead	U	606	2000	586	103.3%	27.0	160.5	41.2
1/4	east--entry Ahead	U	594	2000	586	101.3%	22.4	135.5	36.4
1/5	east--entry Right	U	280	2000	1008	27.8%	1.7	21.5	6.1
2/1	north--entry Left	U	240	2000	406	59.1%	3.9	58.8	8.7
2/2	north--entry Left	U	240	2000	406	59.1%	3.9	58.8	8.7
2/3	north--entry Ahead	U	459	2000	481	95.4%	12.9	100.9	23.2
2/4	north--entry Ahead	U	441	2000	481	91.6%	10.5	85.8	20.3
2/5	north--entry Right	U	270	2000	962	28.1%	1.7	23.3	6.1
3/1	west--entry Left	U	490	2000	466	105.1%	27.3	200.7	38.0
3/2	west--entry Ahead	U	624	2000	586	106.4%	35.0	202.2	49.4
3/3	west--entry Ahead	U	626	2000	586	106.7%	36.0	207.0	50.4
3/4	west--entry Right	U	200	2000	1008	19.9%	1.1	20.4	4.2
4/1	south--entry Left	U	450	2000	406	110.8%	35.5	284.3	44.5
4/2	south--entry Ahead	U	474	2000	481	98.5%	15.9	120.4	26.6
4/3	south--entry Ahead	U	476	2000	481	98.9%	16.3	123.6	27.1
4/4	south--entry Right	U	300	2000	962	31.2%	2.0	23.8	7.0

proposed

Item	Lane Description	Lane Type	Demand Flow (pcu)	Sat Flow (pcu/Hr)	Capacity (pcu)	Deg Sat (%)	Total Delay (pcuHr)	Av. Delay Per PCU (s/pcu)	Mean Max Queue (pcu)
Network	-	-	-	-	-	**74.5%**	**39.1**	-	-
1/1	east--entry Ahead	U	160	2000	1436	11.1%	0.3	6.2	1.5
1/2	east--entry Ahead	U	1070	2000	1436	74.5%	4.2	14.3	21.1
1/3	east--entry Ahead	U	1070	2000	1436	74.5%	4.2	14.3	21.1
1/4	east--entry Right	U	0	2000	2000	0.0%	0.0	0.0	0.0
2/1	north--entry Ahead	U	300	2000	527	56.9%	3.6	43.0	8.6
2/2	north--entry Ahead	U	300	2000	527	56.9%	3.6	43.0	8.6
2/3	north--entry Ahead	U	300	2000	527	56.9%	3.6	43.0	8.6
2/4	north--entry Right	U	0	2000	2000	0.0%	0.0	0.0	0.0
3/1	west--entry Ahead	U	160	2000	1436	11.1%	0.3	6.2	1.5
3/2	west--entry Ahead	U	1030	2000	1436	71.7%	3.8	13.4	19.3
3/3+3/4	west--entry Ahead Right	U	1030	2000:2000	1436	71.7%	3.8	13.4	19.3
4/1	south--entry Ahead	U	317	2000	527	60.1%	3.9	43.9	9.2
4/2	south--entry Ahead	U	317	2000	527	60.1%	3.9	43.9	9.2
4/3+4/4	south--entry Right Ahead	U	317	2000:2000	527	60.1%	3.9	43.9	9.2

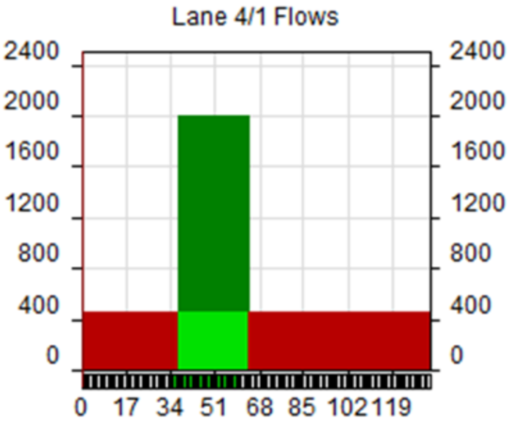

current (2015)
From east to left
Lane 1/1 Flows
Lane 1/1 Queue
From east to straight
Lane 1/3 Flows
Lane 1/3 Queue
From north to left
Lane 2/1 Flows
Lane 2/1 Queue

current (2015)

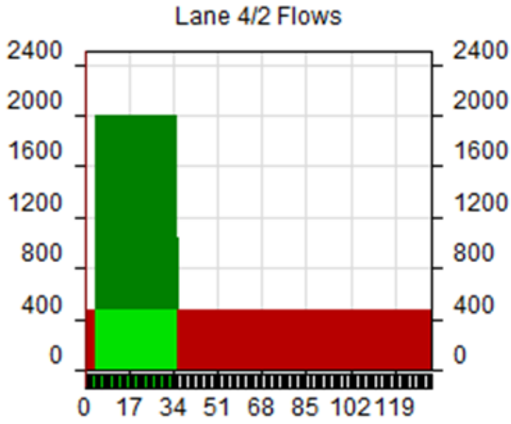


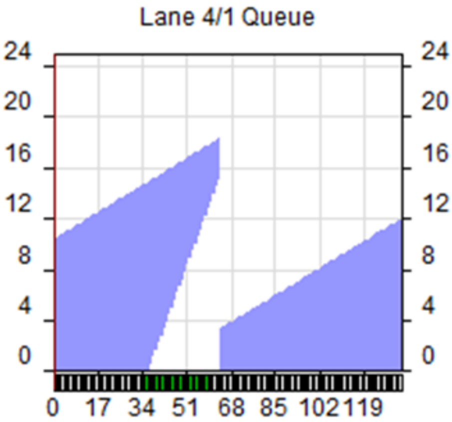
current (2015)

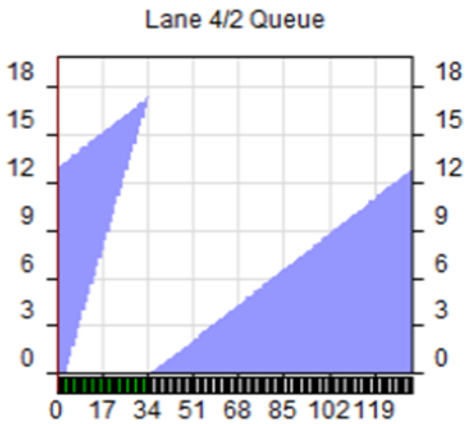
From south to left

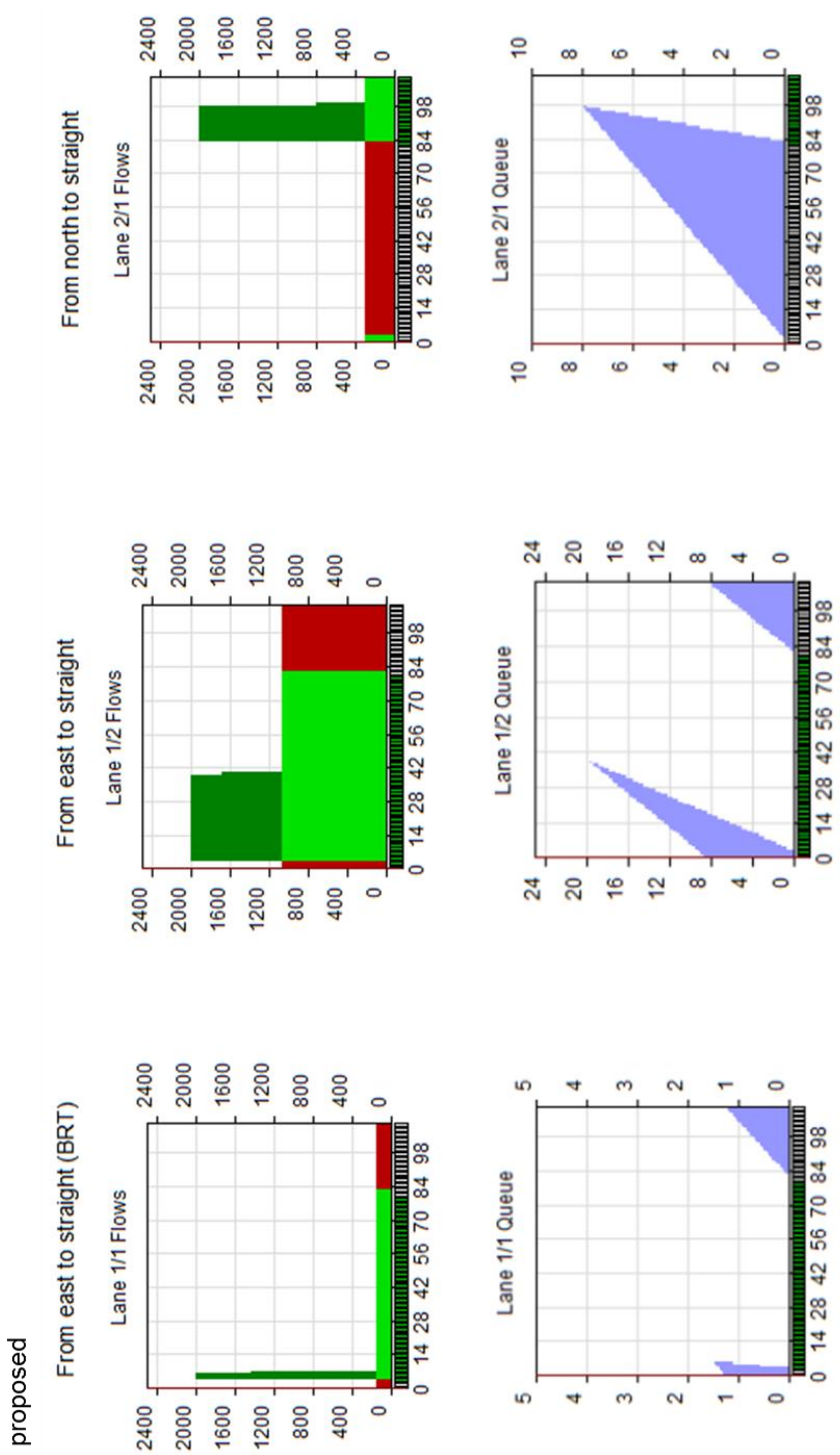


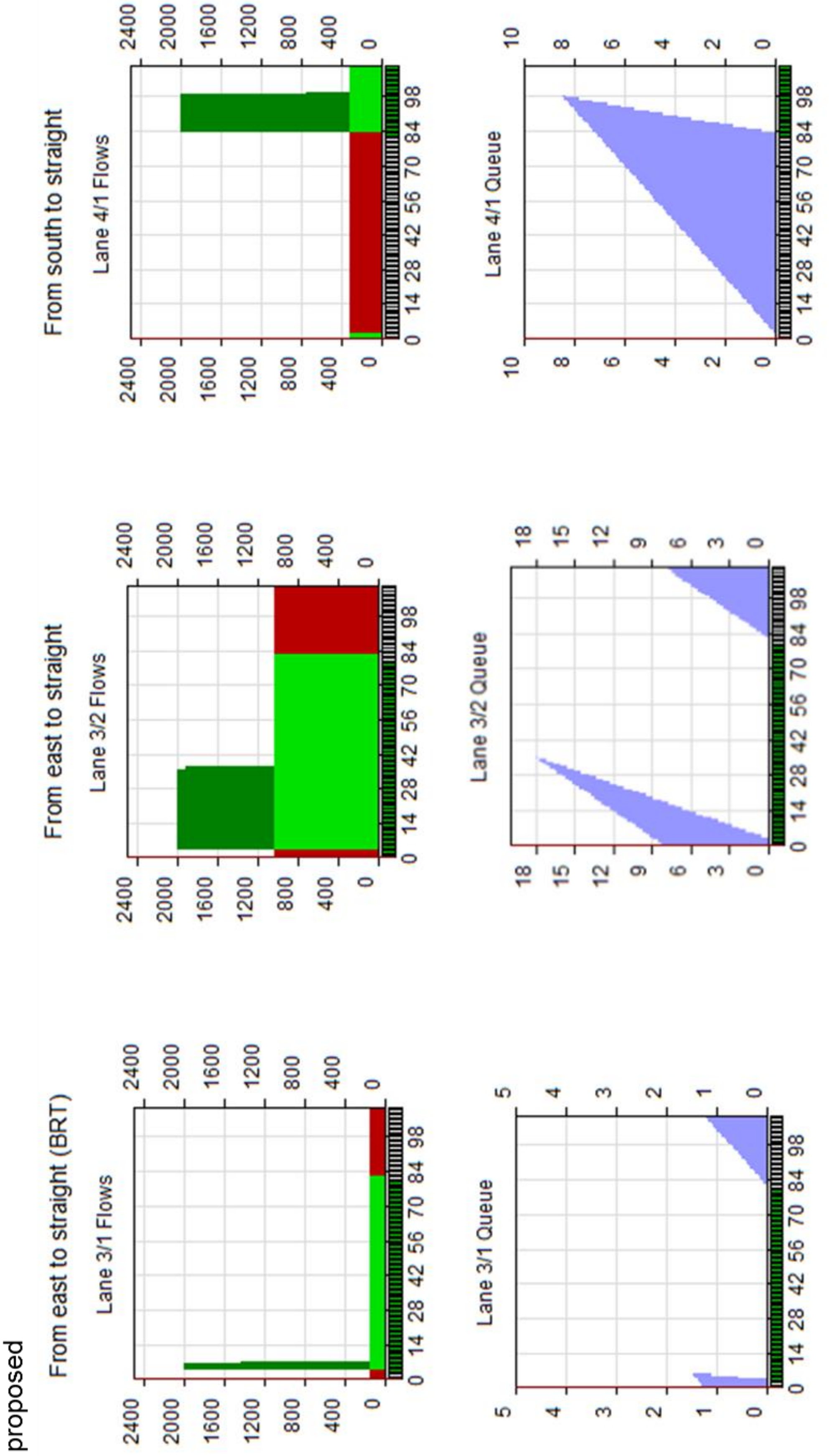
From south to straight








proposed
From east to straight (BRT)
Lane 1/1 Flows
Lane 1/1 Queue
From east to straight
Lane 1/2 Flows
Lane 1/2 Queue
From north to straight
Lane 2/1 Flows
Lane 2/1 Queue


proposed
From east to straight (BRT)
Lane 3/1 Flows
Lane 3/1 Queue
From east to straight
Lane 3/2 Flows
Lane 3/2 Queue
From south to straight
Lane 4/1 Flows
Lane 4/1 Queue

Conclusion:

The analysis based on the traffic count data from 2015 shows that the proposed change from 4 phase to 2 phase at the intersection of Peace Avenue with East Cross / Namyan Ju provides major improvements to the intersection capacity and performance by all measures.

Saturation falls from 110% to 75%.

Total delay falls approximately seven-fold from 264 PCU hours to 39 PCU hours.

Note that this improvement is achieved with the implementation of BRT and without the need for any flyover at this location.

The results of this analysis are confirmed by a separate analysis of the intersection saturation carried out as follows. The results are almost identical to the analysis above. **Saturation falls from 102% with the current four phases to 69% with the proposed two phases plus BRT.** This indicates a major improvement to intersection performance without the need for a flyover in this location.

Present 4 phase						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	north	str	900	2	4000	23%
	south	str	950	2	4000	24%
	max					24%
2	south	left	450	1	2000	23%
	north	left	480	2	4000	12%
	max					23%
3	east	str	1200	2	4000	30%
	west	str	1250	2	4000	31%
	max					31%
4	east	left	650	2	4000	16%
	west	left	490	1	2000	25%
	max					25%
	total					**102%**

Proposed 2 phase plus BRT						
phase	side	to	volume	lanes	sat. flow (pcu/h)	saturation
1	east	str	2140	2	4000	54%
		brt	160	1	2000	8%
	west	str	2060	2	4000	52%
		brt	160	1	2000	8%
	max					54%
2	south	str	950	3	6000	16%
	north	str	900	3	6000	15%
	max					16%
	total					**69%**

Жуков [p17] Station, Кино үйлдвэр [p18] Station and Оффицеруудын ордон [p19] Station

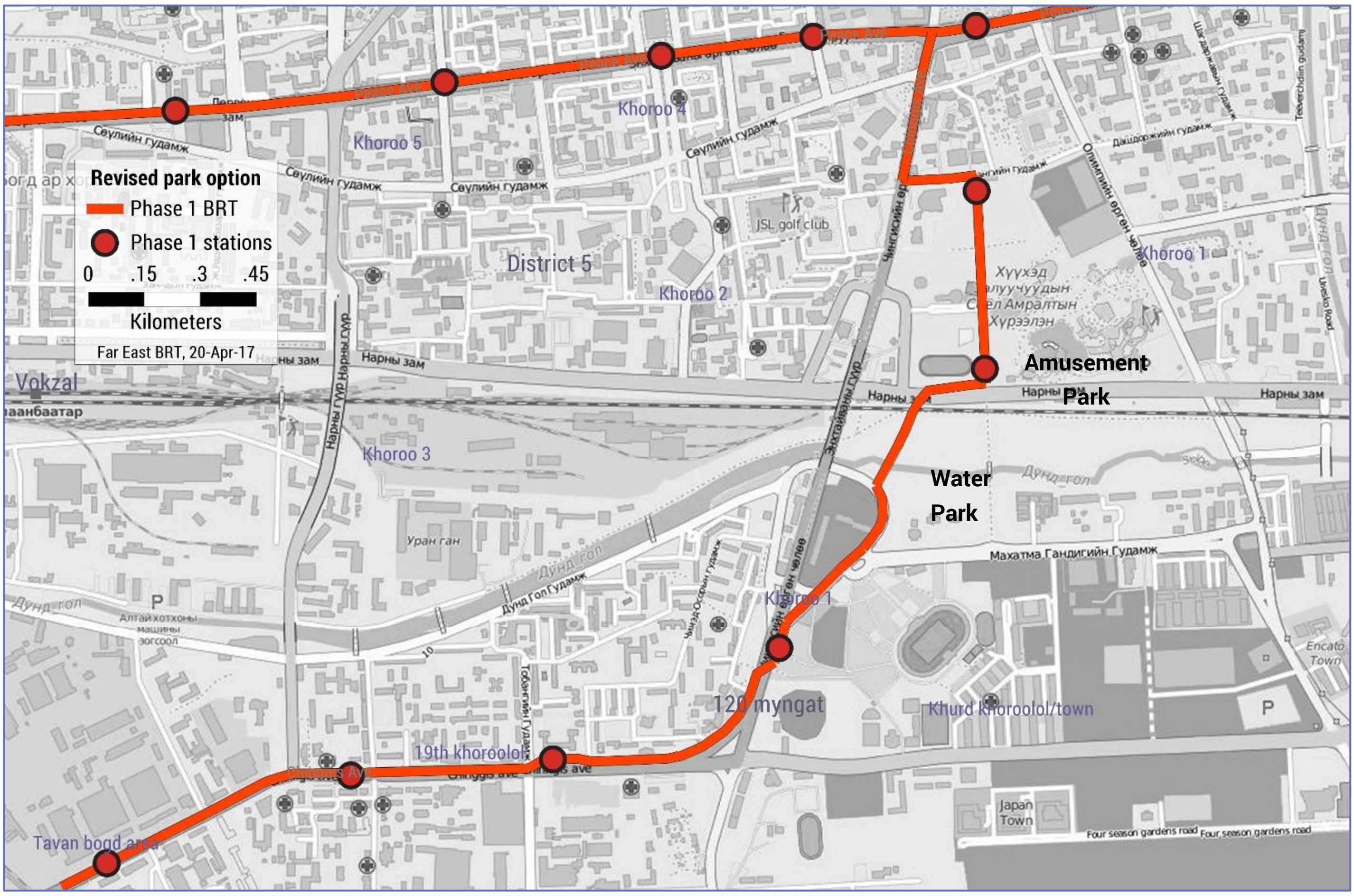

No.: P30
Date: 20170120
Жуков [p17] Station
Ulaanbaatar BRT Conceptual Design
Far East BRT Planning Co., Ltd.
BRT


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Кино үйлдвэр [p18] Station
Date: 20170120
No.: P31
BRT


Far East BRT Planning Co., Ltd.
Ulaanbaatar BRT Conceptual Design
Офицеруудын ордон [p19] Station
Date: 20170120
No.: P32

11 Southwest connection

In November and December 2016 the team developed a 'southwest connection' BRT alignment through the area bordered by Genden Street, Olympic Street, Narnii Road and Chinggis Avenue. This alignment provides an alternative to the use of Peace Bridge for the BRT alignment, providing a key connection between the city centre and the 19th khoroolol area around Chinggis Avenue between Engels St and Peace Bridge.



Southwest connection corridor and stations

Possible advantages of the southwest connection include:

- Construction in several sections could be carried out without disruption to general traffic.
- The congested Peace Bridge, a major bottleneck, is avoided.
- A BRT station does not need to be built in the narrow and congested section along Chinggis Avenue between Peace Bridge and Peace Avenue.
- The high demand area of 120 myngat can be served. The phase 2 BRT corridor can extend to 120 mygnat.
- The overall BRT phases can be reduced from four to three.
- The water park (under construction) and amusement park can be much more easily accessed than is presently possible.

- The currently degraded or abandoned areas around the foot of Peace Bridge and Narnii Road can be developed as a form of transit-oriented development. The area, though very close to the city centre, is currently difficult to access. Similarly the southwest connection can support transit-oriented development along Narnii Road, which would be much more accessible to transit than is presently the case.

Possible disadvantages of the southwest connection are:

- Less direct connection compared to using Peace Bridge.
- The need for use of the right-of-way through the park, between Narnii Road and Genden Street, for around 550m, and the need for use of right-of-way in the northern and southern section of the park, for BRT station platforms.
- The need for a flyover over the railway line. A street level crossing may be preferable, but the railway bureau prefers grade separation, and the Roads Department prefers a flyover.
- The possible need for some land in front of the water park to be used.

Each of these advantages and disadvantages are discussed in turn following.

11.1 Advantages of the southwest connection

11.1.1 Construction without impacting road users

Though measures will be taken during BRT construction to minimize and mitigate construction impacts, it is inevitable that road users will experience some disruption and negative impact. Impacted road users will include pedestrians, cyclists, public transport passengers, and private vehicle drivers and passengers. This is especially true of BRT stations, which involve a larger footprint and where in many locations the entire roadway for a stretch of around 200m will need to be rebuilt.

A positive aspect of the southwest connection is that much of the construction can take place in locations which will have little or no negative impact on other road users. Of the four station platforms in the two stations at the north and south end of the park, all are located in the park. None of these spaces are currently used by pedestrians, motorists, or anyone else.

11.1.2 Avoiding Peace Bridge

Peace Bridge serves traffic from a large part of the rapidly developing area of the city south of the railway line, and is often congested. Bus speeds, reflecting mixed traffic speeds noting that there are no stops on Peace Bridge, average 16km/hr during 7AM to 7PM on weekdays. (Weekend speeds are around 27km/hr according to the smart card bus speed data discussed earlier in this report.) Congestion on Peace Bridge is likely to increase as development continues in the Zaisan area and in other areas south of the railway including along Chinggis Avenue and the Airport Road.

There are various options for the BRT alignment across Peace Bridge, including two-way BRT and one-way traffic, but the most likely approach will involve the BRT operating in mixed traffic in either one or both directions of traffic on Peace Bridge. In this case, given the declining traffic speeds, the BRT speed across the bridge is likely to be less than 15km/hr. In some periods of heavy traffic congestion, the BRT speeds may be slower than 10km/hr.

Alternatively, if segregated lanes are taken for BRT on Peace Bridge, there is likely to be a strong negative impact on mixed traffic.

