Principles of Bus Service Planning

"Bus Route Planning is not a Science, it's an Art"

1. Introduction

Claims similar to the above are made about a number of processes – we at AHA are perhaps not qualified to claim that it applies to planning for buses any more than anything else, but a case can certainly be made.

While various software modules are available to assist with bus planning, the human brain, together with an understanding of the geography of the area in question and the needs of users, is always the best tool – it's an area where we are experts.

A number of documents are publically available giving guidance on bus planning – a selection are listed in Chapter 9 of this note **.** *Our own take* on the ***main*** issues (principally with urban areas in mind) is set out below. Much of it applies to planning any form of public transit, not just buses. Note that this document does *not* claim to cover all the issues; particular coverage is given to the issue of bus stop spacing and its effect on accessibility.

2. What are the Objectives?

The list of objectives, and even more their priority, will vary according to who is doing the planning (a commercial bus operator, a government body, or whatever), and who the target market is (commuters, shoppers etc.). In any planning exercise, defining the objectives is an essential first step. However, they are likely to include some or all of the following (in approximate order of priority);

- Accessibility – having bus stops and routes close enough to where the people are;
- Capacity – ensuring demand is met;
- Journey time – getting people where they want to go quickly;;
- Economy – meeting financial objectives;
- Convenience – being easy to use;
- Comprehensibility – being easy to understand;
- Integration with other modes – usually rail, Metro or tram;
- Integration with public policy – e.g. good links to employment sites;
- Environmental Factors – visual, noise, air quality etc;
- Safety – more an operational issue, but may affect both routing and location of stops;
- Sustainability – usually depends on the technology chosen.

Note that some of the above objectives may work against each other; e.g. curtailing bus routes at suburban Metro stations, rather than running them to downtown, may be good in terms of Integration with other modes, but may be less convenient for users.

3. What Information is needed?

There are certain basic information needs, as follows;

Demand Information

- Data on existing public transport users -
- how many?,
- from where to where?,
- at what times do they wish to travel?,
- any particular characteristics (e.g. how many might have baby buggies, how many are elderly/infirm and have limited walking abilities ...);
- Data on potential users –
- As for existing users, plus
- What is needed to encourage them to use PT?

Supply Information

- Physical characteristics of the vehicle involved – size, speed, acceleration etc;
- Operating cost data, and other financial requirements;
- Road (and walking route) network configuration;
- Prevailing climatic conditions;
- Any constraints on locating bus stops; and
- Capacity constraints of roads, depots etc.

4. The Key Issues

Having defined the objectives, and gathered the necessary data, there are a number of key issues that need to be addressed, as follows;

- How many bus routes?
- How closely should routes be spaced in urban areas?
- What bus frequency should be aimed for?
- How closely should stops be spaced?
- What level of interchange (transfer) should be planned for?
- Should routes run across the city centre, or terminate there?

5. Frequency and Simplicity vs Coverage

Again, solving these issues may involve a trade-off between different objectives and goals. In particular, given finite resources, there is trade-off between -

- providing lots of closely spaced routes which penetrate housing areas, giving good geographical coverage but at lower frequencies (the "***coverage***" model), ***or***

- a smaller number of more direct routes with higher frequencies (the "***direct***" model).

Modelling shows that the latter will minimise total travel time in most circumstances, as any extra time spent walking to and from routes is more than offset by lower waiting times and/or less time on the bus. However, in adverse climatic conditions or where many passengers are less time-sensitive or less able/willing to walk, the "direct" model may be less attractive.

6. Spacing of Bus Stops

Much guidance on bus stop location concentrates on the distance between stops. In fact, actual walking distance to bus stops (from the entrance to any particular premises) depends on a number of factors, namely:

- How far apart the routes are;
- The placing of stops on each route;
- The geometry and degree of connectivity of the network of routes available for walking in the area concerned; and
- The provision of road crossing facilities, where a stop is on the far side of a main road (typically, the bus route itself).

In addition, the perceived walking distance (and time) depends on other "soft" factors, such as the quality of the environment surrounding the walking route, as well as the climatic and weather conditions at the time.

Route Spacing

As mentioned above, for several reasons it is desirable to aim for a simple route structure with a minimum number of routes. In particular, given likely resource considerations, the more routes that are operated the lower the bus frequency on any one route; international research clearly demonstrates that "choice" riders (those with a car or other alternative available) are unlikely to use low-frequency routes.

In any event, route spacing is in many respects dictated by the form of the urban fabric. Typically in most cities, bus routes run along the main roads bounding blocks. This to an extent dictates route spacing, and can make it difficult if not impossible to run parallel routes less than (say) 1 km apart.

Bus Stop Spacing

A variety of guidance is given on bus stop spacing, and a variety of standards are followed in various parts of the world. The closer bus stops are on any given road, the less distance intending riders will need to walk once they have walked to that road. This increases convenience, and reduces overall journey time by decreasing access time. But closer bus stops also result in lower bus operating speeds, which both makes the service less attractive to riders and increases operating costs. Peter White[1] has shown that these two considerations

[1] Page 118 of Public Transport, its planning, management and operation (5th Edition); White, Peter, published by Routledge, 2009.

are best in balance at a stop spacing of about 550m – at this distance, overall travel time is minimised.

In many places bus stops are placed much closer than this – in North America, stops are often found spaced as close as 100m apart. In Europe and Australia longer spacings are typical – 400m or more.

UITP guidance is as follows (the assumed walking speed equates to 4.5 kph);

Utilisation	Stop spacing	average walking time (at 75 m/min)
City area, central commercial, service, administration, conventional activities	300 m	4 min
urban areas with high density, dense residential areas, commercial activities, educational sites	400 m	6 min
urban areas with low density, residential area	600 m	8 min

Table 1; UITP Guidance on Bus Stop Spacing

It is certainly desirable to have stops closer together in city centres – the high volume of boarding and alighting passengers justifies reducing their walking distances, and it is often desirable to spread both passengers and stopping buses over a number of locations to minimise congestion (although this will require greater carriageway and footway space at the expense of other uses).

It is less clear why longer stop spacings might be appropriate in low-density residential areas; in such areas routes are likely to be further apart, so intending riders will have to walk further to the route in the first place, before they walk along the route to a stop. Such a strategy can only be justified for operational reasons – to avoid too many stops slowing the bus down.

It is worth noting that the disadvantages of short stop spacing – slower bus speeds and increased costs – can be mitigated by not having every bus stop at every stop. This could be achieved by having a hierarchy of services including both limited stop and all-stops services, or by having all services running on a "skip-stop" basis – calling, perhaps, at each alternate stop. The former of these alternatives is probably more sensible both operationally and in terms of ease of understanding for passengers, and could be applied as part of a service hierarchy approach.

Note also that both the number and location of bus stops may be affected by a number of factors associated with safety, pedestrian and traffic flow and the public realm. This means that discussion of whether stops should be placed "mid-block" or at intersections may well be academic, particularly if urban blocks are of such a size that there are several stops along the block.