By avoiding Peace Bridge, the BRT corridor can avoid problems of congestion around Peace Bridge even as traffic volumes increase in coming years, and the BRT will not have a negative impact on mixed traffic on Peace Bridge. On the contrary, traffic on Peace Bridge will improve, because most or all of the buses currently using the bridge will use the southwest connection BRT alignment instead.

11.1.3 Avoiding the need for a Bayangol BRT station

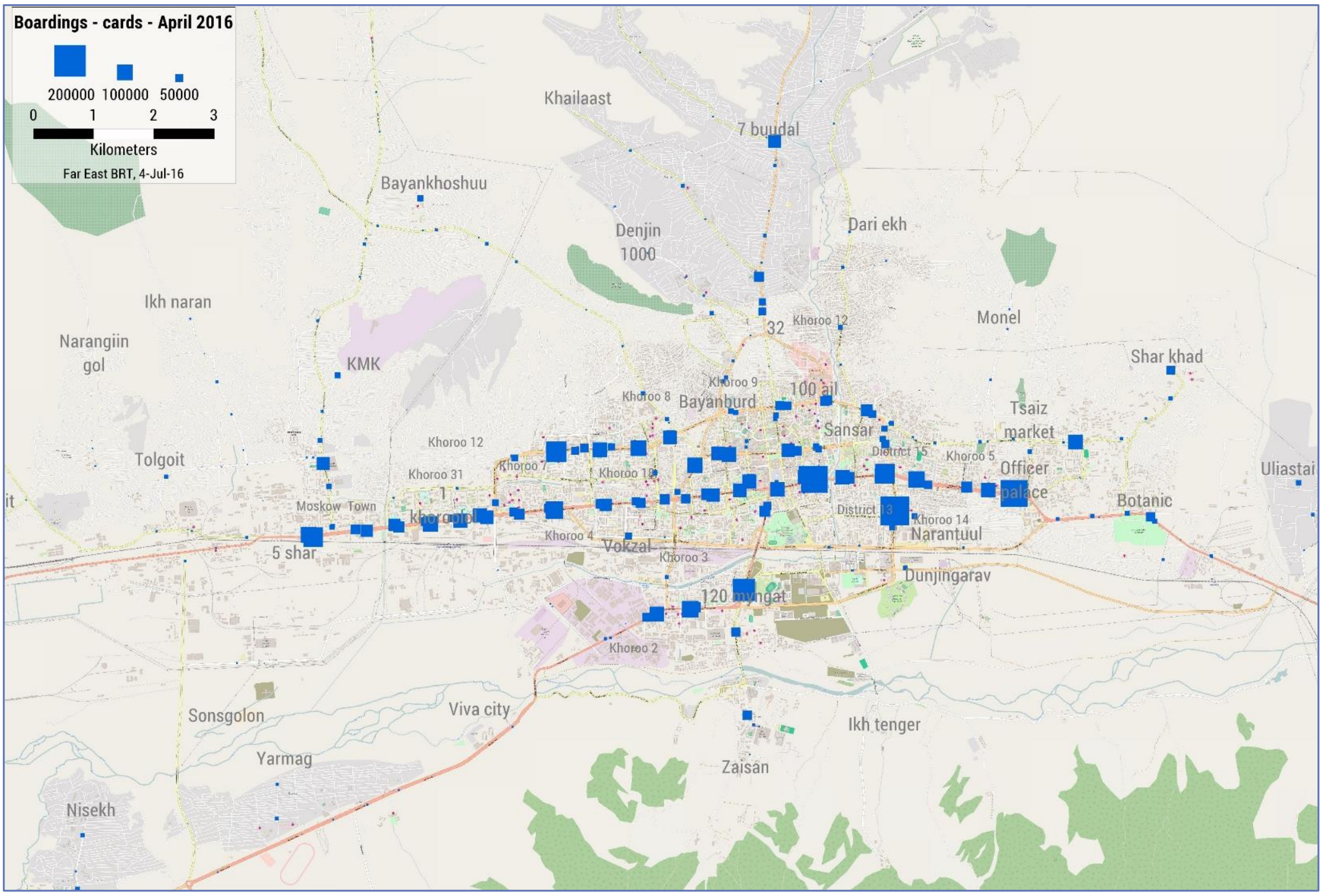
A significant difficulty associated with the Peace Bridge alignment option is that a BRT station needs to be located along Chinggis Avenue between Peace Bridge and Peace Avenue. The only realistic location for such a station is approximately in front of the Bayangol Hotel. Although it is possible to 'squeeze' a BRT station into a limited existing right-of-way if mixed traffic is reduced to two lanes at this location and on Peace Bridge (either two lanes one-way, or one lane in each direction), if 4 lanes of mixed traffic are to be retained it will be essential to acquire part of the land in front of the Bayangol.

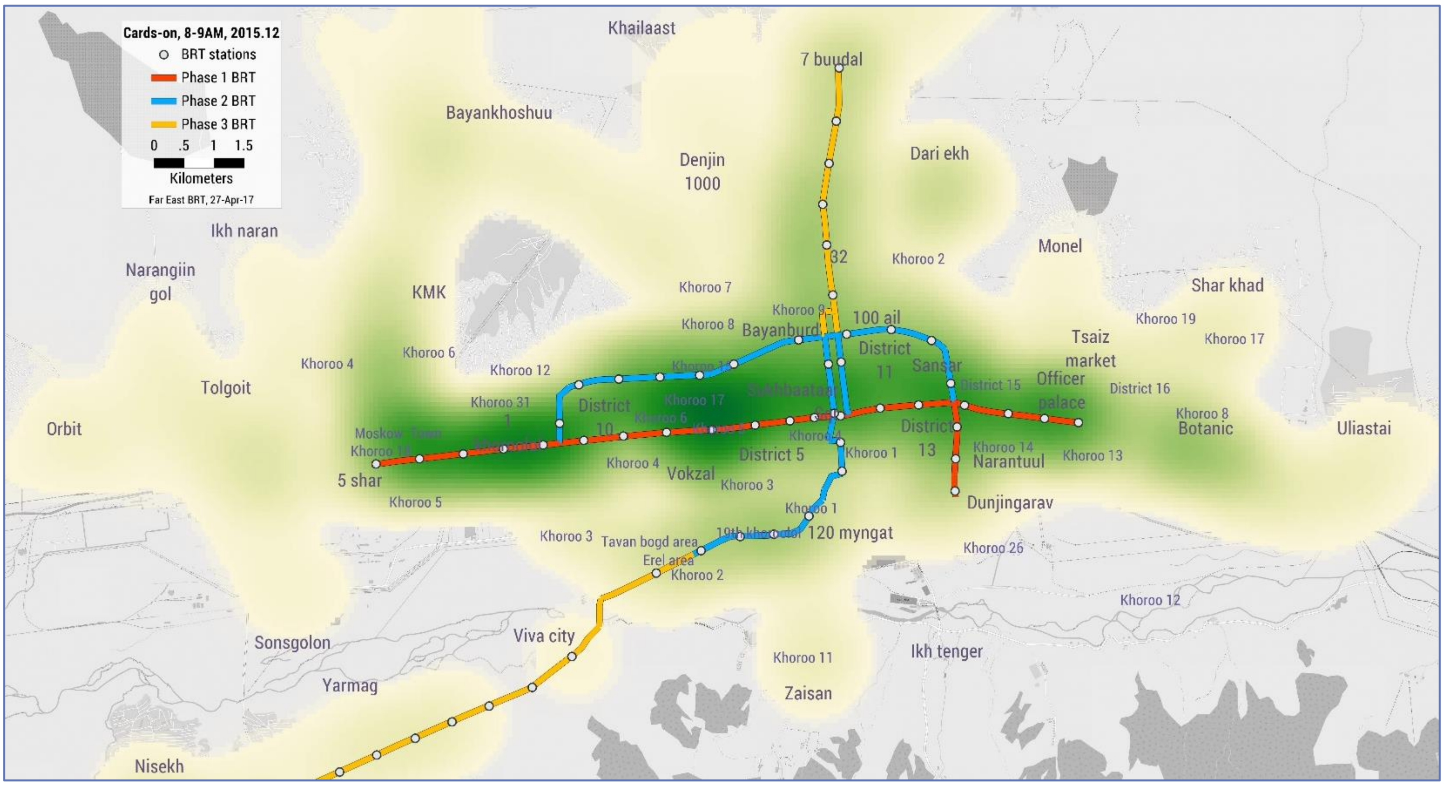
In the southwest connection presented in this report, there is no longer any need for a station in this critical section of Chinggis Avenue between Peace Bridge and Peace Avenue. Rather, the station will be located at the north of the park and will be accessed from Genden Street. While this station placement means passengers from west of Chinggis Avenue around the Bayangol will need to walk an extra 200m to access the BRT station, other passengers from east of Chinggis Avenue, including from the Shangri-La mall and Olympic St, will save 200m in walking distance. An elevated walkway which connections to the BRT station and to surrounding buildings and is heated in the Winter is proposed for this area.

11.1.4 Serving the high demand area around 19th khoroolol & Tavan bogd

The demand analysis of both current bus ridership and BRT system ridership provided earlier in this report show the importance of the 120 myngat, 19th khoroolol and Tavan bogd areas. The April 2016 smart card bus boardings and a 'heat map' of the average boarding demand from 8-9AM in December 2015 show the importance of this area south of the Peace Bridge along Chinggis Avenue.

If the BRT system used Peace Bridge, which is a viable option though subject to various design challenges, the implementation of BRT serving this important area would not take place until phase 3 or phase 4 of the BRT system, largely due to the concerns about negative impacts on mixed traffic. With the southwest connection, however, this important area can be included in the phase 2 BRT system, providing major benefits for the citywide transportation system and greatly boosting the BRT system ridership.





April 2016 smart card boardings (top) and a heat map graphic showing bus passenger boardings by smart card from 8-9AM over a one week period in December 2015.

11.1.5 Reduction in implementation phases

With the southwest connection included in phase 2, the BRT implementation phases can be reduced from four to three phases, which reduces the complexities of administering and implementing the project, and should result in a more rapid time frame.

11.1.6 Amusement park and water park accessibility

Amusement park overview

The National Amusement Park or National Culture and Recreation Center (Children's Park) features rides, an artificial lake and castle, a bowling alley, ice skating in Winter, a roller coaster, and other amusements. The government owns the land. The castle was built in 1969 and upgraded in 2010, and the roller coaster was built in 2013.

Water park overview

The owner and developer of the Shonkhor Tower Waterpark & Sports Complex, which is currently under construction, is M & G Construction. According to reports in the early stages of project preparation in 2012, the all-season and all-weather park is expected to provide employment for up to 1,200 people (http://intergameonline.com/coin-op/news/8349/mg-contract-vitala-for-mongolian-theme-park).

The website http://www.shonhortower.mn/index.php?show=information has more information about the project. M & G Construction apparently own the site, and a director is quoted as saying:

> *"We are planning to build a sport complex due to the necessity of the people and the geographical position of our tower. We lack places for our children and elders to spend their leisure time. We want this to become a place which people at any age to enjoy their quality time with their families and friends. The complex plan includes gym, open/closed swimming pool, classic and modern entertainment center, spa resorts; children care center, four-season skating field, non-alcohol selling pubs and places which people can spend time with their families. The operation will continue without concerning about the weather conditions." (http://www.shonhortower.mn/index.php?show=information)*

Following are photos from the water park construction site in December 2016. As of April 2017 the construction activities had not yet commenced, apparently pending resolution of the BRT design in this area.

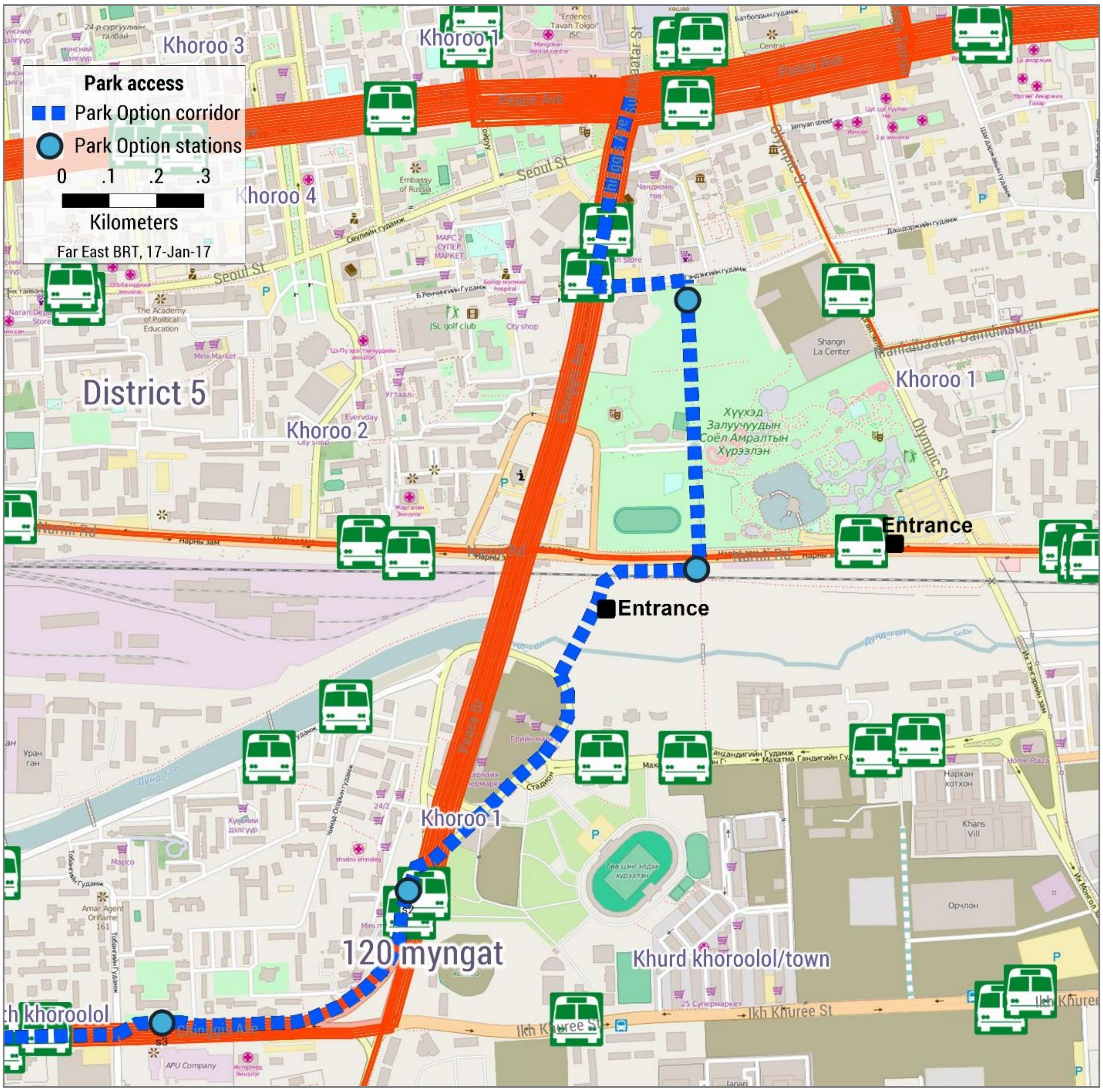

M&G
M&G

Water park layout shown to Far East BRT at a meeting with M & G Construction design consultants on 9 December 2016 in Ulaanbaatar. The proposed southwest connection BRT alignment passing the top edge of the photo above, has no significant impact on the water park design.

Water park design with BRT alignment superimposed.

Accessibility

Without BRT, both the amusement park and the water park (when it opens) suffer from very poor transit accessibility for workers and visitors, as the following graphic shows.



Entrances to the Amusement Park and the Water Park, which is under construction. Neither entrances are near high frequency bus routes, except for a single route along Narnii Road.

The graphic shows the high frequency routes and bus stop locations in the vicinity of the park entrances, with high frequency defined as at least 6 buses per hour, or 1 bus every 10 minutes in the peak hour. There is only one high frequency route within easy walking distance of the entrances, route 6, which has around 8.2 buses per hour in the peak hour. The focus in this study was on collecting peak hour data, so off-peak data is not available, but it is highly likely that the off-peak frequency is much lower, and the interval between buses both unreliable and more than 10 minutes on average, during the off-peak times when the parks are most likely to be accessed.

Regardless, route 6 provides access to only a small proportion of the population. Most passengers accessing the park would come from the large bus stops at 120 myngat and Bayangol. From the graphic, at first glance the water park appears to have access to many high frequency routes crossing Peace Bridge. However, when the bus stop location is taken into account, the actual walking distance from the water park entrance to 120 myngat is more than 750m. The amusement park has even less accessibility via public transport. For any high frequency route other than route 6, passengers have to walk either 1.3km to the Bayangol bus stop, or 1.5km to the 120 myngat bus stop. Both walks are highly unpleasant, with no street frontage activity, high traffic volumes along Narnii Rd, narrow walkways, little or no protection from wind, sun (in Summer) or snow (in Winter), and either missing or unsafe street crossings.

Meanwhile, the areas within convenient walking distance of both parks are middle and higher income areas, and car access is provided through ample car parking space in both parks. A large portion of the design of the water park is allocated to car parking. This means that the parks are in practical terms only accessible to the higher income city residents who either live within walking distance of the parks or can drive there. The lower income population making up the large majority of city residents are excluded due to the very poor public transport accessibility. Furthermore, the heavy congestion around the parks does not provide convenient accessibility to the higher income residents either, apart from those living within easy walking distance.

With a ‘southwest connection’ BRT, this situation of poor accessibility is completely reversed. Assuming that new entrances are opened at the southwest corner of the amusement park and the northeast corner of the water park, both parks are within around 50m of the BRT station platform access points. If no new entrances are added, the walking distance from the BRT station platform access point is around 400m to the amusement park and 250m to the water park, which is less than 1/3 the current walking distance to the major bus stops and a fairly easy walking distance.

If the southwest connection is implemented, it can be expected that both the amusement park and water park will implement measures to ensure a pleasant and convenient walking trip from the BRT station access point to the park entries, as this will be to their strong commercial advantage. Options could include at minimum a covered walkway, lighting, possible additional shopfronts and amenities, signage and information, seating, landscaping elements, and other facilities.

11.1.7 TOD along Narnii Road and around Peace Bridge

Narnii Road currently has very poor transit accessibility, with only one high frequency (more than 1 bus every 10 minutes in the peak hour) along its entire length – route 6 – and one other route partially along its length – route 30.

Although the Peace Bridge BRT option would pass directly over Narnii Road, accessibility of transit would remain poor, with the nearest stations either 700m to the north or 800m to the south. Though various design options are being considered, Narnii Road accessibility would be poor regardless of the traffic circulation approach, because there would be no nearby BRT stations.

The southwest connection, however, provides a mechanism to potentially transform Narnii Road by providing both easy transit route access and BRT station access to multiple high frequency BRT routes.

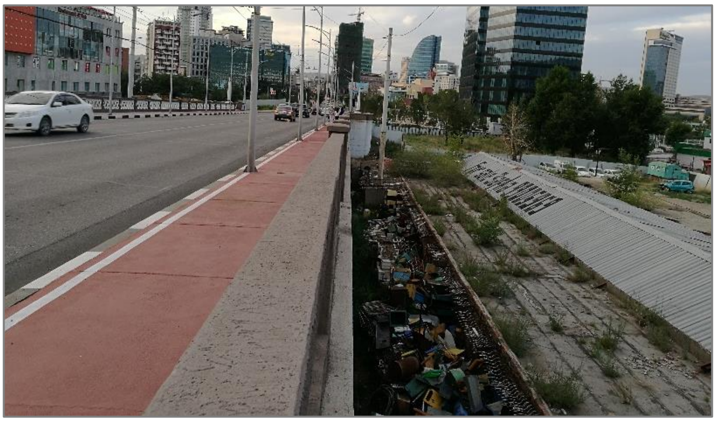
Narnii Road can be considered in three main divisions: East, West, and Central. Each division, along with the potential TOD impacts of a southwest connection BRT, are discussed following.

West Narnii Road

The section of Narnii Road to the west of Peace Bridge has inactive street fronts, very few pedestrians, many low value land uses, medium density, and moderate potential for transit-oriented development and changes in land use.

Central Narnii Road

The central portion of Narnii Road between the Peace Bridge access ramps and Olympic Street is essentially dead, with inactive park frontage blocked by a fence, and almost no pedestrian flows, reflecting the lack of appeal. TOD potential is high.



Narnii Road looking eastward from Peace Bridge (above) and low value land use around the Peace Bridge northern approach (top). The area has good potential for redevelopment, densification and revitalization and would be boosted by transit access provided by the southwest connection.

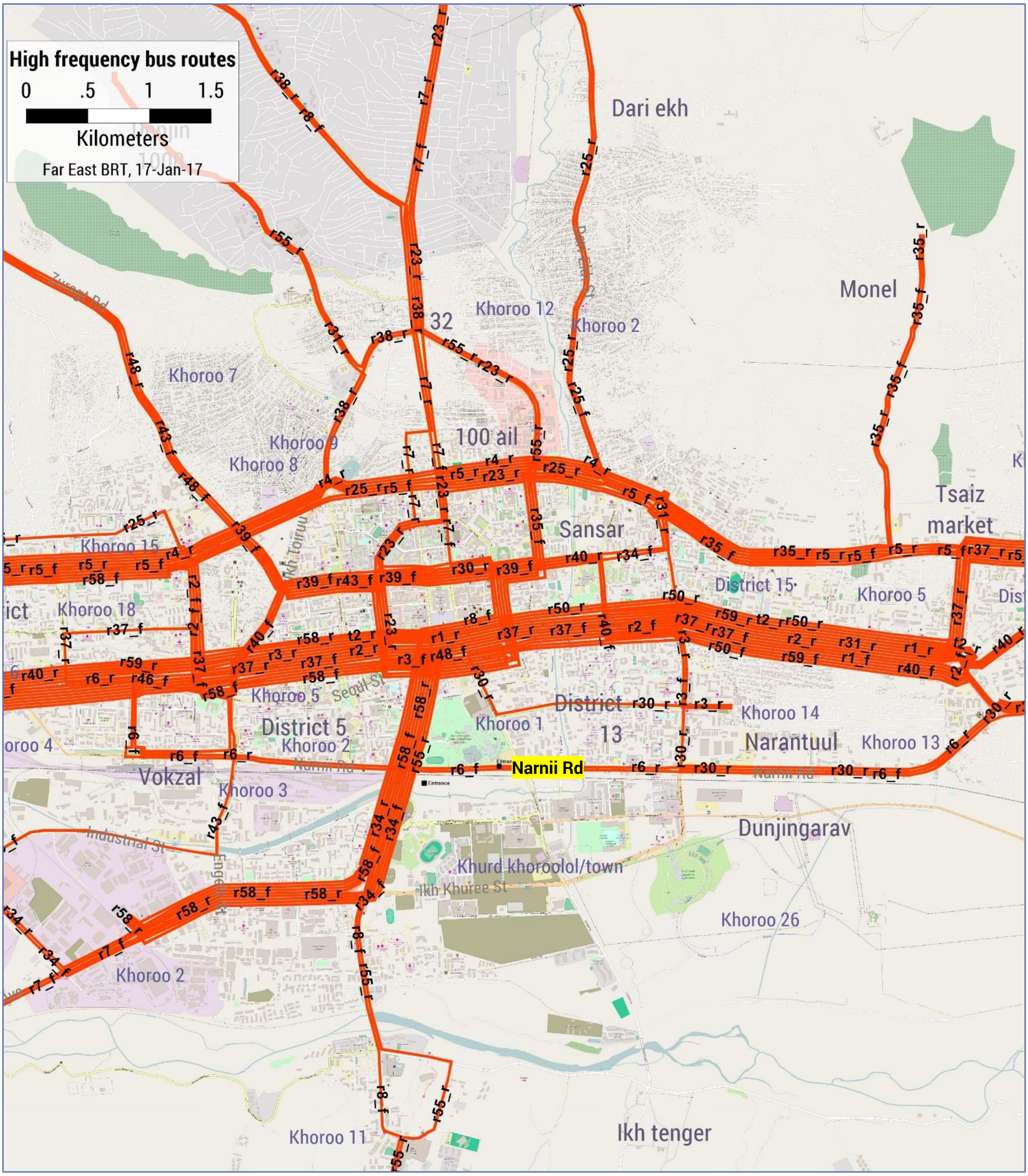
The central section of Narnii Road has almost no pedestrians, at any time of the day. The area around the northern foot and approach to Peace Bridge, a potentially prime location within walking distance of the city centre, is used partly as a car scrapyard.

East Narnii Road

The eastern portion of Narnii Road, between Olympic Street and the intersection with Peace Avenue, is quite diverse and can be considered in two main sections. The section between Peace Bridge and Namyan Ju / Dunjingarav is more developed and dense than the central and western sections of Narnii Road, and has frontage activity resulting in significant pedestrian volumes. This area also has existing connections and good potential for new pedestrian connections to new high density residential and mixed use developments south of the railway. These features mean the area would benefit from improved transit access.

East of Namyan Ju, Narnii Road passes the Dunjingarav market area, with many vendors selling from converted shipping containers. Further east toward the intersection with Peace Avenue, Narnii Road has low density, low value land uses, very few pedestrians, and features inactive streetfronts. The area along and to the north of Narnii Road is already starting to densify, and redevelopment and densification will be supported by improved transit access to Narnii Road.

From an urban development perspective, it is preferable to concentrate development in in-fill areas rather than in outer suburban areas, especially where in-fill areas can be served with good public transport. As well as improved transit access along Narnii Road, Narnii Road will benefit from proximity to the Peace Avenue BRT, with the entire area north of Narnii Road less than 1km from the Peace Avenue BRT corridor.



High frequency bus routes. Narnii Road has only one such route (route 6), with route 30 also providing partial coverage.

11.2 Disadvantages of the southwest connection

11.2.1 Less direct connection compared to using Peace Bridge

From 120 myngat, the option for the BRT to pass directly over Peace Bridge requires 1.26km to reach the intersection of Genden Street and Chinggis Avenue. The southwest connection requires 1.74km, so the southwest connection is 480m longer. The southwest connection also requires a signal at Genden Street. The southwest connection requires more expensive infrastructure, including a flyover over the railway and Narnii Road. The segregated BRT roadway in the southwest connection will allow rapid BRT speeds, so that even with the additional signal and the BRT station at the south of the park, at current speeds on the bridge the bus time travel will be shorter than using the bridge.

At current speeds of around 16km/hr, an option where BRT buses use Peace Bridge in mixed traffic will require 5.23 minutes for the 1.26km trip from 120 myngat to the Genden Street intersection with Chinggis Avenue. The southwest connection, although 480m longer and with one extra BRT station, will require only 3.88 minutes for the same trip. Passengers will therefore save more than a minute (1.35 minutes or 81 seconds) with the southwest connection option.

The following figures compare the time from 120 myngat south of Peace Bridge to the intersection of Genden Street and Chinggis Avenue north of Peace Bridge.

Southwest connection				
		distance	time (mins)	
fr 120 myngat	straight	0.99	1.485	
park sth	station		0.5	
in park	straight	0.57	0.855	
park nth	station		0.5	
genden st	signal		0.25	
genden st	straight	0.19	0.285	
TOTAL		**1.74**	**3.88**	mins
Average speed			**26.94**	km/hr
straight speed	40			

Peace Bridge option (unsegregated)				
		distance	time (mins)	
fr 120 myngat	straight	1.26	4.725	
bayangol	station		0.5	
TOTAL		**1.26**	**5.23**	mins
Average speed			**14.47**	km/hr
straight speed	16			

If, as expected, speeds on Peace Bridge deteriorate further in coming years, the time saved through the southwest connection becomes larger. If speeds on Peace Bridge decline to 10km/hr, the southwest connection will still take 3.88 minutes, because the southwest connection is not influenced by the speeds on Peace Bridge. The Peace Bridge option, however, will take 8.06 minutes. Thus the southwest connection, although 480m longer, will be more than 4 minutes faster.

Peace Bridge option (unsegregated)				
		distance	time (mins)	
fr 120 myngat	straight	1.26	7.56	
bayangol	station		0.5	
TOTAL		**1.26**	**8.06**	mins
Average speed			**9.38**	km/hr
straight speed	10			

If the BRT segment across the Peace Bridge is segregated, the shorter distance and the fact that one less station is used means that the BRT trip will take only 3 minutes from 120 myngat to Genden St. This is 51 seconds faster than the southwest connection. (In this analysis, a free flow speed of 30km/hr is assumed for Peace Bridge, noting the narrow traffic lanes).

Peace Bridge option (segregated)				
		distance	time (mins)	
fr 120 myngat	straight	1.26	2.52	
bayangol	station		0.5	
TOTAL		**1.26**	**3.02**	mins
Average speed			**25.03**	km/hr
straight speed	30			

These rough comparisons assume a 30 second stopping time at BRT stations (which includes deceleration and acceleration when entering and leaving the station, as well as the time for doors to open and for passengers to board and alight), and an average 15 second delay at the Genden Street signal.

In summary, if the southwest connection is compared to a Peace Bridge option which requires the BRT buses to operate in mixed traffic over the bridge, **the southwest connection will be faster than the bridge option despite the 480m longer trip and additional BRT station**. If however the southwest connection and the bridge option are both segregated, the bridge option would be 51 seconds faster than the southwest connection.

11.2.2 Right of way and safeguard requirements

Right of way through the park

The major difficulty with the southwest connection is that right of way is required for the BRT to pass through the park for around 550m, and for station platforms to be placed in the park. However, it was indicated in meetings with senior officials in December 2016 that these issues were not insurmountable.

Environmental impact in the park

As well as the right of way, environmental issues will need to be considered. In our preliminary and non-environmental-expert impression, since there is an existing roadway in this location, it will be possible to implement the BRT roadway without needing to remove trees, without needing to demolish any existing structures, and without impacting any wildlife. Noise and air pollution impacts are expected to be minimal because there are currently no people in that area to be impacted, and because the BRT buses will be clean buses meeting stringent environmental standards.

View of the existing roadway where the proposed southwest connection would pass.

Right of way at the front of the water park

The southwest connection alignment passes in front of the water park. It is not clear that any land from the water park will be needed, but if any land is required, it will be a narrow strip going past the front entrance, not more than 7m wide, consisting of one BRT lane in each direction.

A meeting was held on 9 December 2016 with two of the design team members associated with the water park development. These were non-executive staff and so not able to authorize any land issues, but from the meeting the following positive impressions were received:

- It is clearly in the interests of the water park development to have good transit access, as this can greatly benefit visitors and workers, making the development more attractive and valuable.
- Most critically: there is no significant conflict between the water park construction design and the proposed southwest connection BRT corridor alignment. There are no buildings proposed where the BRT alignment passes the front entrance of the water park. On the contrary, much of the area is devoted to surface parking lots.

If the southwest connection proceeds, the water park planners should revise their design to ensure convenient access to the BRT station.

Additional infrastructure costs

The southwest connection would be costlier to implement, because it involves:

- an additional BRT station
- a flyover over the railway and Narnii Road
- one additional sets of traffic signals, at Genden Street
- a low bridge across the waterway.

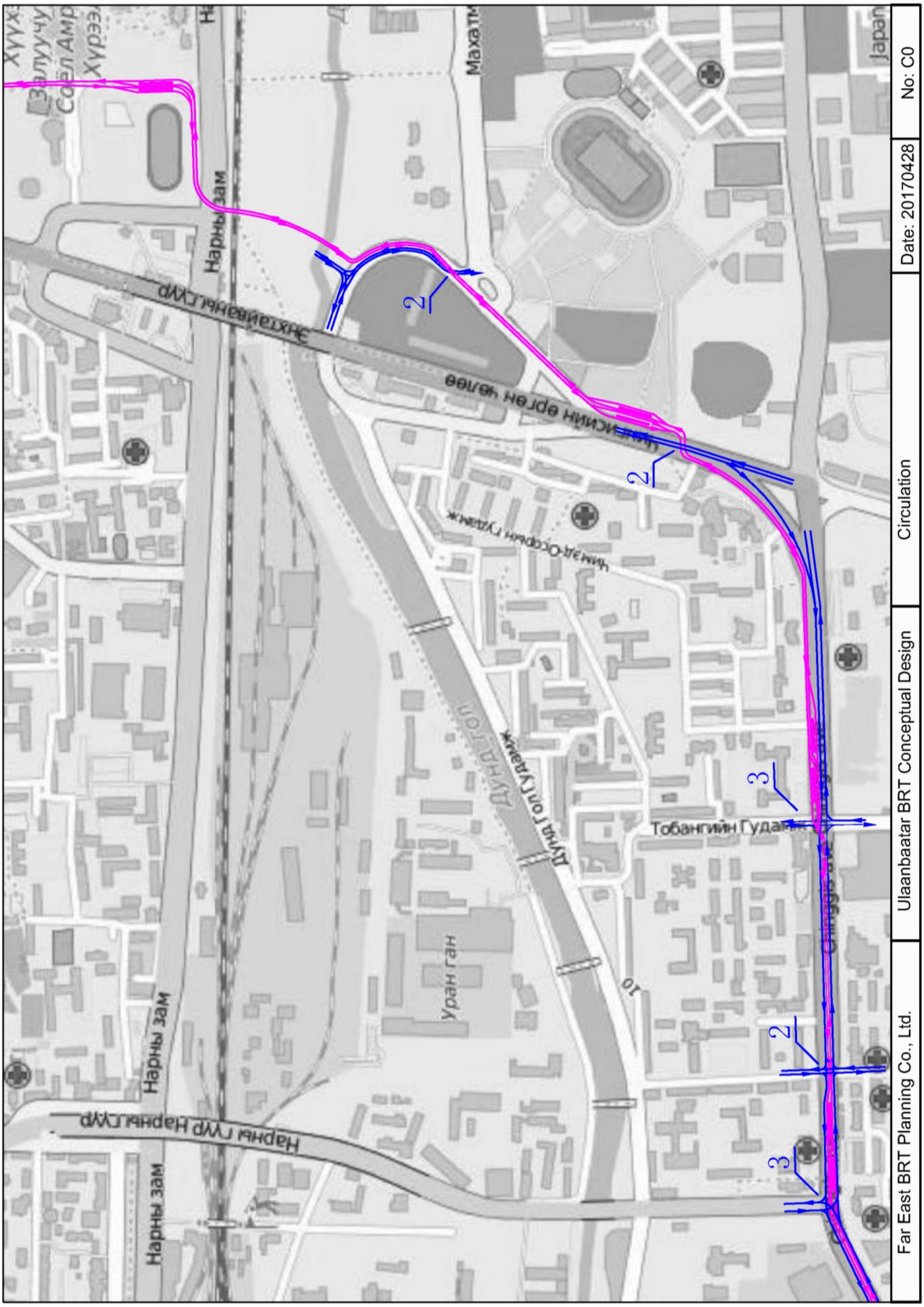
With the exception of the flyover, none of these items are extremely expensive, though. To put the costs in perspective, the cost of the bridge/culvert across the waterway will be approximately the same as the cost of a single pedestrian bridge. The detailed costs will be determined during the engineering design stage. The greatest unknown factor in this regard is flyover over the railway and Narnii Road. For the railway crossing a level crossing is probably preferable, and would be cheaper, but the railway bureau prefer grade separation and the Roads Department prefers a flyover to a tunnel. This issue can be further addressed during the engineering design stage.

While it would probably be possible to use the existing low bridge to cross this waterway, a BRT-only crossing is preferable.

Approximate southwest connection alignment superimposed on aerial photo from Nov.