Geometry of walking network, and effect on distance to stops

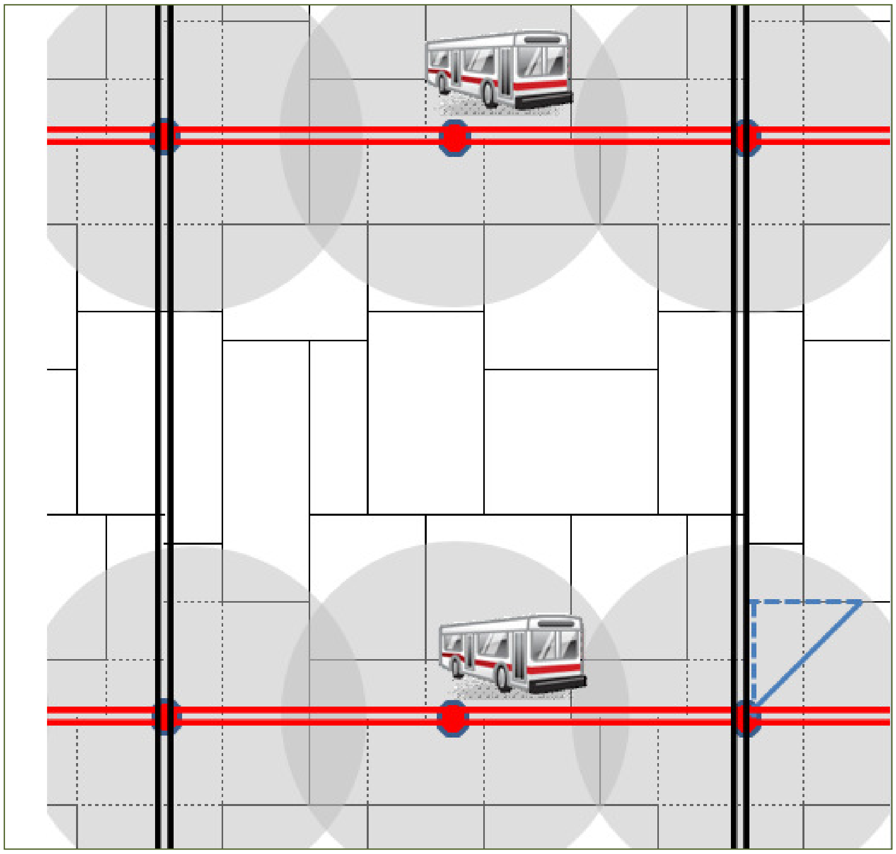

Figure 1; Nominal circular bus stop catchments[2]

Walking routes to and from bus stops are necessarily constrained by the routes available, which may be along sidewalks or may be along dedicated footways, where these are available. Where possible people will often cut across undeveloped areas to reach a bus stop. However, particularly in fully developed areas, it is rarely possible for riders to travel by "straight-line" to a bus stop. If they were able to do this, the catchment area for each stop would be a circle, as illustrated in Figure 1 above. Assuming a block size of one km with bus routes running along the opposite sides only, this would mean that around 55% of the ground area of each block would be within 300 m. "straight line" distance of a bus stop.

Note that the example given shows routes running only "East to West", and not "North to South". In practice, some blocks may have bus routes running along three or even four sides, rather than just two as shown here – but even if this is the case, the routes are most unlikely to serve the same destinations – it is not just a matter of passengers having a convenient bus stop, but of having the right services from that stop.

However, walking in a straight line is seldom an option; the grid pattern of development in many cities usually means that people have to walk around "two sides of a [right-angled] triangle" rather than taking the shortest distance. This can add up to 41% walking distance

[2] Idealised one km square block. Red lines indicate bus routes – heavy black lines are main roads without bus routes. Red circles indicate nominal positions of bus stops, grey shading = nominal "300m" catchment.

compared with the straight-line distance; in Figure 1 above, people have to follow the dotted blue lines rather than the solid blue line.

Furthermore, if the network of walking routes is coarse, incomplete or irregular, or if a large building or other obstacle lies between the user and the bus stop, walking distances can be further increased.

As a result of this, the idealised catchment area of a bus stop in a typical grid-pattern city, assuming a fine rectilinear grid network of walking routes, is a diamond shaped area as shown in Figure 2 below; for a maximum walking distance of 300m, the area of the catchment is 18 ha. (If, on the other hand, everyone in the catchment area was able to walk to a bus stop on a "straight-line" route, the catchment would be a circle of area 28.3 ha, 57% greater.)

For a one km. square block, these diamond catchments cover 35% of the ground area within a 300m walking distance.