11.3 Intersections, roads, and stations

An intersection concept design and BRT station and road layout for the southwest connection corridor is provided following, covering stations, intersections, and road sections.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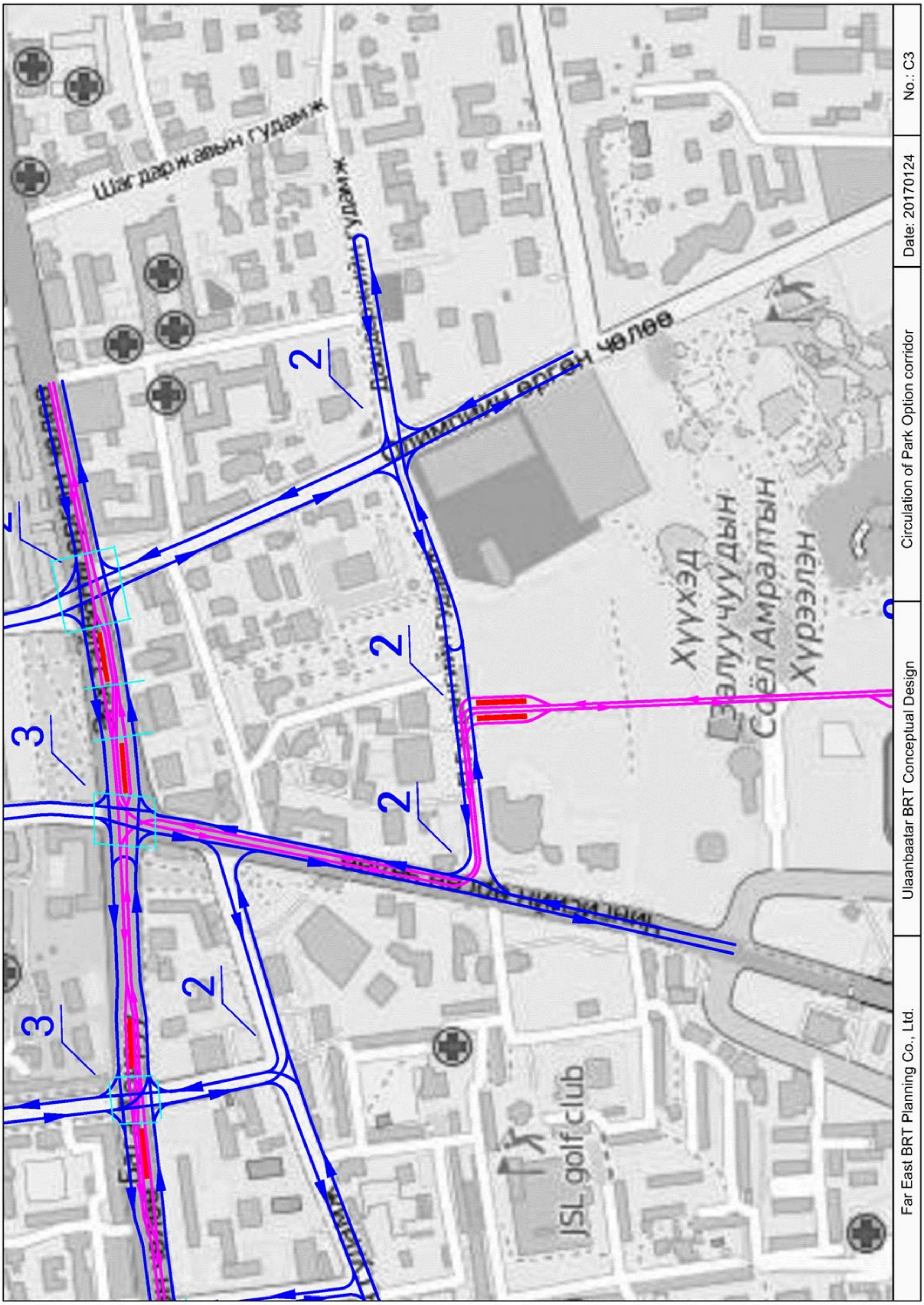
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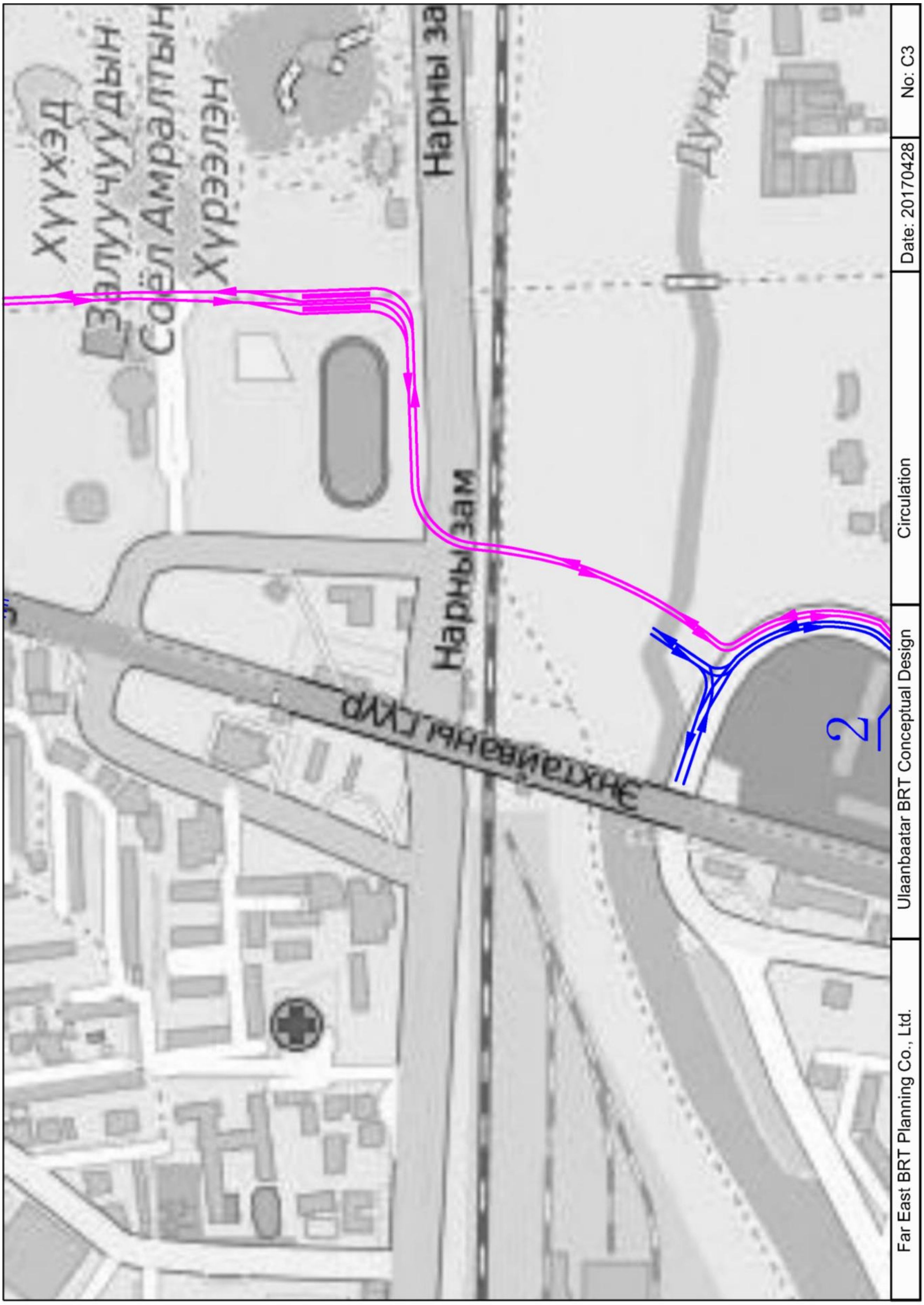
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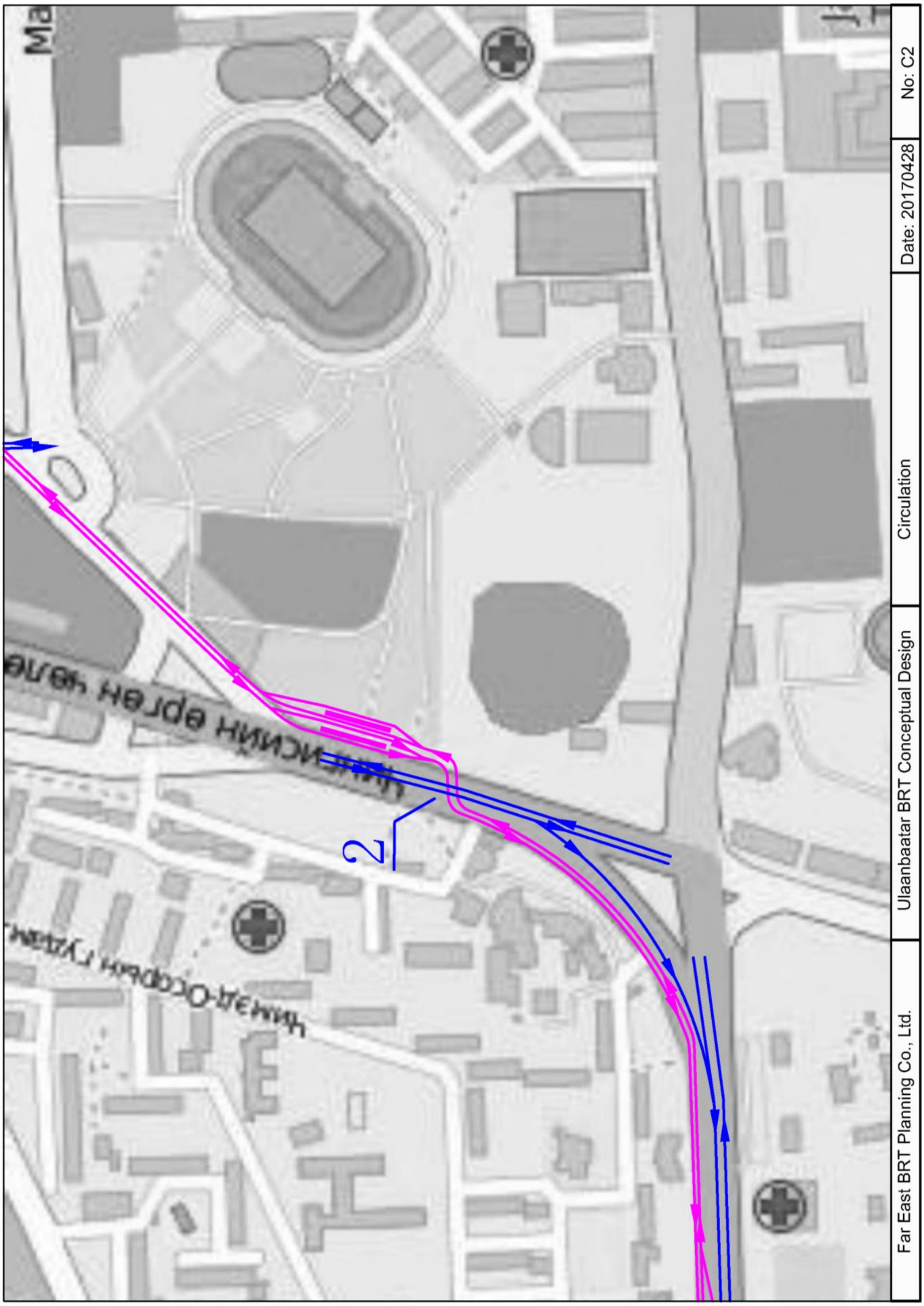
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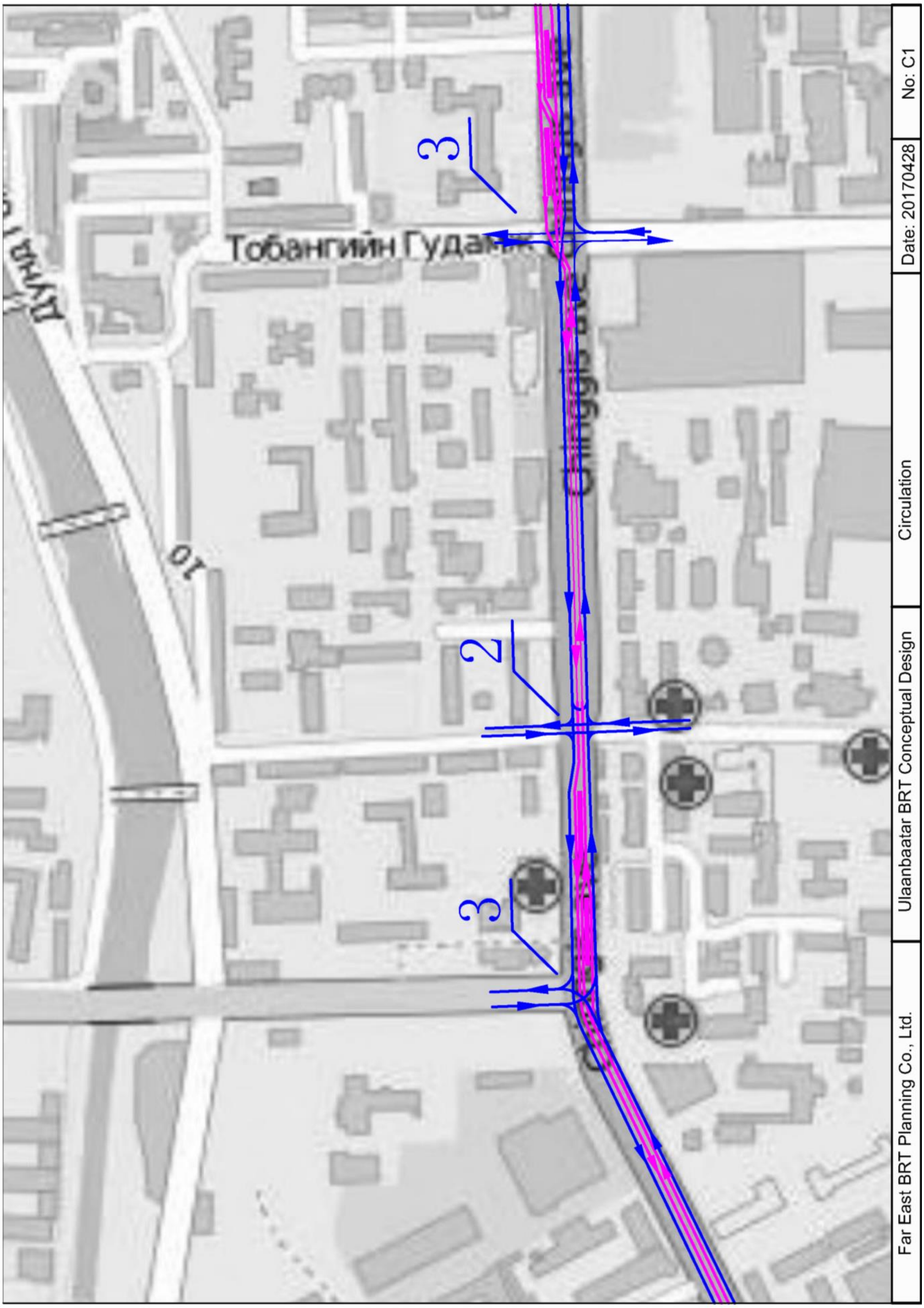
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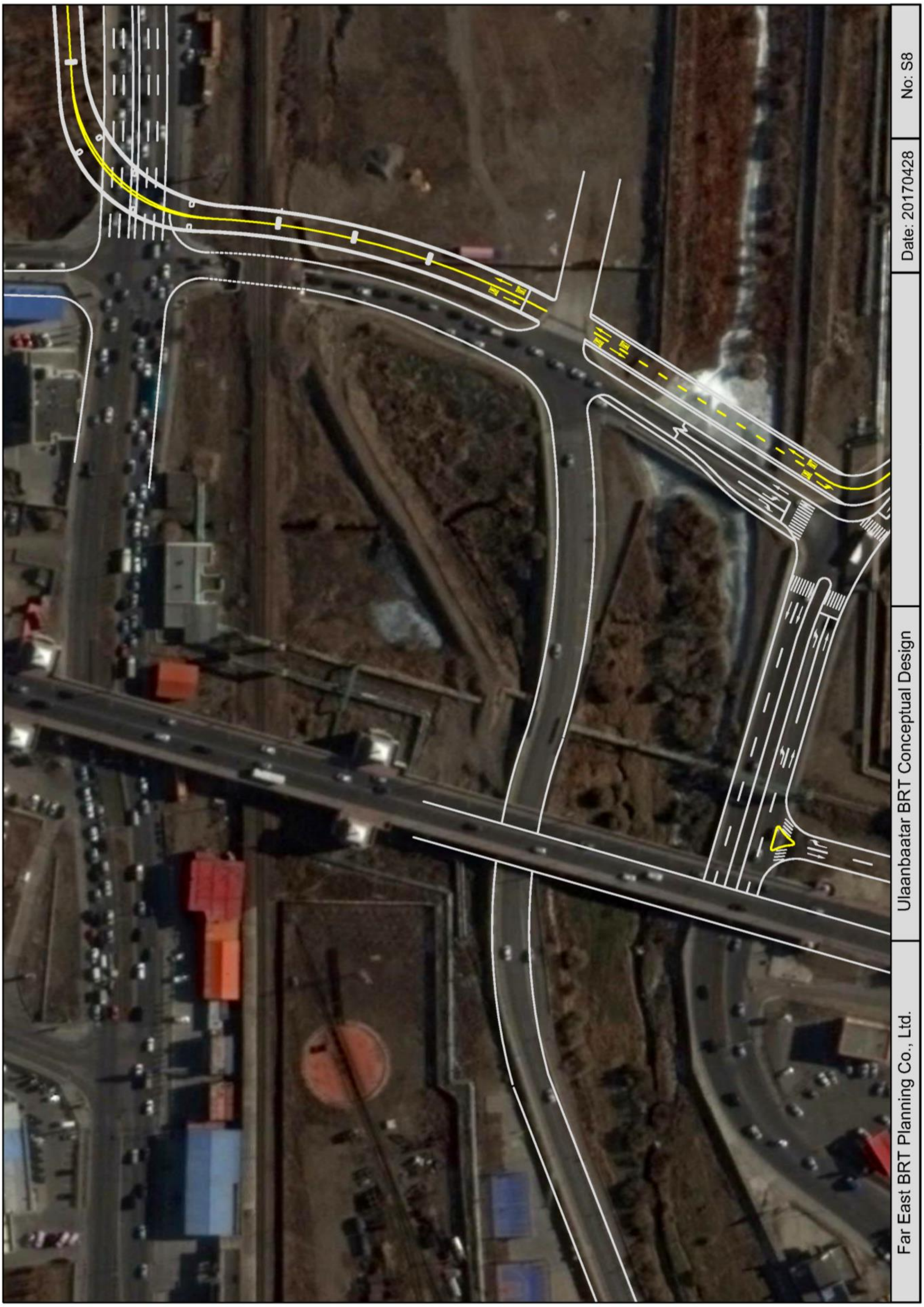
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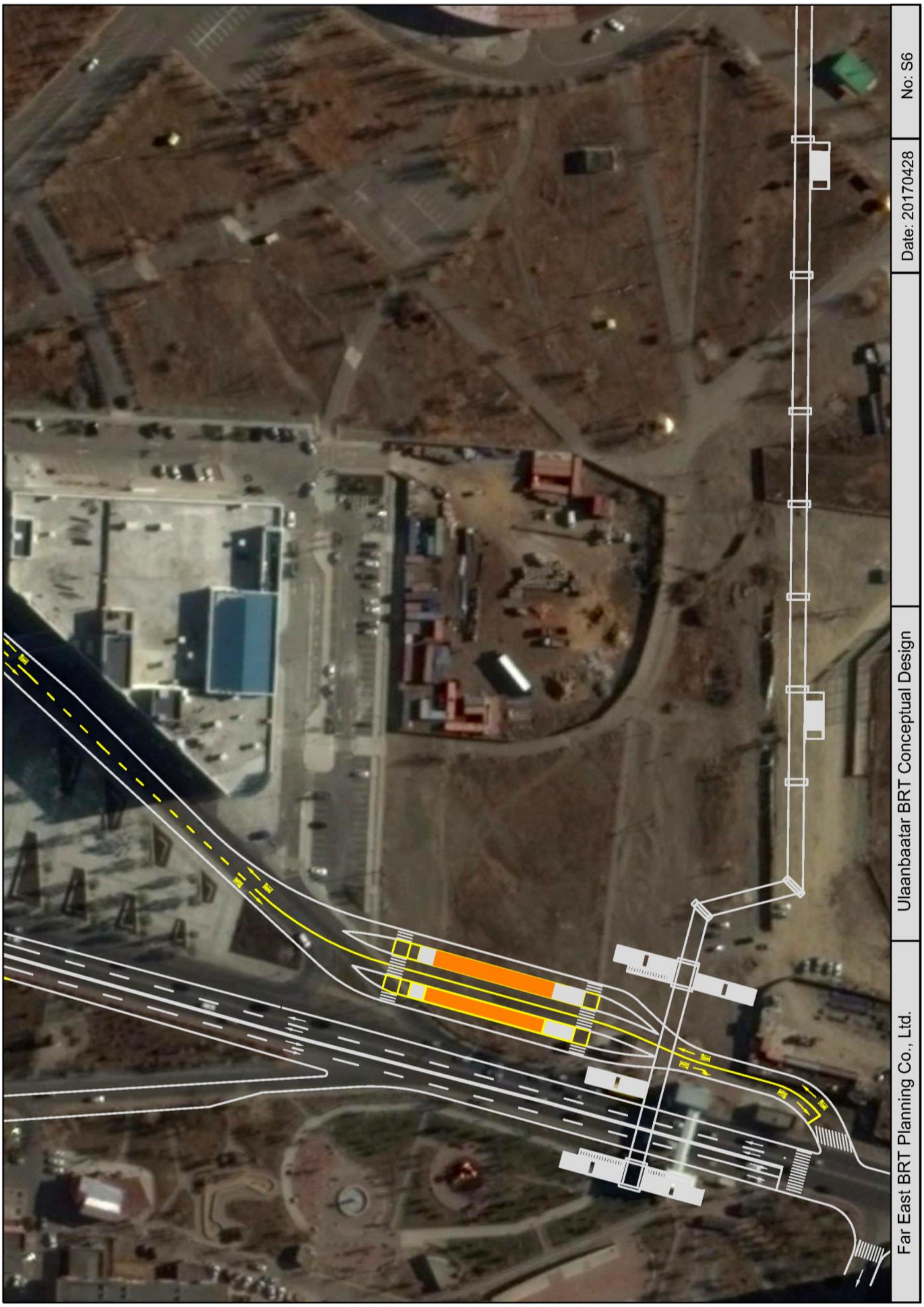
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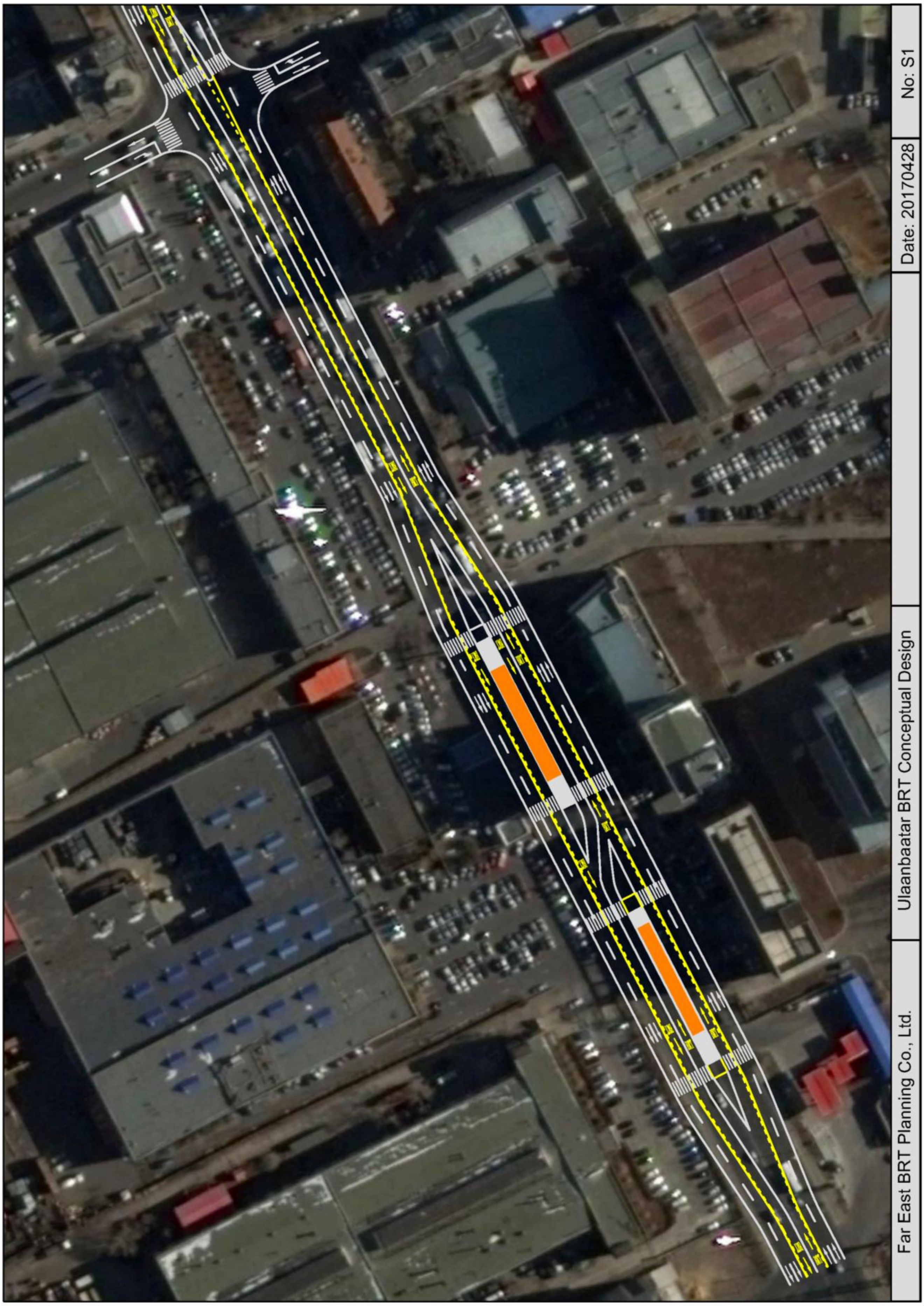
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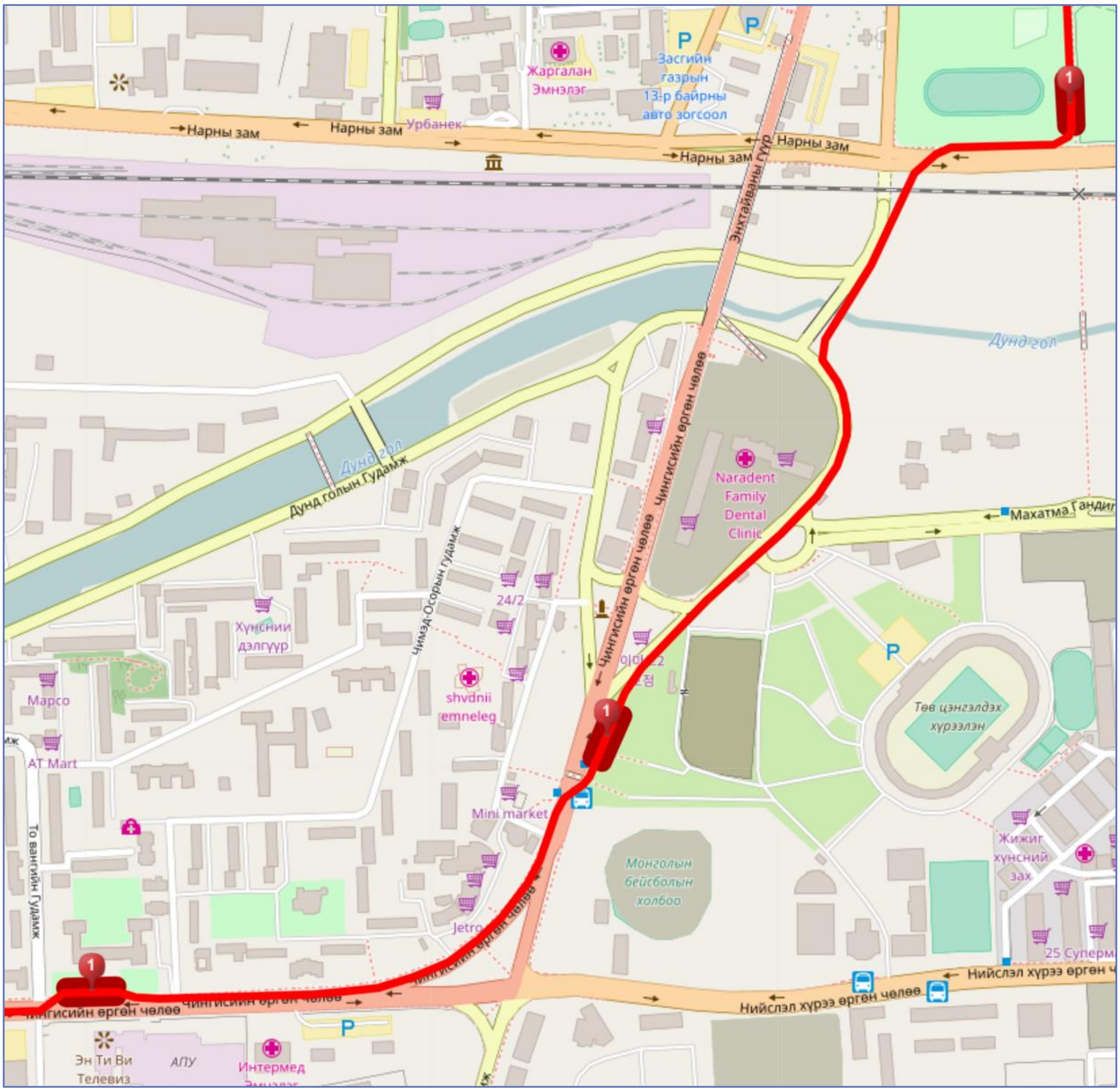
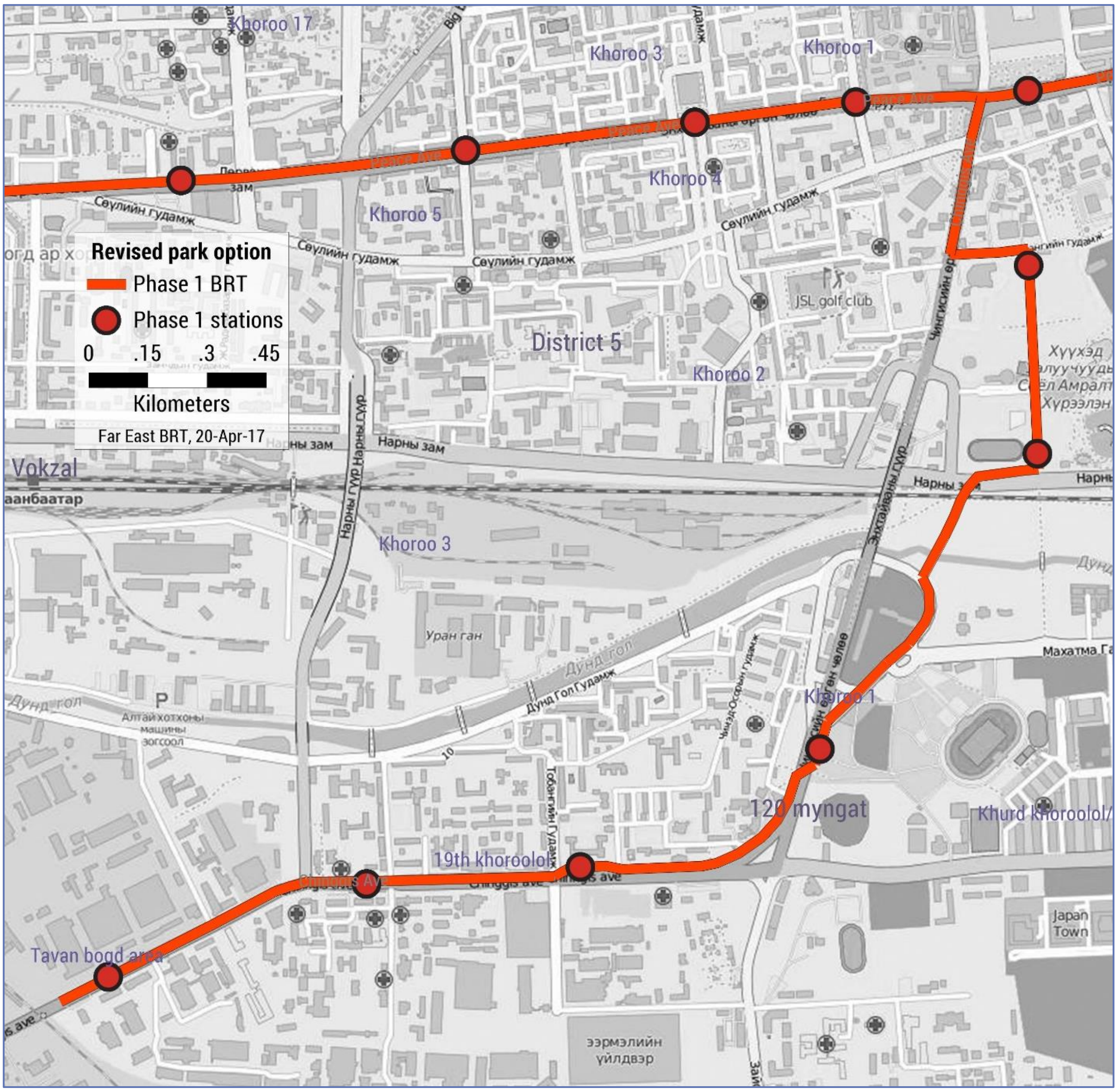
Revisions to phase 2 connection to area southwest of Peace Bridge

During a visit to Ulaanbaatar during April 2017, and following feedback from the Roads Department in March 2017, some adjustments were made to the concept for connecting to the area southwest of Peace Bridge. The changes are:

- For the rail crossing, instead of the underpass in our previous design, the Roads Department prefers a flyover crossing both the railway and Narnii Road. The concept is shown in the revised design above.
- Taking into account the large demand in the area, an additional station was provided in the southern section of Chinggis Avenue, and the phase 1 corridor was extended by 300m.
- At the 120 мянгат station immediately south of Peace Bridge, there are at least three main options for the station and platform placement. One is to use the park/plaza on the western side, as proposed in the earlier drawings. This land is owned by the government. Another option is to use the plaza on the eastern side of the road and 175m north of the current bus stop, though this land is privately owned. A third option could be to use the currently vacant land on the eastern side of the road opposite the park/plaza. Since the park/plaza is an attractive and fairly heavily used public space, it would be preferable to use this vacant space on the eastern side of the road for the BRT platform placement. The revised concept is has the BRT platform located on this eastern side.



Revised station and platform placement for the southwest connection (www.ubbrt.net)



Revised southwest connection option corridor and stations.

Corridor parameters

Corridor	Length	Stations
Phase 1 – Peace Avenue & Namyan Ju	16.3 km	25
Phase 2 – Ikh Toiruu & 3/4 khoroolol & southwest connection	12.7 km	17
Phase 3 – Doloon Buudal & Airport Rd	15.9 km	18
Total	**44.9 km**	**59**

12 Modal integration and station area improvements

12.1 BRT and transit oriented development (TOD)

The Ulaanbaatar BRT is a major project with a large infrastructure cost and in order to get the most benefit from this investment, **the BRT project needs to be approached as an urban development project**, not just a transit project. Viewing the project as an urban development project entails a major focus on station area public space, landscaping, parking, station access and integration with bicycle and pedestrian facilities.

Special zones should be established within 500m of BRT station areas allowing for lower off-street parking provision, improved on-street parking management, implementation of high quality plazas and public spaces, bicycle facility integration, high density mixed use buildings with attractive ground floors, and other improvements that can later be expanded citywide.

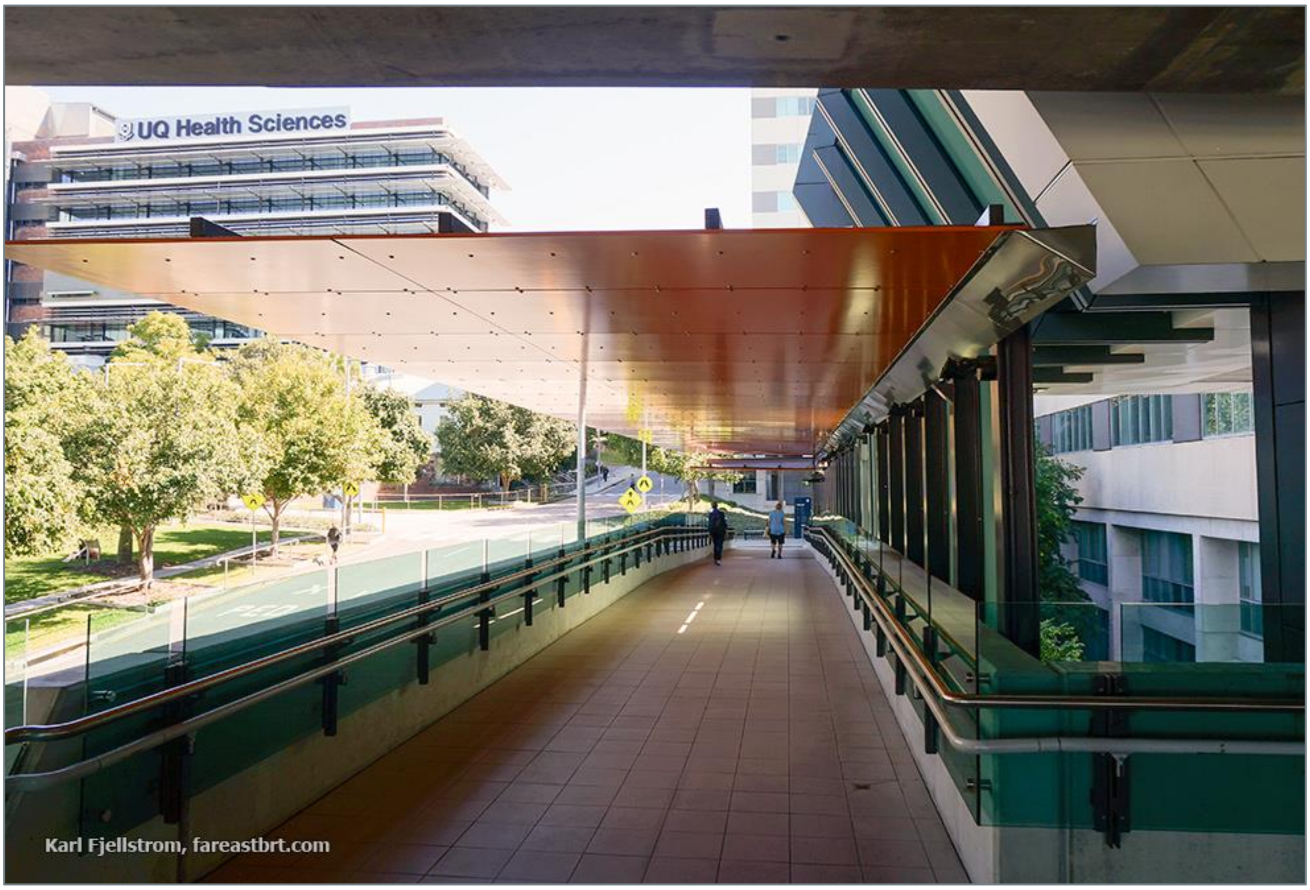
Experience elsewhere shows that these station area and BRT corridor improvement issues must be addressed during the detailed design phase. If not addressed at that time and included in the project definition, many of the improvements will probably never be implemented.

Examples of cities with special zoning around transit stations.

City	Increase Floor Area Ratio (higher density)	Encourage Mixed-use of land	Parking space reduction	Pedestrian access layout and quality requirements	Bike facilities required or encouraged	Housing required or encouraged
Hong Kong	√	√	√	√	√	√
Shanghai	√	√	√	√	√	
Shenzhen	√	√	√	√	√	√
Wuhan	√					
Nanning			√	√	√	
Nanchang			√			
Nanjing			√	√	√	

Source: Li Yang

BRT station area development concept. Source: Li Yang



Station area and access improvements and integration are a key feature of the Brisbane Busway.

12.2 Bicycle integration with BRT

Ulaanbaatar has good potential for bicycle usage, with a fairly flat topography and many trips within an ideal cycling range of 500m to 5km. This issue was beyond the scope of the present report but anecdotal observations and discussions suggest:

- As in many other cities, the main impediment to bicycle usage is that they have no place in the roads as currently designed. Even experienced cyclists are unwilling to ride in mixed traffic on major roads and usually try to find detours and back streets, or ride on the pedestrian walkway.
- Many people are supportive of increased bicycle usage in Ulaanbaatar, and interest in cycling is increasing as the traffic conditions worsen.
- The argument that it is 'too cold' to ride bicycles in Ulaanbaatar is not tenable. As in other cold cities, bicycle usage, like walking, can be expected to decline during the coldest months, but people can still walk and use bikes in cold weather. Given the exercise expended, riding a bike is probably warmer than walking, and also results in faster trips which, compared to walking, significantly reduce exposure to the cold weather.

Bicycles can be incorporated into the BRT project in several ways:

- Bicycle parking can be included in BRT station areas.

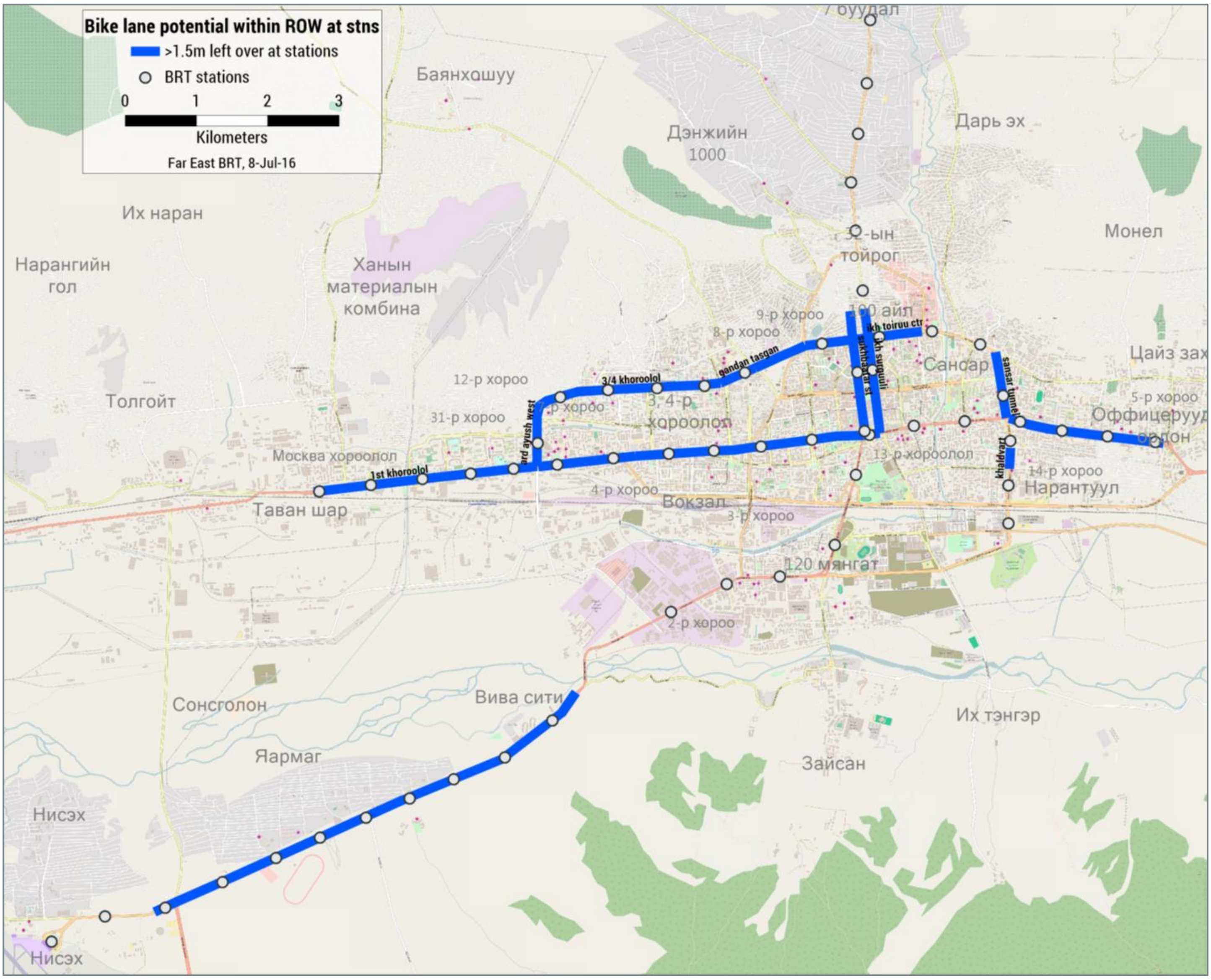
- Bicycle sharing can be implemented along and around the BRT corridors. Bike sharing was implemented along the BRT corridor in Guangzhou and Lanzhou, and Yichang.
- In BRT corridors the road right of way typically needs to be rebuilt. This provides an opportunity for implementing bike lanes.

The new 'dockless' bike sharing can be introduced, such as Mobike and Bluegogo. Mobike and other new generation bike sharing systems that do not require docks or stations and can be quickly and easily used via a smartphone application linked to mobile payments. In Guangzhou and other cities in China, these dockless bike sharing systems have reversed years of gradual decline in cycling, made cycling cool and popular again, and rendered the old bike sharing model based on docks and stations obsolete (http://www.fareastbrt.com/en/feature/gznmtfeb17).

New generation dockless bike sharing bikes in Guangzhou.

In China, these new generation bike sharing systems work well because mobile payment is ubiquitous, especially through the Wechat app and payment platform. This would appear to be the main constraint to implementing such systems in Ulaanbaatar, where mobile payment is not yet ubiquitous. However, there may be a way around this problem, if the smart card can be used for payment for the bike sharing bikes. Since 1 April 2017, buses only accept payment by smart card, so all bus users have smart cards. If these smart cards can be used for payment for the new generation bikes, along or combined with mobile payment platforms, this key constraint of payment technology could be solved. This could potentially be a major new business and opportunity for the smart card company in partnership with a bike sharing operator and perhaps financial institutions. Of course, the market, willingness-to-pay, technology, weather-related and other issues would need to be further investigated, including the feasibility of operating the on-bike GPS in very low temperatures during Winter.

A very preliminary assessment of the potential for implementing bike lanes along BRT corridors is provided below, based on the space required for the BRT stations, BRT lanes, mixed traffic lanes and pedestrian walkway. When these space requirements are taken away from the total available right of way (edge of walkway to edge of walkway) with a remaining space of more than 1.5m, it is considered possible to implement bike lanes. This is a conservative and rapid analysis, and if bike lane implementation proceeds, the 'gaps' in the potential network should be further investigated. Further investigation may show that some setback space can be converted to bike lanes.



Very preliminary view of the potential for bike lane implementation along BRT corridors, based only on the current right of way space availability at stations.

Bike lane under a BRT station in Bogota, Colombia.

Bike lane around a BRT station in Brisbane, Australia.

12.3 Station access integration with buildings

A form of modal integration which can support transit-oriented development is to connect the BRT stations with buildings along the BRT corridor. The easiest way to achieve this connection is simply through physical proximity, so that people can walk out of the BRT and into an adjacent building, and vice versa. However, it is also possible to make physical connections through bridges and tunnels.

In general, pedestrian bridge and tunnel access to the BRT stations in Ulaanbaatar is not recommended. Street level access is far preferable and can be achieved in nearly all locations. However, where an extensive network is planned, or where bridges or tunnels can connect directly to buildings, and where bridge access provides a benefit in terms of traffic flow, BRT access to stations by bridge or tunnel can be considered.

This approach was mentioned in a meeting in December 2016 and again in April 2017 with the Vice Mayor of Ulaanbaatar, who suggested connecting the Park North (s0) BRT station to the Bayangol Hotel side of Chinggis Avenue via a pedestrian bridge which would also connect to adjacent buildings, as part of a network. Considering the very cold Winter weather in Ulaanbaatar, providing passengers with access to an elevated network of pedestrian walkways which are also weather-protected could be advantageous to BRT passengers and pedestrians as well as to the traffic flow in that section of Chinggis Avenue north of the Peace Bridge.

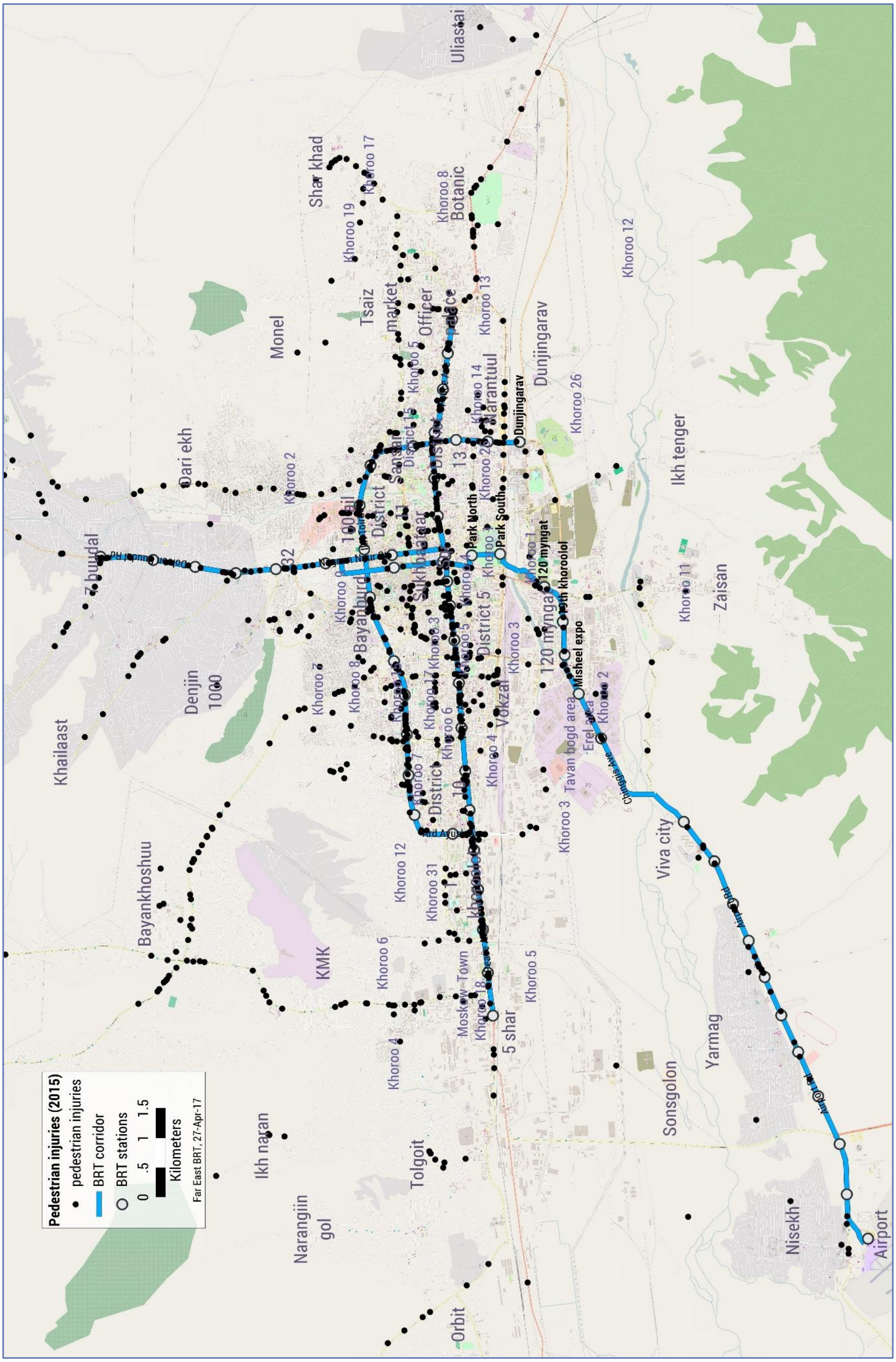
12.4 Road safety improvements

A well-designed BRT can dramatically reduce the incidence of pedestrian injuries and fatalities along the BRT corridor.

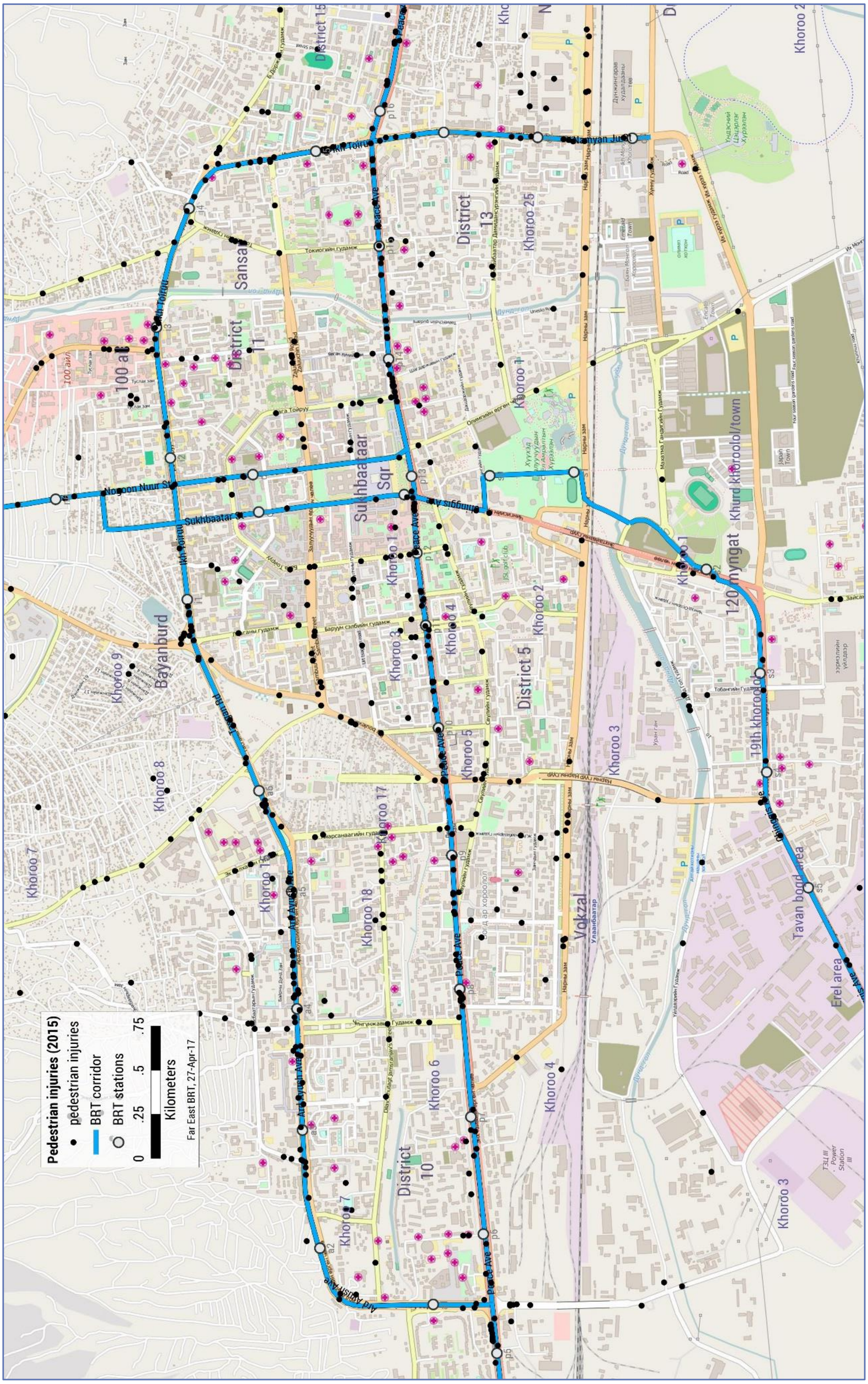
The following graphics are based on raw data from traffic police which was processed by the local study team. This is a selection of 986 pedestrian injuries from 2015, and 286 pedestrian fatalities from 2013, 2014 and 2015. The full data set was much larger but included records which the study team were unable to locate in Google Earth from the location data. Locations which could not be identified in Google Earth were discarded.

The traffic injury and fatality data is a rich and useful data set for further analysis. For example, 35 (12%) out of 286 recorded pedestrian fatalities during 2013-2015 and 128 (13%) out of 986 pedestrian injuries occurred within 50m of a signalized intersection. Further analysis could be carried out to identify problems at the intersections and at the unsignalized locations where around 87% of pedestrian injuries and fatalities occur. This can in turn be used to develop a priority listing of proposed interventions.