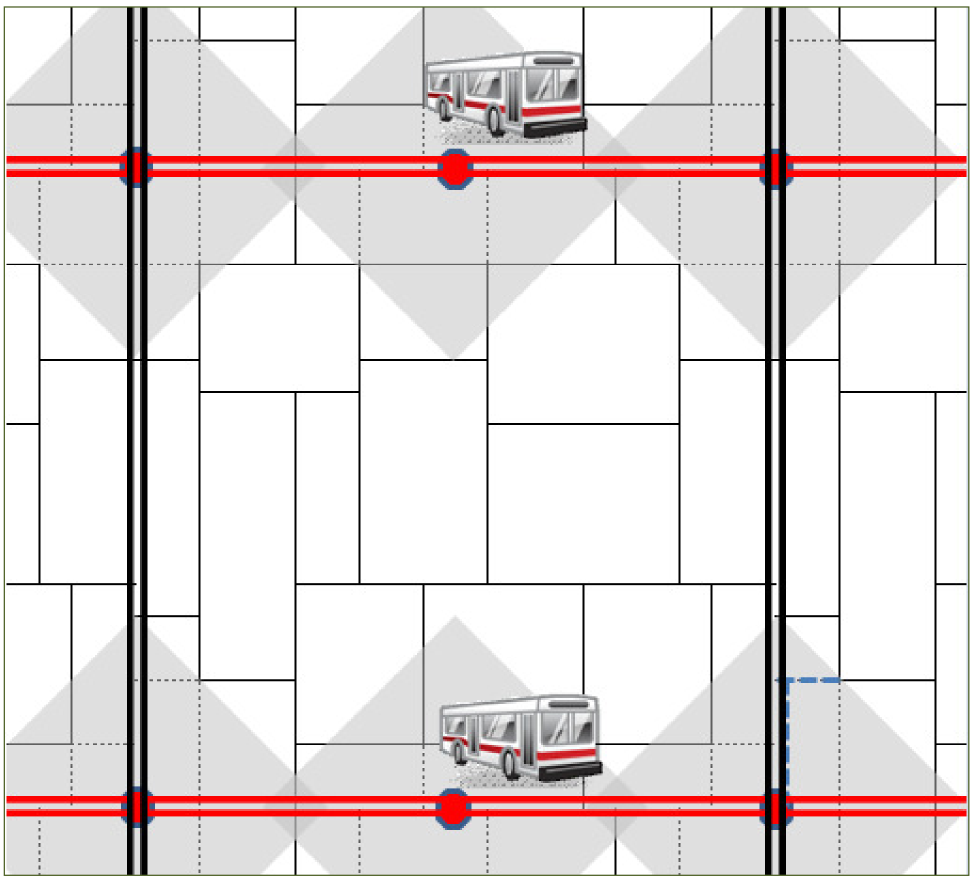

Figure 2; More practical "Diamond" bus stop catchments

Effects on coverage of route and stop spacing

The diagrams below show bus stop catchments based on a 300m walking distance and a fine rectilinear grid of walking routes (not shown) within one km square blocks for three scenarios of route and stop spacing. (Stops are shown as red octagons, grey shading indicates coverage areas, thicker lines indicate main roads with bus routes, broken lines indicate "mid-block" bus routes, and thin lines indicate roads without bus routes.);

- First scenario; Routes parallel and 1 km apart, stops every 500 m. along each route, stops opposite each other;
- Second scenario; Routes parallel and 500 m. apart, stops every 500 m. along each route, stops opposite each other;
- Third scenario; Routes parallel and 500 m. apart, stops every 200 m. along each route, stops opposite each other;

Note that:

- As already mentioned above, no crossing bus routes are shown – all routes are assumed to run "East-West". (Provision of such routes, with mid-block stops, on the First Scenario would increase coverage to 52%.);
- Stops are shown at intersections, as well as mid-block; in practice, while it is desirable to place stops close to intersections for a variety of reasons, they are unlikely to be within 30m of an intersection (measured from the mid-point of the bus stop to the nearest kerb-line of the intersection).
- Having stops staggered from route to route, rather than opposite each other, would improve coverage a little; again however, this would be impracticable;
- A most important proviso: the idealised catchment areas shown make no allowance for any additional walking distance required to cross roads – this can be considerable in cities designed mainly for the car, where multi-lane main roads can be difficult to cross except where specific facilities are provided, and medians may have a pedestrian barrier along them. (Even at intersections where pedestrians are catered for, they may have to wait some time for a green light.)

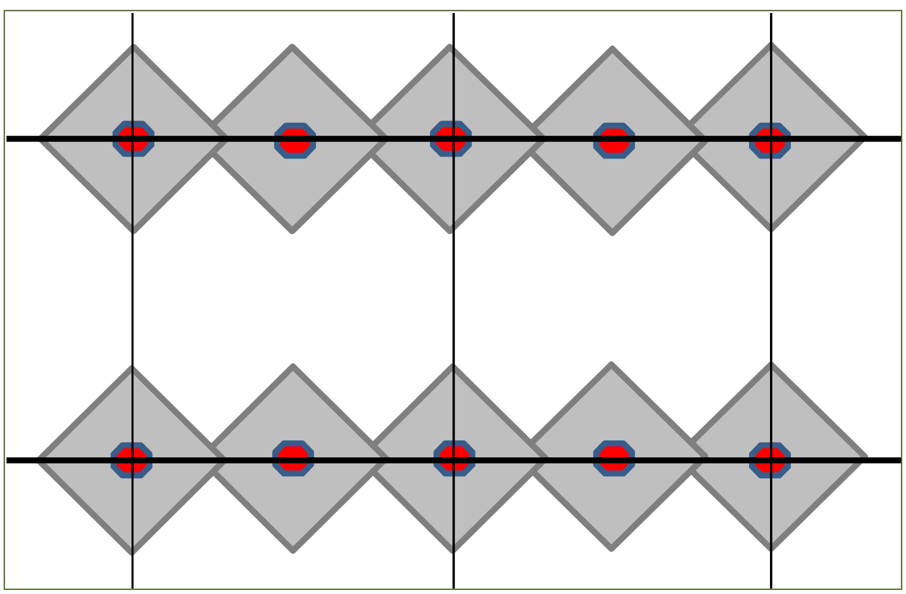

Figure 3; Bus Stop Coverage First Scenario, Routes 1 km apart, Stops 500m apart (35% coverage)