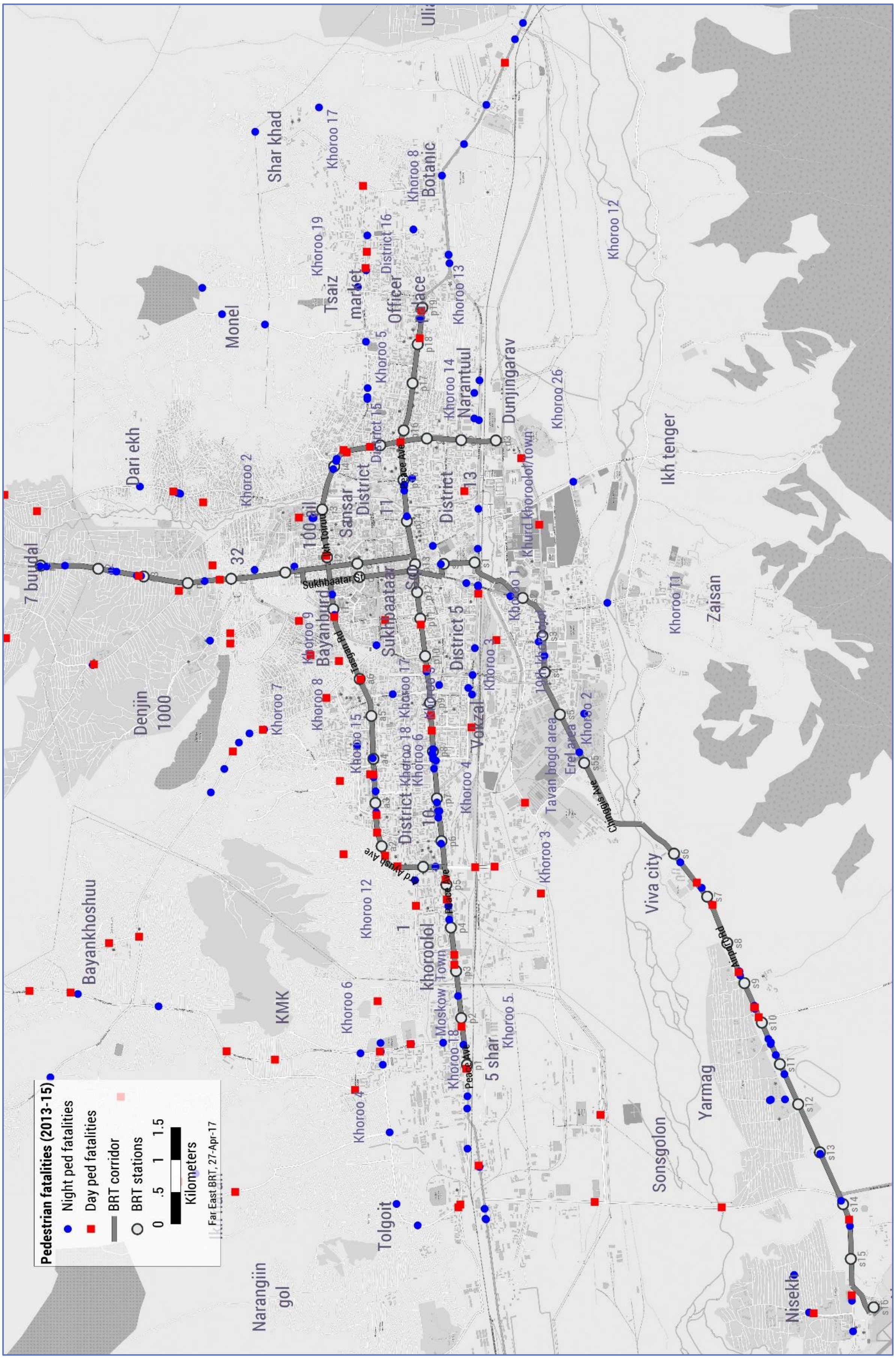
The phase 1 and phase 2 BRT corridors feature a major concentration of pedestrian injuries and fatalities. A total of **617 pedestrian injuries, or 63% of the total recorded injuries, occur within 50m of a phase 1 BRT route**. A total of 154 out of 286 pedestrian fatalities, or 54% of the total recorded fatalities, occur within 50m of a phase 1 BRT route. This suggests that a useful focus area related to the BRT planning is to improve the road safety situation along roads used by BRT buses.



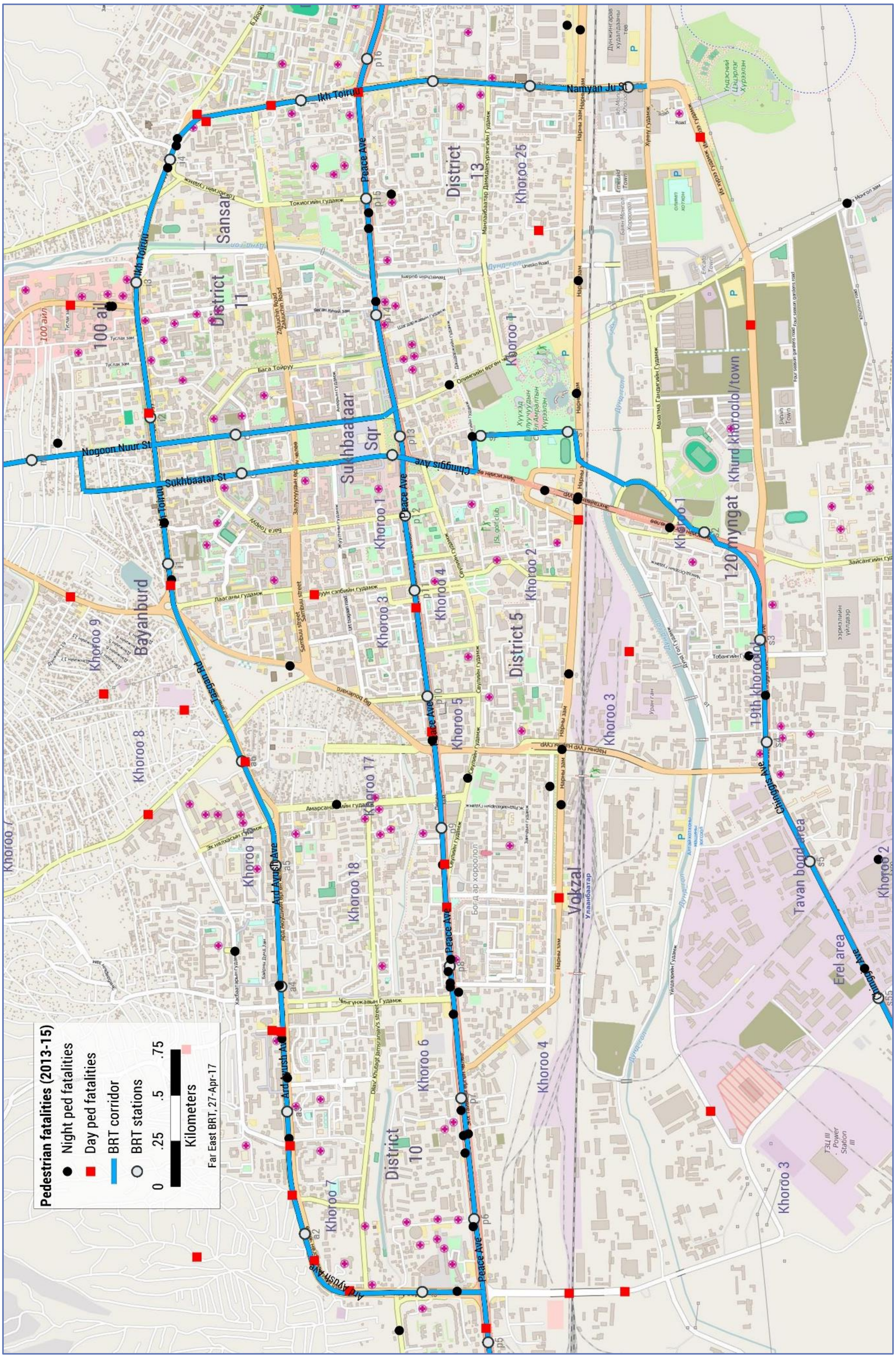
2015 pedestrian injuries.



2015 pedestrian injuries – central area.



2013-2015 pedestrian fatalities, by day and night. **183 night fatalities (64%), out of 286** in total.



2013-2015 pedestrian fatalities – central area.

The following table provides an indication of the benefits of pedestrian safety improvements along the BRT corridors. In 2015, 37% of the recorded pedestrian injuries were within 50m of a BRT corridor, mostly concentrated in the phase 1 and phase 2 BRT corridors. Nearly one-third of all the recorded pedestrian fatalities during 2013-2015 which the team were able to identify on a map, were within 50m of a BRT corridor. With a well-planned BRT, a very large reduction in pedestrian injuries and fatalities along the BRT corridors can be achieved. One of the major 'indirect' benefits of BRT is that the stations require the installation of many additional safe pedestrian crossings. These safe crossings will benefit all road users, not only BRT passengers.

Pedestrian injuries and fatalities within 50m of a BRT corridor

	Occurrences	% of total
Night pedestrian fatalities (2013-15)	59	20.6%
Day pedestrian fatalities (2013-15)	33	11.5%
Pedestrian fatalities (2013-2015)	92	32.1%
Pedestrian injuries (2015)	368	37%

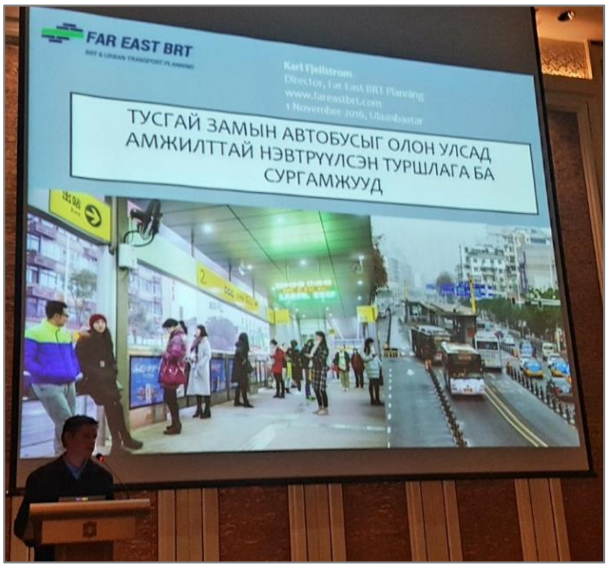
13 Stakeholder consultation

November 2016 seminar

The BRT proposals were developed throughout 2016 but underwent a significant change in July with the inclusion of Peace Avenue as the preferred phase 1 BRT corridor. Discussions on the BRT planning were held with bus operators and officials during the earlier PPIAF work in March and April 2016, but the first time the designs and plans proposed in this report were presented outside the TA group was in a TA seminar at the Shangri-La Hotel during 1-2 November 2016.

For the seminar, BRT station renderings were prepared, printed in A0 size, and prominently displayed at the entrance to the venue.


MON "УЛААНБААТАР ХОТЫН ТЭЭВРИЙН ЧАДАВХИЙГ
БЭХЖҮҮЛЭХ ТЕХНИКИЙН ТУСЛАЛЦАА"
ЯПОНЫ ЯДУУРЛЫГ БУУРУУЛАХ САН
ТЭЭВРИЙН БОДЛОГЫН АСУУДЛУУД БОЛОН ТУСГАЙ ЗАМЫН АВТОБУС
/BRT/-ЫГ НЭВТРҮҮЛЭХ НЬ
Шангри-ла Их танхим, Улаанбаатар, Монгол Улс
2016 оны 11 дүгээр сарын 1-2 ны өдрүүд


FAR EAST BRT
Karl Fjellstrom
Director, Far East BRT Planning
www.fareastbrt.com
1 November 2016, Ulaanbaatar
ТУСГАЙ ЗАМЫН АВТОБУСЫГ ОЛОН УЛСАД
АМЖИЛТТАЙ НЭВТРҮҮЛСЭН ТУРШЛАГА БА
СУРГАМЖУУД

Participant list for seminar on 1-2 November 2016 at the Shangri-La Hotel, Ulaanbaatar. Not all participants attended for the full two days. Some media also attended but are not listed below.

NAME	ORGANIZATION/POSITION
Batbold S.	Mayor of the Ulaanbaatar City
Yolanda Fernandez Lommen	Asian Development Bank Country Director
Ki-Joon Kim	Asian Development Bank Senior Transport Specialist
Arnaud Heckmann	Senior Urban Development Specialist
Munkhzolboo	Project Management Specialist
T. Gantumur	General Manager of Ulaanbaatar city, Head of Mayor's office
G. Ulziibayar	Head of Policy Planning Division, MUB
Otgonbaatar D.	DG, UTD
Anar E.	DG, Urban planning and Mater Plan Agency
Togtokhbayar	DG, Road development Department
Battsooj L.	DG, Traffic Control Center
Davaajargal A.	Head of Legal Division, MUB
Bolorchuluun	DG,Land Department
Odnasan Ch.	DG, Property Relations Department
Battulga	DG, Environment and Green Development Department
Dashdorj	DG, Municipality traffic inspection Department
Chinzorig O.	DG, IT Department
Nerguibaatar Ts.	Senior Transport Policy Specialist, MRT
Oyundelger B.	ADB Desk Officer, MRT
Batbold B.	Head of Traffic Coordination Division, Municipality Police Department
Nyamdorj S.	Head of Division, UTD
Oyunbileg T.	Transport Specialist, Mayor's office
Dorjpalam G.	Deputy Head of UTD
Bayart E.	Head of division of UDT
Galbadrakh D.	Head of division of UDT
Munkhbat Ts.	Head of division of UDT
Myagmarsuren Ts.	Senior specialist of UDT
Dulguun B.	Senior specialist of UDT
Dulamsuren G.	Specialist of UDT
Khongorzul O.	Specialist of UDT
Davaasuren J.	Head of Planning Roads Department

Ganbagana D.	Parking and Planning Specialist Roads Department
Battsolmon	Parking Specialist Roads Department
Ochir-Erdene D.	Traffic Control
Batkhuu I.	Project and Cooperation Unit, MUB
Anujin	Project and Cooperation Unit, MUB
E. Gankhuu	Head of Finance and Treasury Division of MUB
Amarbayar	Specialist, Policy Planning Division, MUB
Erdenechuluun L.	Head of Inspection Department Road control, Infrastructure Inspection Division
Batbold S.	Head, Transport Policy Regulation Dept, Ministry of Roads & Transport
Narantsetseg P.	Specialist, Transport Policy Regulation Department, Ministry of Roads and Transport
Sod Erdene Y.	CEO of Ulaanbaatar Smart Card Company
Lkhagvaa E.	Global Shapers NGO
Bat-Erdene G.	Urban Planner
Enkhtur S.	Road Safety Association
Altantsetseg	Bus operators NGO
Tumurbaatar	Director of Passenger Transportation Consortium
Gankhuyag A.	Director of Tenuun Ogoo LLC
Nayanchuluun N.	Director of NChB LLC
	Head, Vice Minister for Construction and Urban Development
Dondmaa E.	Parking Law Working Group
Nyamdash B.	Parking Law Working Group, Ministry of Construction and Urban Devt
Naranbaatar.E	Mongolian University of Science and Technology (School of Mechanical and Transport)
Erdenetuya.A	Mongolian University of Science and Technology (School of Mechanical and Transport)
Tsolmonbaatar D.	Director, School of Transport (MUST)
Asralt B.	Prof. School of Transport (MUST)
Martin Kerridge	Team Leader
Willem Brouwer	Parking Specialist
Karl Fjellstrom	BRT Specialist
Enkhtuvshin G.	Deputy Team Leader
Baigal L.	PMS
Zuvtsetseg B.	Safety Specialist
Enkhsanaa S.	Procurement Specialist

Bulgaa Kh.	Transport Planning and Management Specialist
Nurmukhamyed	IT Specialist

The BRT part of the seminar consisted of two presentations with a total duration of three hours on 1 November and a discussion session on 2 November. In the discussion session the meeting participants divided into three groups on policy, parking, and BRT. The presentation section was divided into two parts, on BRT Best Practices and Lessons Learned for Ulaanbaatar, and on the specific proposals for BRT in Ulaanbaatar.

The best practices presentation focused in the most detail on the case study of the BRT implementation in Yichang, China. More information on the Yichang BRT can be seen at http://www.brtdata.net/en/cities/yichang.aspx, with photos at http://www.transportphoto.net/cmtbrt.aspx?cmtc=114 and impact analysis at http://www.fareastbrt.com/en/other/impacts-yc. As a recently implemented, successful ADB loan-funded BRT project in a city of a similar size to Ulaanbaatar, Yichang provides an excellent case study for Ulaanbaatar to learn from.

The Ulaanbaatar BRT presentation, "Ulaanbaatar BRT: current conditions, corridor selection, demand, operations, vehicles, intersections, modal integration and next steps", covered the material presented in this draft report.

Brief notes from the discussion session held on 2 November are provided following:

1. BRT has never been implemented in Mongolia and covers many areas, so this was mainly a question and answer session covering a wide variety of topics on BRT. The discussion was useful and positive.

2. Questions were raised and points made about management issues during the BRT construction phase:

    - Traffic flow management during construction – what kind of traffic management and control will be needed?
    - There has to be coordination of the engineering design work for all phases of the BRT, as the intention is that the first phases will be developed rapidly.
    - There are utilities under the centre of the roadway, so the cooperation of the utility companies will be needed.
    - The general approach will be to first widen the roadway lanes as required in the station areas, and to then build the traffic lanes in the widened area, followed by BRT station construction and related paving and installation of utilities. When one side is done, construction is moved to the other side of the road. In this way, the traffic impacts can be reduced during construction. In the areas between the BRT stations, only minimal road works will be required, though more might be undertaken to upgrade pedestrian facilities and public space along the corridor.
    - In addition, the construction work can be combined with other planned improvements along Peace Avenue including planned flyovers and bridge reinforcements. In this way, the various improvements along Peace Avenue can be implemented as much as possible in the same time frame, minimizing the overall disruption.

3. Traffic circulation:
    - Need to pay attention to intersection traffic flow management on BRT corridors.
    - BRT services must be planned to take account of current routes. BRT routes will be largely based on the current routes, but with adjustments that will be defined in detail during the detailed design and construction phase.
    - Pedestrian access and associated traffic management is an important issue. Street-level access to BRT stations is preferred, and the pedestrian crossings will be coordinated with the design and signals of nearby intersections to avoid negatively impacting traffic and BRT speeds.
    - A bike lane plan was approved by the City Council in 2015. The TA team will be provided with this and need to take it into account.
    - The BRT needs to serve the existing airport (this will be a terminal for domestic flights) as well as the intercity railway and bus stations.
    - It is expected that at least 90% of the buses operating in Peace Avenue, especially in the central portion, will be BRT buses. Depending on the operational design it is possible that in some or all sections of Peace Avenue, 100% of the buses which are stopping will be BRT buses, with no buses operating outside the BRT lanes.
    - In terms of traffic capacity, an important design and planning approach being applied in the BRT planning is to ensure that the mixed traffic performance is not worsened than the current situation. In Peace Avenue, the current bus lane will be removed, and will be replaced by a median BRT lane. The mixed traffic capacity is not affected, as the mixed traffic lanes remain the same as now.
    - In fact, as part of the BRT implementation it is expected that mixed traffic capacity and performance will be substantially improved, for two reasons. First, intersection performance, which is currently very inefficient, will be improved. Second, issues of bus stop congestion, including situations where queuing buses obstruct other traffic, will be solved by the BRT implementation.
4. BRT stations:
    - The stations must be in harmony with the city's image and must be architecturally attractive. The proposed station platforms, which are 50m-55m long in the central area, will fit well architecturally in the corridor.
    - The stations must be able to cope with the climatic conditions, with insulation for winter and selection of appropriate materials to avoid slipperiness.
    - Stations should have good natural lighting and maximize the use of glass walls to enhance visibility and sight lines from within the stations.
    - The current pedestrian subways should be utilized if possible for BRT station access.
5. Intelligent transport system (ITS):

- The BRT stations will need real-time passenger information systems. In a discussion on who will be responsible for this investment, it was mentioned that the project set aside funds for this, but the respective roles of the project and the Smart Card Company need to be resolved as part of the bidding procedure.
- It was asked whether there would be cooperation with the Smart Card Company, and of course there will need to be discussions about their role and capabilities. The Smart Card Company as an established smart card operator will be in a strong position but will need to meet the project requirements and join competitive bidding procedures.

6. BRT buses and subsidies:

- Except on Namyan Ju Street and Peace Avenue east of Namyan Ju Street intersection, the station platforms will be double-sided, so a portion of the existing bus fleet will be able to use them.
- New buses for the BRT will have doors on both sides, so that they can use all the BRT stations and also serve bus stops off the BRT corridors. They will be built to international standard, and will include a combination of 12m and 18m long vehicles with low floors and low-emissions meeting at least Euro IV standards. There is a possibility that the Global Climate Fund can help with financial assistance for the purchase of hybrid low carbon vehicles (diesel/electric).
- Another question was how the BRT buses would be financed, and who would buy them. This has not yet been determined, because it relates to fare revenues, which have not yet been fixed. The BRT system will be much more cost-effective and efficient than the current bus operators, because fewer buses will be needed to serve the same number of passengers due to the much higher bus speeds. This means that the operational costs will be significantly smaller than the current costs. An initial analysis shows that if the current fare and subsidy level is maintained, this subsidy will be sufficient to pay for the procurement of around 230 new BRT buses without requiring any additional government funds. The likely mechanism is that the government would guarantee loans for the buses by the operators, and would pay a monthly amount corresponding to the subsidy required to maintain existing fare levels. It is recommended that the operators and not the government should be responsible for the procurement of the BRT buses. The operators will need to meet strictly defined BRT bus specifications.

April 2017 seminar

A second major seminar was held at the Shangri-La Hotel on 19 April 2017. This half-day seminar focused on the BRT proposals, with two major presentations by Far East BRT. The first presentation was on international experience and lessons learned, with an emphasis on applicability to BRT in Ulaanbaatar. The second presentation was on the BRT planning and proposals for Ulaanbaatar.

The seminar was attended by the Vice Mayor, ADB officials from the East Asia division and from the country office, and a range of related agencies. The Vice Mayor in his opening remarks delivered a strong endorsement of the project and set out a vision for using the Ulaanbaatar BRT as a transformative urban development project in the city. He emphasized that the BRT should be a signature project for the city, and must be of very high quality and achieve internationally recognized standards of excellence. The Vice Mayor stated that the first phase BRT should be implemented along Peace Avenue, and the implementation should proceed quickly, with the first two BRT phases operational by 2020.

Ki-Joon Kim, in opening remarks for the ADB, showed the proposed phase 1 BRT corridor along Peace Avenue and Namyan Ju, noting that the Namyan Ju extension would provide many benefits and provide a good opportunity for also upgrading this road.

Although the seminar did not include time for formal discussion, the proposals were well-received, and were reported in the media.

The BRT proposals were presented to the government and ADB on 19 April 2017.

14 Project tasks and timeline

14.1 Outline timeline

Few cities are better suited to BRT than Ulaanbaatar. The main corridors are heavily congested and especially in the proposed phase 1 and phase 2 corridors have good physical space and high bus demand. BRT implementation should proceed immediately, with additional work on aspects of this conceptual plan followed closely by commencement of the detailed engineering design. Phase 1 BRT corridor construction could commence in 2017 and the system can potentially open in early 2019.

This study needs to be followed up with additional conceptual design work, detailed engineering design, additional operational analysis and modelling, BRT station architecture, communications and outreach, fare system studies and design, additional business & financing planning, investigation of BRT vehicle options, modal integration planning, and institutional and regulatory capacity building. Plans should be carried out for BRT station area improvements in order to maximize the land development benefits from the BRT investment.

Many other aspects of the work would proceed in parallel with the engineering design and construction, including institutional issues, contracting, operational design, depot design, communications and outreach, fare collection systems, bus procurement and other aspects.

The government should set a target date for the commencement of BRT operation, e.g. 1 Jan 2019, which would be two and a half years from the election of the new government in 2016. This date then becomes the target date for all the related systems and arrangements to reach an operational stage.

The project planning team and ADB can use this date to count backwards to determine deadlines for key system components, including the bus procurement.

	2016				2017				2018				2019				2020			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Timeline stages																				
Revised conceptual design	x	x	x	x																
Engineering design (phase 1-2)						x	x	x												
Phase 1 BRT construction									x	x	x	x								
Testing													x							
Phase 1 operation														x	x	x	x	x	x	x
Early operations adjustment														x	x					
Phase 2 construction														x	x	x				
Phase 2 testing																	x			
Phase 2 operation																		x	x	x
Phase 2 operations adjustment																			x	x

Possible project implementation time frame, with an aggressive schedule. The schedule assumes that some construction tasks such as on station structures and ITS systems are above ground and can be done even during the non-construction period.

14.2 Risk management

14.2.1 Overall project planning and design

It is especially important to ensure a successful phase 1 BRT corridor, because experience elsewhere shows that the phase 1 corridor always provides the template for later corridors.

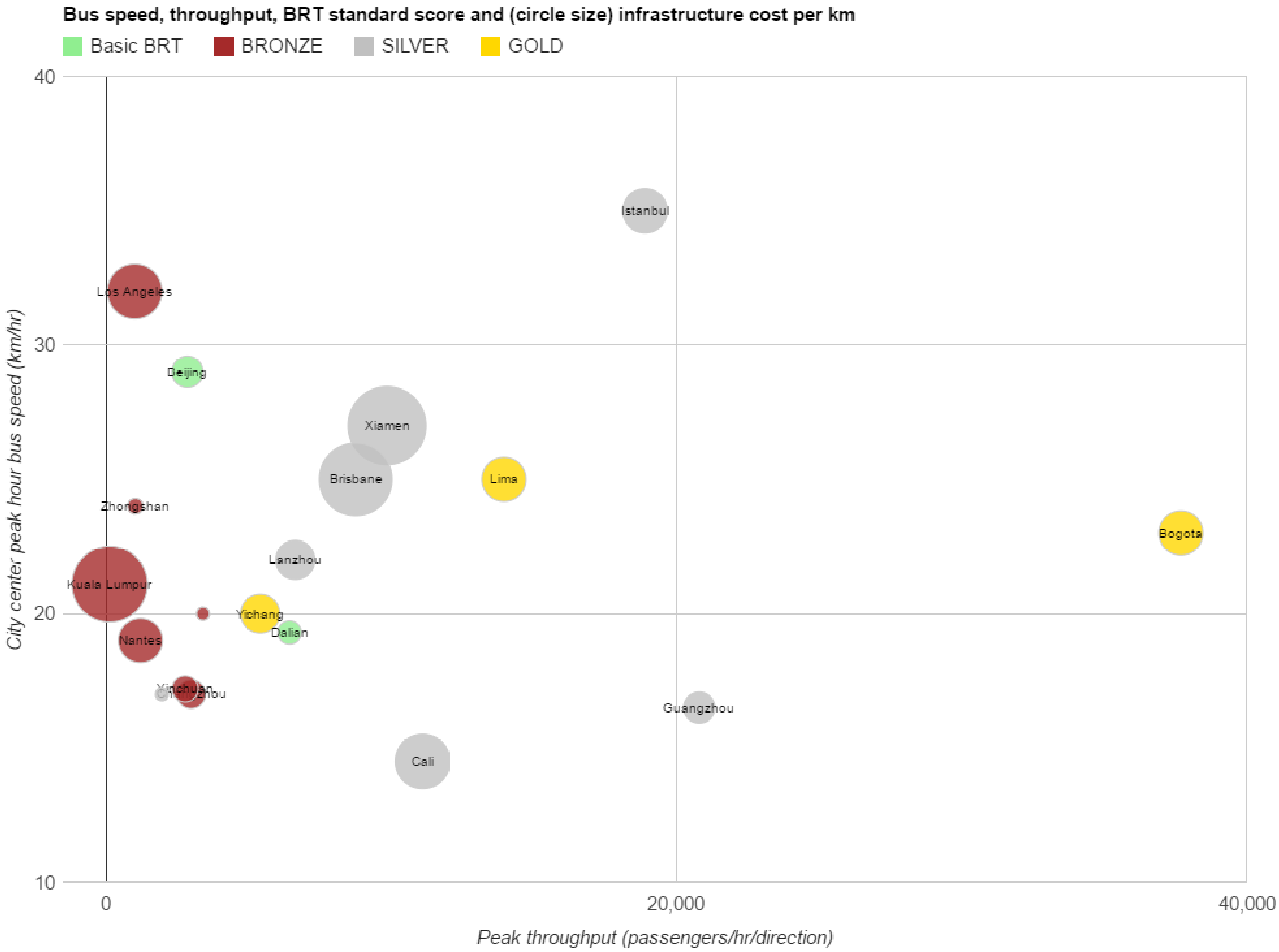
Risk management is an important part of such an important and high profile project as the Ulaanbaatar BRT. After the first phase alone, it is likely that more than half of all bus boardings in the city will take place on BRT buses. This percentage will increase with later phases and probably reach nearly 100% by the time the phase 3 BRT is implemented, with nearly all urban bus routes incorporated into the BRT system.

The main risk with any BRT project is that the infrastructure is poorly designed, wrongly located, incorrectly specified or does not properly match the BRT operations. If the design has major deficiencies, which has been common in BRT systems around Asia, then no matter how effective the project management and contracting is and no matter how high quality the construction or capacity building is, there is a high risk or even certainty that the project will deliver poor results and will be seen as a failure. Similarly if the operational concept is flawed, resulting in incorrectly specified stations, there is a very high risk that the project will be seen as a failure regardless of all efforts in capacity building, supervision of construction, project management, reporting, and so on. If the project were to fail or have major negative impacts, noting that the BRT will be very high profile in Ulaanbaatar, there is a risk that all associated with the project including the designers, financiers, project management personnel, system operators and especially the related and responsible government officials will be negatively impacted. (Conversely if the project succeeds, all associated can expect to reap major benefits in terms of their individual careers.)

BRT project failures are quite common in Asia, as the following examples show:

- Chongqing BRT was demolished in July 2012
- Delhi BRT was demolished in January 2016
- Median bus lanes were partially demolished in Kunming and Tapei
- A high cost and extremely poorly performing BRT system opened in Kuala Lumpur in 2015 (see http://brtdata.net/en/cities/kualalumpur.aspx)
- The Bangkok BRT is a low capacity system which probably provides no overall benefit
- China has very poorly performing BRT systems in several cities including Beijing, Hangzhou, Dalian, Hefei, Urumqi, Zhongshan, and others
- Indonesia has several 'BRT-lite' systems which provide no benefit to the cities
- Hanoi opened a very poorly planned and predictably poorly performing BRT system on 31 December 2016 (see http://www.fareastbrt.com/en/feature/hnbrtjan17)
- Many cities had poorly planned BRT systems which were fortunately never implemented.

In all of these cases the BRT system was incorrectly planned and designed, and the resulting poor performance and results were therefore predictable. Furthermore there is not a particularly strong correlation between the cost of the infrastructure and the results, although the very low cost systems tend to rank poorly in terms of BRT standard score, speed, and passenger throughput. BRT systems can have a high cost and construction quality, such as in Kuala Lumpur, but deliver very poor results due to the poor BRT planning and design. The Bangkok BRT also has excellent construction quality and a high cost, but the operational concept, station design and corridor selection were all critically flawed.



Source: http://www.brtdata.net/en/charts.aspx, accessed 1 August 2016

The main way to mitigate risk in a BRT project is to ensure an excellent BRT plan and design. This will go a long way toward ensuring excellent project results. The surest way to achieve this outcome is to mobilize a planning and design team which has experience with successful, high capacity BRT implementation and can work closely with the local teams. In this regard the experience of a 'company' is largely irrelevant; most important is the experience of the particular experts who will work on the project. These experts can provide the initial key planning and design inputs and later can review and revise the design if necessary, and can guide and assist the local project team through the process of implementation.

In addition to risks around the corridor selection, operational design, and infrastructure design there are also many other risks including intersection control and configuration, the role of traffic police, the operating contracts, the smart card system, the ITS components, the way the project is communicated to the public, the capability and susceptibility to supervision of the construction contractors, the business model, and the composition of the bus operating industry in the project. It is necessary to address these multiple risk factors by learning from and applying the lessons learned from successful as well as failed BRT projects in other cities.

Many key decisions are made during the engineering design stages, and it is essential that international expert input provide guidance during this stage. This technical supervision function can be carried out by a relatively small international expert team, with a budget of around $1 million spread over three years. It is important that the input be spread over at least three years, in order to ensure continuity of input. Spreading the input over a longer period also ensures that the international technical expert supervision team can also provide input during the initial operation phases, developing recommendations to optimize the performance of the system.

14.2.2 Lack of enforcement of bus lanes

Enforcement of the bus lanes along Peace Avenue is at best sporadic. Field observations on several days during 2016 indicated that during snow conditions on Peace Avenue the enforcement of the bus lanes becomes largely non-existent, with the bus lanes occupied by cars. During snowfall the traffic conditions tended to worsen and the collective attitude amongst drivers appeared to be that due to the poor conditions, it became acceptable to drive in the bus lanes. Whereas in regular conditions the intrusion by drivers into bus lanes tends to be sporadic – but highly damaging to bus speeds – during conditions of snow and ice the intrusion is routine and widespread. During these times when conditions are worsened and traffic congestion is even worse than usual, the enforcement of bus lanes becomes even more important, but it is precisely at these times that enforcement is waived.

Also, the lane definition can be lost because the snow & sludge covers the lane markings, which would further complicate attempts to enforce bus lanes in the absence of physical segregation.

For the BRT system, to mitigate the risk of poor enforcement it is essential that the BRT lanes include well-designed physical segregation, whether as a fence or as proposed in this report a concrete barrier 0.2m wide and 0.2m high, which minimizes discretion of the traffic police to allow mixed traffic into the BRT lanes.

14.2.3 BRT barrier design

Sloping kerbs or Kassel kerbs in a busway in Nantes, France (left) and in Amsterdam (right). This kind of sloping barrier can be ideal for situations in which lateral slipperiness due to ice may occur.

The exact form and design of the barrier needs more investigation, but in icy conditions Far East BRT observed buses using the bus stops with a narrow lane demarcated by a fence and lateral sliding does not seem to be a problem. The buses just get into that 'groove' left by previous buses. The "Bogota-style" concrete dividers that are proposed earlier in this report seem to be well-suited because they are angled so that if a bus slides into it, it would just slide off again, somewhat like a Kassel kerb. See http://www.transportphoto.net/dt.aspx?dtid=207 for examples of Kassel kerbs.

BRT lane dividers in Bogota. The design may need to be modified to suit Ulaanbaatar.

14.2.4 Materials and stations suited to Ulaanbaatar's extreme weather

The tactile pavement or blind/sight-impaired-person pavement strips installed on many walkways around Ulaanbaatar, especially all the newer ones, are extremely dangerous and greatly degrade the walkway capacity and performance. The tactile paving is extremely slippery when coated with any snow or ice, which is the condition through most of the winter. They cannot be walked on. It seems unbelievable that such a poor concept and design could be implemented considering Ulaanbaatar's weather, but presumably it was implemented in the summer time when they are not a problem, and was not first tested under conditions of ice and snow.

Hazardous tactile paving in a new walkway in Ulaanbaatar.

It was also noticeable that the marble-like very smooth paving at the plaza immediately south of the State Department store is also extremely slippery when there has been snow and ice. So although the paving looks very attractive, is excellent in Summer and is presumably of higher quality and cost, it is a dangerous and poor choice of materials when Ulaanbaatar's weather is considered.

A key recommendation for the BRT implementation is that paving materials should be tested during ice and snow conditions before they are implemented in or around the BRT corridor and especially in the BRT stations.

The problem of slipperiness of high quality, smooth paving was an issue in the Lanzhou BRT stations. During conditions of ice or snow, inevitably some moisture formed on the station floor as ice and snow fell off passengers' shoes and clothing. When combined with the slight upward slope to enter the BRT station platform (which is 30cm higher than the roadway), this can lead to passengers walking more slowly and carefully to avoid slipping, including at the fare gate point. More significantly for station capacity, this problem of slippery materials during ice and snow conditions occurred at the BRT boarding points, in front of the doors of the BRT buses. Slippery conditions in this critical boarding & alighting location leads to slower boarding and alighting speeds, which reduces the system speed and capacity. This problem was mitigated by adding a mat-like non-slip material at the boarding area, but it is clearly preferable to address this issue during the design stage.

These issues of slipperiness caused by moisture from snow and ice will be exacerbated in Ulaanbaatar, where some form of heating will be used in the stations. The heating will lead to melting of ice and snow from clothing.

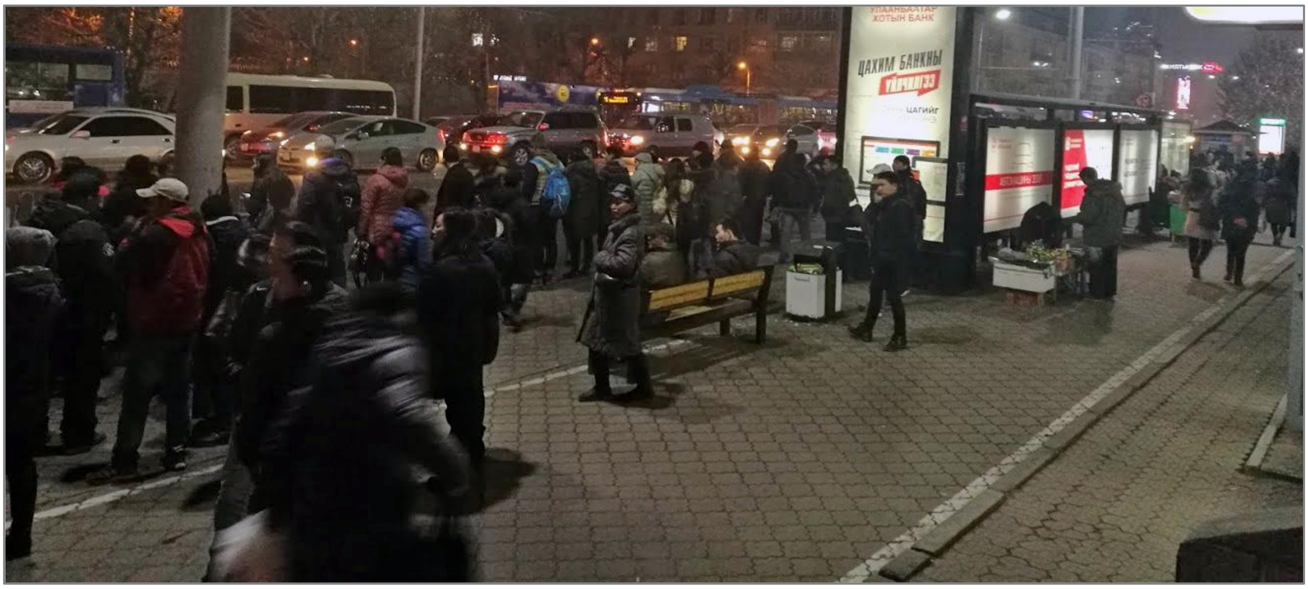
For the BRT system the paving material design, especially inside the stations, needs to be done carefully and the materials need to be tested during snow and ice conditions in situations similar to station entry and station boarding and alighting. This will be an important aspect of the work of the BRT station architect.

Some form of BRT station heating is highly desirable, but there is the issue of station access and also boarding and alighting buses, where doors will need to be regularly opened. It will be useful to learn from experience in locations such as department stores and malls or large office buildings which have similar high pedestrian flows. Another possibility may be to have smaller glass-enclosed areas within the BRT stations in which people can wait for buses. Ideally for the BRT any heat enclosing measures will be able to be used only in Winter, and taken out in Summer, when greater air flow and visibility will be desirable. This will be an important issue to address in the BRT station architecture.

14.2.5 Manual traffic signal operation by traffic police

Manual intersection control by traffic police overriding the existing signals is widespread especially during peak periods and when traffic conditions are poor, including during inclement weather. During one period of snowfall on Saturday 5 November traffic police were manually operating all of the central area traffic lights observed along Peace Avenue, Chinggis Avenue, Olympic Street and even on more minor roads such as the intersection of Genden St and Olympic St. Cycle times at UNESCO St and Olympic St exceeded 10 minutes. The manual operation by traffic police always leads to much longer cycle operation and is a major potential risk factor for the BRT operation, as the bus frequency is heavily disrupted and speeds are also reduced.

The problems caused by manual intersection operation overriding the signals are just as great outside as inside the BRT corridor in terms of the negative impact on bus operations, for affected BRT routes, noting that BRT routes operate both inside and outside the stations. Where BRT buses are held up at intersections outside the corridor, a build-up of passengers will also occur in BRT stations consisting of passengers waiting for those routes (see photo). To mitigate this risk, it is necessary for the BRT planning team to devised two or maximum three phase solutions for all intersections at which there are BRT routes operating, even where those intersections are outside the BRT corridor.



Passengers waiting at the bus stop in Peace Avenue between Baga Toiruu and the State Department Store (Mungun Zavya bus stop) during a typical evening peak hour in November 2016. The unpredictable frequency caused by bus delays at previous intersections can lead to a build-up of passengers.

Mitigating the risk associated with manual signal operation can be achieved in several ways:

- The traffic police need to be involved and represented in the Project Implementation Unit and in the regular meetings associated with the project, so that they support the BRT implementation and operation or at least do not drastically undermine it.
- It becomes even more important to reduce the signal phases from four to either three or two phases, not only along the BRT corridor but also outside the corridors where BRT buses are operating. When the police do manual operation, they allocate excessive chunks of time to each phase, which means the problems associated with manual operation are exacerbated where more signal phases are used. This problem is in addition to the already poor operation of the four phase signals.

14.2.6 Proposed flyovers at East Cross & West Cross intersections on Peace Ave

Flyovers at two key intersections along Peace Avenue have been proposed and in October 2016 were approved by the City for implementation, though the status of financing for the flyovers remains uncertain.

The two flyovers, as the East Cross and West Cross intersections (Namyan Ju and Ikh Toiruu / Amarsanaa Rd) in the original designs were both incompatible with BRT, and alternative concept designs that are compatible with BRT were developed by Far East BRT in late 2016 and early 2017, and provided to the Roads Department and ADB. Importantly, Far East BRT also developed traffic circulation changes which could deliver major intersection and traffic improvements without the need for these two flyovers. Assuming that the proposed flyovers proceed, the construction should be carried out at the same time as the BRT corridor construction, which can concentrate the negative impacts imposed during construction along Peace Avenue into the shortest possible time frame.

The ADB and this TA have already taken steps to mitigate the risk posed by these flyovers, by assuming responsibility for the re-design of the flyovers to ensure that they are compatible with BRT operation. The city government and in particular the Roads Department understand and support the need to ensure that any flyovers built at these locations should be compatible with the BRT. The BRT-compatible design concepts developed by Far East BRT for the flyovers are not included in this report, because our analysis shows that major improvements can be achieved without the need for these flyovers.

14.3 Selected next steps

14.3.1 Surveys and data collection

With the priority phase 1 corridor determined, a more extensive survey program should be carried out focusing on this corridor. This should include:

- Boarding and alighting surveys along proposed BRT routes, and routes which are proposed to be modified as part of the BRT project, where there are gaps in the smart card data.
- Bus stop counts done along all BRT corridors and selected off-corridor locations, where there are gaps in the smart card data and also to verify the smart card data.
- Transfer surveys, especially at high transfer locations, to see which proportion of passengers are transferring and which routes they are transferring from and to.
- Surveys to assess likely mode share impacts of BRT.
- Any additional traffic counts needed to prepare a microsimulation of the proposed traffic circulation changes in the central area.
- Identification of all pedestrian access pathways accessing the BRT corridor, and counts of volumes of pedestrians at and along different access points along the BRT corridor. This can help to prioritize where pedestrian and bicycle access conditions along the BRT corridor should be improved, and to decide on BRT station access and fare collection points.
- Surveys of off-corridor locations where BRT routes may encounter delays. This can be followed up with proposals to address bus speed black spots for those locations.
- Baseline surveys for a later BRT impact analysis study. This survey should be carried out at selected bus stops along the BRT corridors as well as in a defined 'control' survey location which has broadly similar conditions but where no project is being implemented, for later comparison purposes. Impact analysis surveys are asked to bus passengers, pedestrians, car drivers and cyclists (if any bicycle condition improvements are planned as part of the project). See http://www.fareastbrt.com/en/other/impacts-yc for an example of BRT impact analysis results.
- Parking-related surveys and a parking plan for the BRT corridors should be carried out, starting with an inventory of all spaces along and around the BRT corridors.

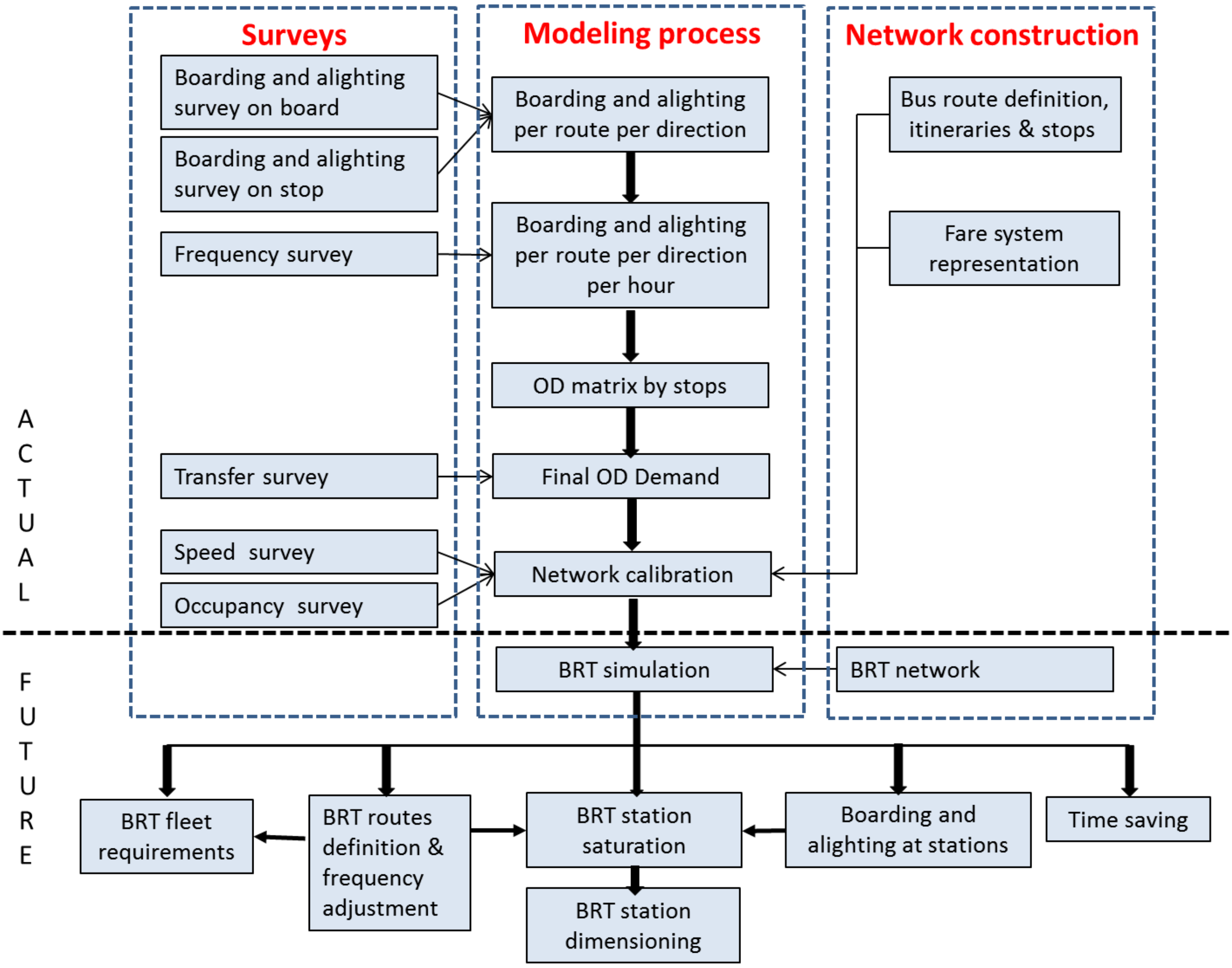
14.3.2 BRT demand and operational model

A BRT-focused demand and operational model should be developed using the smart card data as a starting point. The general procedure for developing the model can include the abbreviated approach illustrated below. This is an approached applied by Far East BRT experts in many cities including in the BRT planning and design in Guangzhou, Lanzhou and Yichang and in BRT studies in Guiyang, Tianjin, Vientiane, Metro Manila and other cities. Various supplementary counts will be needed, as discussed above, and a mode shift analysis should be incorporated to improve accuracy and get a more accurate representation of likely mixed traffic impacts.