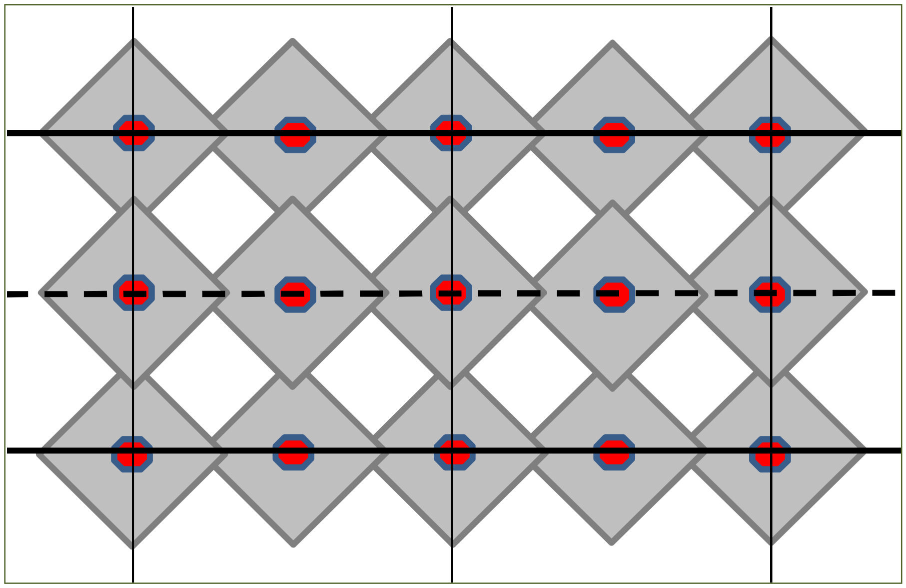

Figure 4; Bus Stop Coverage Second Scenario, Routes 500m apart,

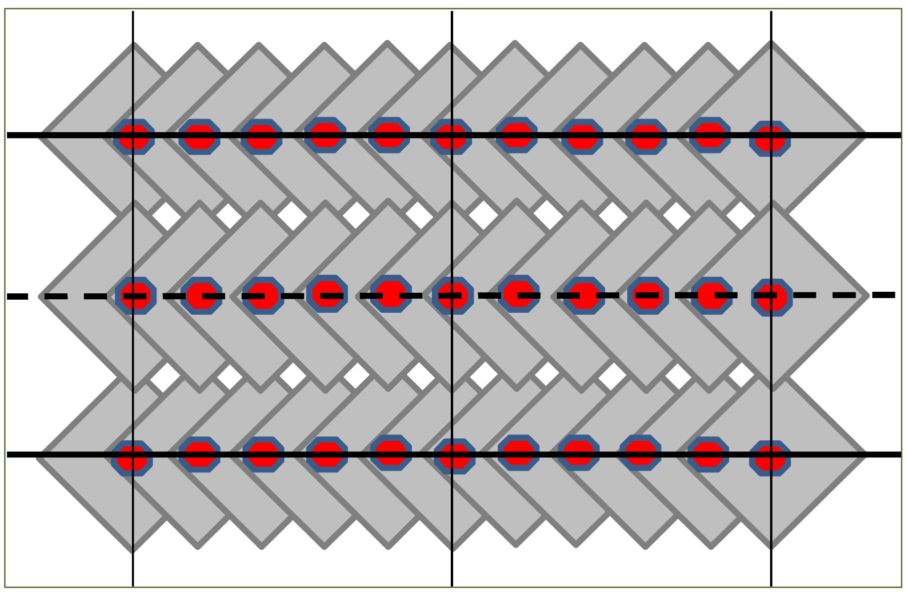

Figure 5; Bus Stop Coverage Third Scenario, Routes 500m apart, Stops 200m apart (90% coverage)

In the three scenarios, the extent of ground area coverage (within 300m catchment) is 35%, 68% and 90% respectively. It is noteworthy that even with routes 500m apart and stops every 200m, 100% coverage is not achieved – and there is much duplicate coverage. In practice, having stops every 200 metres is not likely to be achievable or desirable, either in terms of finding space for stops on the street, or in terms of being able to run bus services stopping so frequently – unless a "Limited Stop / Local" hierarchy is to be employed as suggested above.

With routes 1 km apart, even if stops were placed 200m apart, coverage would only be increased to 50%. Only by reducing the spacing between routes can reasonable levels of coverage be achieved with fixed-route services.

7. Extent of Interchange (Transfer)

Public transport faces a difficult challenge in satisfying dispersed origins and destinations. One approach to the challenge is to provide for 'anywhere-to-anywhere' travel patterns through tailor-made services that directly connect everywhere to everywhere. The problem with this approach is that the more public transport is tailor-made, the more it surrenders its environmental and economic advantages. Such networks are less easy to understand and market, and hence are less attractive both to core bus users and to occasional riders (e.g. tourists). Taxis are a more appropriate way of connecting "everywhere to everywhere else".

The alternative is a suitably concise network. Instead of having tailor-made direct services satisfying all trips, the judicious introduction of transfers for some journeys can better enable the provision of services. Provided there is sufficient coverage within the overall network, this approach will enable 'anywhere-to-anywhere' travel, with high occupancy rates, by carrying different kinds of travellers on the same services. At the same time, the number of interchanges must be sensible – few riders will be attracted to a journey which involves multiple changes to complete a short journey. A maximum of two (and preferably one) interchange is generally considered desirable.

In most cities with well developed public transport networks, trips often require a transfer (e.g. London, Paris, New York, and Sydney). Public transport networks which facilitate transfer open up new travel possibilities whilst supporting large resource savings. However, whilst transfers may present many new travel opportunities, they may also impose inconvenience. Creating effective transfer-based public transport systems requires careful planning to ensure that the inconvenience is minimised as much as possible. Within the most successful networks, integrated fares and ticketing ensure that there is no fare penalty for transfer, and high frequencies result in minimal waiting times at transfer points.

Easy transfer also requires attention to timetables and physical facilities. 'Random' transfers are possible when all lines servicing an interchange point operate frequently, generally every 10 minutes or better. 'Timed' or 'pulsed' transfers are needed when services are less frequent, and in this case the timetables for connecting routes must be coordinated.

Designing networks which support convenient transfers can bring about significant improvements in operational efficiency and improve the simplicity of the network. This not only means that concentrating resources on fewer routes leads to increased frequencies, but also results in a network that is easier for users to understand.

8. Cross-city operation of bus services

In many urban areas the central area is surrounded by lower density suburbs and a decision must be made about whether to operate services across the city centre, or to have a series of simple radial routes terminating in the centre. There are advantages and disadvantages to both (see Table 4.3), and it is likely that an optimum network will comprise a mixture of simple radial and cross city services.

Simple Radial Services	Cross City Services
Provides fewer direct travel opportunities	Offers more direct travel opportunities
Provides more flexibility to tailor frequency of service and bus capacity in response to demand	Can result in inefficient operations if the demand either side of the centre is uneven
Requires more terminal space in the central area which might be difficult to obtain	Does not require central area terminal space
Can improve operational reliability as delays through the central area can be mitigated by providing for recovery time at the central terminal	Operational reliability can be adversely affected by delays through the central area.
Journeys which start or terminate in the CBD will be involved in either picking up or setting down, not both	Improves resource utilisation – as buses travel through the CBD they are both picking up and setting down passengers

Table 2; Comparison of Radial and Cross City Services

Care must be taken that cross-links are sensible, and offer genuine benefits. For example, a service which has to pass through the whole breadth of the CBD may prove to be unreliable due to the volume of congestion encountered, or the overall route length may prove too long to feasibly operate. The following check list offers a guide to sensible cross-linking; the route pattern should:

- cater for any existing / potential cross-town demand between specific Origin-Destination pairs;
- provide as many people as possible with a link to as much of the CBD as possible;
- equalise demand on the two ends so as to enable operation of optimum headways;
- have sensible, "marketable" routing in the town centre, providing common stops for common corridors;
- put together services so as to get a total cycle time that fits with desired headways so as to minimise wasted time; and
- balance each of the above to achieve the most attractive network in the specific scenario.

9. Transit Planning References

- '**Public Transport, its planning, management and operation**' (5th Edition); White, Peter, published by Routledge, 2009. (Priced hard-copy)
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- US TCRP '**Transit Capacity and Quality of Service Manual**', Overview and Full Manual, available at http://www.tcrponline.org/bin/publications.pl?mode=abstract&cat_id=23&pub_id=1102
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