Now that smart-card-only payment on buses is allowed, this smart card dataset will provide a comprehensive, excellent basis for the BRT planning and design.

The modeling work needs to take into account the proposed fare model.

The model zones need to be defined such that each BRT station is in a separate zone, and the zones should be sufficiently small to distinguish between different types of BRT access trips.



Far East BRT's proposed approach for developing a BRT model.

14.3.3 Intersections, road design, traffic circulation, and revised CAD preliminary design, to guide the engineering design

The BRT preliminary design carried out in 2011 included CAD drawings of the BRT corridors. These drawings are no longer relevant, because the station dimensions and locations have been revised, and other major changes have been made. This report includes a revised preliminary design which can be used to guide the work of the local engineering design team, but the budget and time frame for this work was limited, and the work is not yet complete. The intersections, BRT platform placement, BRT station access design, traffic circulation, and road layout are all closely related and should be considered in additional preliminary design work during 2017.

Although a substantial portion of the revised preliminary design work has been carried out and is included in this report, much more analysis and design work is required, especially to confirm the central area intersection designs, traffic circulation and platform placements. Some intersections have not yet been designed, including the key section between Sukhbaatar Square and Tokyo Street. More work on the flyover design concepts should be carried out, and a microsimulation of the proposed central area changes should be done. Design and planning work to improve the off-corridor portion of BRT routes should also be carried out, together with consideration of off-corridor stations in selected locations.

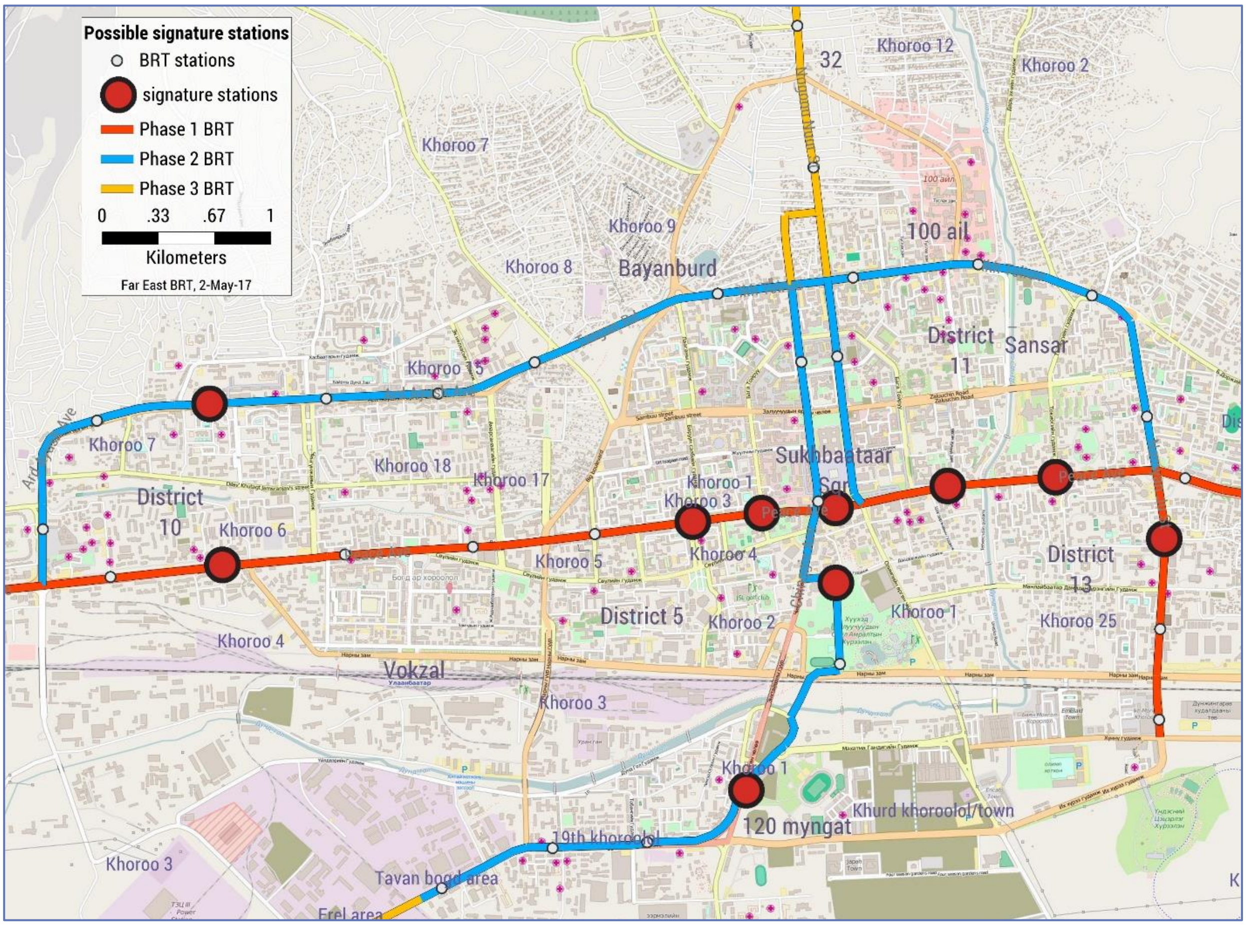
14.3.4 BRT station architecture

The BRT stations will become one of the major landmarks and identifying features of the city, and the station architecture needs very careful consideration and attention.

BRT station architecture needs to consider the functional needs of the BRT system as well as the need for aesthetically appealing stations along Peace Avenue. The BRT stations need to be designed taking into consideration the extremely cold Winter weather conditions and the BRT lines serving the stations as part of the direct service operational approach. Station architecture also needs to take into account the relatively more sensitive locations such as adjacent to Chinggis Square. The designs developed in 2011 were preliminary and need to be revised, including learning from the experience of other recent cold climate BRT situations such as Lanzhou and Urumqi. Ground level cold weather rail and metro stations in cities such as Sapporo might also provide useful references especially regarding approaches to protecting passengers from cold weather. Study trips should be considered.

The station architecture and planning of the Park North, Park South and 120 myngat stations requires additional consideration on issues of access, design, and the possibility of later construction above the stations. Zoning and planning issues will also need to be considered.

‘Signature stations’ should be an important aspect of the BRT planning in Ulaanbaatar, for selected key stations such as in front of the State Department Store, in front of Sukhbaatar Square, the Park North station, and a few other major stations. These stations can include additional architectural and other features. Integration with nearby buildings including construction of retail facilities together with the stations could be considered.



Possible signature BRT stations, based on demand and local conditions. Signature stations can include additional components such as public artwork, escalators connecting to elevated walkways, retail integration with stations, higher cost materials, additional heating, and so on.

14.3.5 Depot facilities and BRT control centre

It is good practice to ensure that each operator has a separate depot, and the Ulaanbaatar BRT is likely to have around 3-4 operators after a process of industry consolidation, suggesting that 3-4 depots will be required. It is also good practice for the government to own the depot space, so that if operators change, the new operator can use the depot space.

Ulaanbaatar could potentially combine the BRT control centre functions with the smart card centre, but more likely is that a separate BRT control centre will be required. BRT control centres have many features but the indispensable functionality is the control and monitoring of bus departures and bus-kilometres travelled (or bus-hours in operation, if the payment is made that way instead of per bus-km). These functions are already partly performed with the installation and operation of the new smart card system, although the BRT control will need a closer level of control over the BRT bus dispatching. Each workstation will handle up to two BRT routes, probably requiring at least 15 workstations for the BRT routes.

14.3.6 Selection of consultants

Having a good BRT preliminary design is worthless if later consultants or design teams make a mess of the early planning. Poorly performing BRT systems can almost always be traced back to poorly planned and designed systems. Unsuccessful BRT systems are almost invariably a result of poor consultant advice. So-called experts in public transport can cause major confusion when they pass themselves off as experts in BRT design and planning despite having neither experience nor expertise in this area. This is especially true of so-called 'senior' public transport experts who may have a lengthy CV and many years of experience, but no experience with actual BRT implementation. Such consultants can cause endless confusion, add little or no value, and even undermine and seriously jeopardize the project. To mitigate this serious risk it is advisable that the BRT experts used in the project should preferably have experience with BRT system implementation, and a small team with good experience should be preferred over a larger team with less specific experience.

When hiring consultants to work on different aspects of the BRT implementation, only minimal attention should be paid to the names or profile of the consulting firms. Far more important than a high profile company name is the BRT-related experience of the actual personnel who will work on the project. The Hanoi BRT provides a good example of how even with World Bank funding and the hiring of large international engineering firms (MVA / Systra, Padeco, Wilbur Smith, Egis and Getinsa, among others) to work on and oversee the planning, design and construction, a disastrously poorly planned BRT system can be implemented. See article at http://www.fareastbrt.com/en/feature/hnbrtjan17.

The Hanoi BRT, funded and promoted on site by the World Bank and opened on 31 December 2016, is very poorly planned and designed, despite having large BRT supervision contracts and high profile international firms. Ulaanbaatar and the ADB should learn from the experience of failed BRT systems such as Hanoi. Far East BRT provides a detailed review of the Hanoi BRT at http://www.fareastbrt.com/en/feature/hnbrtjan17.

14.3.7 Supervision of construction

A good preliminary design or engineering design is meaningless if the designs are later modified or not properly implemented during the corridor engineering design and construction. This applies to the BRT station and roadway construction as well as to key supplementary elements such as pedestrian crossings to access BRT stations, and is especially a concern for aspects such as landscaping, pedestrian facilities or bike lanes that the contractors or detailed engineering designers may not understand or may not view as particularly important. The greatest area of concern relates to the BRT station construction and access, and regular supervision input by an experienced international expert on BRT station construction – roughly one visit of 5-10 days every few months and more frequently during the key construction period – is strongly recommended.

In addition, it is advisable to first build a demonstration station to a near complete stage (though without all of the ITS and signage elements) and then review the design and make required revisions prior to the construction of subsequent stations. This approach was used very successfully in the Guangzhou and Yichang BRT construction. In Ulaanbaatar it will be especially important to test the material in the demonstration station in conditions of ice and snow.

Since many key decisions are made during the detailed engineering design and construction of the BRT system, both stages require supervision and technical input by BRT experts. Erroneous changes to key system features such as any aspects of the station design or configuration, BRT station access, the intersection design, and the physical design can have potentially serious negative implications for the later BRT operation. Operational decisions are also extremely important, but provided the physical design is correct, can be fixed after the system starts operation. Physical mistakes, on the other hand, are often either difficult or impossible to fix, short of demolition and reconstruction, which even if technically possible is not usually politically viable.

Technical supervision during construction is very important, as the contractors and local engineering design team will not be familiar with many aspects of the BRT system design. Note that this does not refer to the already-established procedures regarding supervision of matters like administration, contracting, bidding, and auditing. Rather, this refers to additional supervision of the technical aspects of the BRT implementation, to ensure that the designs are properly implemented. Without this supervision, there is a substantial risk that local contractors, inexperienced with BRT implementation, may make errors that will undermine the later project operation.

14.3.8 Traffic management during construction

Traffic management during construction will be a major challenge and will require consideration of alternative parallel roads as well as the BRT corridor itself.

The likely approach at BRT station areas will be to temporarily widen the traffic right of way on one side while the other side of the roadway is built. This will in many cases involve using space that is currently used for parking. In other cases the walkways may need to be temporarily narrowed. Some bus routes may also need to be adjusted during the construction period.

Given the limited construction season, and to minimize disruption, the possibility of prefabricating many station components in off-site locations should be investigated.

Another approach which will help to minimize overall disruptions is to concentrate all related road works in Peace Avenue into the same time frame, as much as possible. This applies to the Peace Avenue plans for flyovers at the East Cross and West Cross intersections and also the plan to reinforce the bridge across the Selbe River. The Roads Department in a meeting in November 2016 proposed and agreed that Peace Avenue road works should be carried out simultaneously as much as possible, so that overall disruption is minimized.

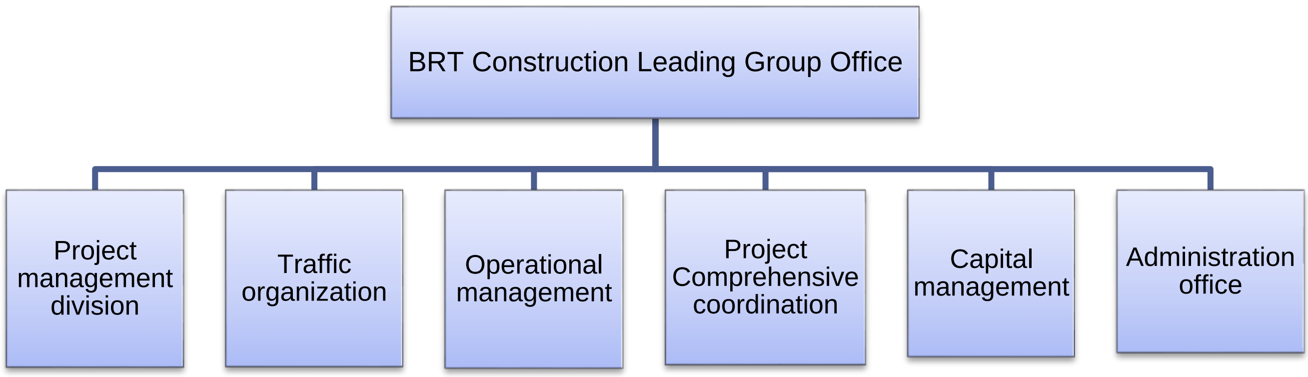
14.3.9 Working group formation and operation, and procurement

Bidding and procurement processes will ideally be performed and supervised primarily by a division of the project implementation unit, which will need to be formed for the project to proceed. The project implementation unit needs to be formed as early as possible in the project planning, and should be chaired by a senior official, possibly the mayor or vice mayor in charge of construction.

Yichang, the second largest city in Hubei province in the PRC, provides a good example in the set-up and operation of a project implementation unit for a major ADB BRT project.

Yichang set up the BRT Construction Leading Group Office in early 2014, just before construction started. The General Secretary of the Yichang City Government is the head of the BRT Construction Leading Group Office. Weekly project meetings were held during construction to report on progress and identify obstacles. The Vice Mayor of Yichang led meetings on special issues, especially during the critical construction stages and in the months leading up to the opening of the system in July 2015. More than 20 full time staff from related government departments were seconded to this BRT leadership office. Related departments providing members of the working group included:

- Yichang City Government
- Yichang Investment Company
- Yichang Bus Company
- Yichang Traffic Police
- Yichang Finance Bureau
- Yichang Construction Commission
- underground utilities company
- resettlement office
- Yichang City Government Publicity Office
- Xiling district, Wujiagang district, and Yiling district (the three districts which the BRT corridor passed through).



Structure of the BRT project implementation unit in Yichang

Ulaanbaatar should consider a similar approach where a BRT implementation unit is set up and importantly where the staff all work from a particular BRT office. The staffing of this unit can start smaller and gradually build up, with peak staffing during the BRT construction period. Meeting frequency will generally be weekly during the construction period, and more frequency during the months approaching commencement of operation. The meeting format involves report on progress and the identification of any obstacles, which need to then be addressed. For this reason, it is important that the implementation unit have high level representation from the city government, so that problems and obstacles can be quickly addressed.

By late April 2017 the Project Implementation Unit had already been formed, though key technical appointments had not yet been made.

14.3.10 BRT station access

BRT station access is an extremely important and often neglected aspect of BRT corridor implementation. BRT station access has two main aspects, both of which require attention throughout the BRT planning, design and construction phases.

The first aspect is the access from the roadside to the station platform. Poor BRT station access forces passengers to undertake long and/or onerous extra walking distances in order to access the station platform. The worst examples usually involve pedestrian bridges and underpasses which are both unpleasant and impose long additional walking distances; problems which can be mitigated with well-designed bridges or underpasses. In Ulaanbaatar the crossings at stations will in nearly all cases be across two lanes of mixed traffic in each direction. A bridge or tunnel is not required to cross two lanes of mixed traffic. Rather, well-designed traffic islands coordinated with nearby intersections and gaps in traffic flow, are preferable. More analysis is required to determine which BRT station access crossings need to be signalized.

The second aspect of BRT station access is the directness and attractiveness of links from the BRT stations to developments around the corridor. There are many large new developments in Ulaanbaatar which are set back around 100m to 500m from the BRT corridors, and it is important to facilitate direct, convenient and safe access by pedestrians to BRT stations from such developments. The ‘detour factor’, or the ratio of the actual walking distance compared to the straight-line distance, should be analyzed for major developments and high demand locations along and around the BRT corridors, with access improvement plans devised where the detour factor is high or where pedestrian facilities accessing the BRT are poor. The BRT station access improvements can be integrated with plans to improve the pedestrian facilities in low income areas, including for example the ger area improvement projects being supported by the ADB in the 7 buudal area.

14.3.11 The Sukhbaatar Square area

During the phase 1 and phase 2 BRT implementation there is no need to build any BRT stations impinging upon Sukhbaatar Square. The nearest station will be located in the centre of Peace Avenue immediately south of the square and garden. However, planning for the possible need for a station in this area to serve north-south traffic (assuming Sukhbaatar St is changed to one-way northbound) should commence so that ample preparation can be made to ensure that this sensitive area is appropriately treated. Various options for this location can be considered and investigated.

14.3.12 Parking management along BRT corridors

Parking management needs to be addressed because at minimum all the current on-street parking in the BRT station areas will need to be removed. In addition, it is preferable to remove on-street parking from the BRT corridor, to enable a more efficient and attractive use of the value public space along the corridor.

Off-street parking should also be considered, with parking codes revised to discourage parking provision in new buildings around BRT stations. Parking caps rather than parking minimums should be applied to new developments within 500m of BRT stations. No public funds should be spent on building parking facilities, especially in the vicinity of BRT stations.

14.3.13 Modal integration, safety, and station area development planning

Modal integration and station area development planning should begin as soon as possible after the BRT corridors are determined, as it is much easier and more effective to include these considerations in the planning and design stage than to try to retrofit them later. This area is multifaceted and includes at least the following basic issues/considerations:

- Setting up a special zone around transit stations.
- Bike sharing planning, for implementation at the same time as the BRT system opens.
- Bike lanes, bike parking, and bike network planning.
- BRT station access improvements (discussed above).

Station area development planning needs to include consideration of parking, and should never include the construction of parking structures near BRT stations, especially publicly financed parking structures.

As discussed earlier, road safety improvements should be carried out along BRT routes.

14.3.14 Benefits analysis

Additional analysis should be carried out to quantify BRT system benefits. Benefits of the BRT system in Ulaanbaatar are wide-ranging. The most obvious and easily quantifiable benefits are the time savings of bus passengers due to faster bus speeds and lower waiting times, and the operational savings for operators due to buses being able to serve more paying passengers due to faster speeds. However, there are many other benefits including:

- Employment generation and economic revitalization due to improved access
- Air quality improvements due to greater usage of public transport and lower emission buses, and smoother driving conditions
- Improvements to the image and attractiveness of the city, including to tourists
- Public health improvements due to more use of active modes of walking and cycling, noting that public transport trips always include a walking component
- Road safety improvements due to improved crossing conditions
- Reductions in crime due to improved security, especially in BRT stations (compared to the current bus stops)
- Time savings for pedestrians due to better road crossing conditions
- Support for local BRT vehicle related industries
- Cost savings for bus passengers due to being able to transfer for free inside BRT stations.

14.3.15 Communications and outreach

A well-planned BRT system will provide major benefits to all groups – bus passengers, drivers and operators – as well as to the general public.

Outreach and communications includes:

- Outreach to public transport passengers
- Outreach to drivers
- Outreach to businesses along the BRT corridors
- Outreach to operators
- Outreach to the general public
- Special events, displays, and activities.

Messages should be segmented and targeted for each group.

Communications and outreach needs to commence soon after the BRT corridors are confirmed, and will be especially important during the construction period, so that people are willing to tolerate the disruption during construction. Major changes to traffic circulation and intersection operation will be needed, which will also require effective outreach and communications.

The period leading up to and including the opening of the BRT system is very important, and the project implementation unit and city government should try to ensure a positive media environment and positive media coverage. One way to achieve this is to periodically release information on particular system features, even if the features are relatively minor. Another important measure mentioned earlier in this report is to start with one BRT station which is built to a more advanced stage before later stations. This approach is recommended primarily in terms of BRT station construction and ensuring that any design or construction deficiencies are addressed, but it also helps with communications during the construction period, enabling the public to visualize the coming system.

14.3.16 Resolution of smart card related issues

The smart card implementation has been problematic in many ways, and was the focus of a PPIAF study carried out during February to April 2016. BRT stations will accept cash and card payment, but passengers should be encouraged to use smart cards, as this reduces queuing issues at BRT stations and speeds boarding in off-corridor locations, which improves BRT vehicle speeds. Card payment is also less prone to fare evasion through incorrect fare payment.

Smart card related issues, which also relate to operator payment, need to be resolved or at least greatly improved prior to the signing of contracts with the BRT system operators.

Although a smart card only policy was implemented from 1 April 2017, it is recommended that cash payments be accepted at BRT stations. There is no negative impact on bus boarding times, since payment takes place at the station entry, and fare evasion and cash leakage can both be controlled at the points of station access.

14.3.17 Off-corridor portions of BRT routes

BRT buses will operate outside the BRT corridor, and in locations outside the BRT corridor where BRT bus or passenger flows are high and bus speeds are low, measures which are taken to improve the speeds will improve the overall BRT system performance and service reliability. When the BRT corridor and phase 1 BRT routes are determined, analysis should be carried as the basis for measures to improve bus speeds in these off-corridor locations.

14.4 Concluding remarks

In the seminar on 17 April 2017 the government and ADB announced their support for BRT implementation starting with phase 1 in Peace Avenue and Namyan Ju. With the corridors fixed, there is now much follow-up work required in many areas.

The Ulaanbaatar BRT has been in preparation for many years. The long gestation and planning time of the project has been highly beneficial in that it has allowed many revisions and updates to the BRT design and plan.

Some earlier BRT design work was carried out in 2010. This was based on a flawed trolleybus concept and was not used in any of the subsequent planning. Preliminary design work was then carried out in 2011. Then over a five year period to early 2016, major bus system reforms were implemented in Ulaanbaatar, provide a good foundation for BRT implementation, though the BRT planning itself did not meaningfully proceed over this time. The BRT planning work then commenced again in early 2016, and was focused on the Ikh Toirru and 3/4 khoroolol corridor, with the central part of Peace Avenue considered off-limits for political rather than technical reasons. Then in July 2016, with a new government in place following elections in June, the constraint against using Peace Avenue was removed, and the BRT plans and designs were revised. Further changes were carried out in late 2016 and early 2017 to include a southwest connection as a phase 2 BRT corridor. The result is an excellent phase 1 and phase 2 BRT network concept for the city.

The government announced in April 2017 that the project would be implemented as planned along Peace Avenue, and set a target for the first two BRT corridors to be operational by 2020. With this study and plan as a foundation, the Ulaanbaatar BRT project is well set up to succeed, though much work remains to be done even during this conceptual design stage, and all of the critical design and other decisions will be taken during the follow-up conceptual, preliminary, and detailed engineering design stages. These decisions will determine the success of the project.