

Future Directions for the Washington, DC Metro Map

A Preliminary Report

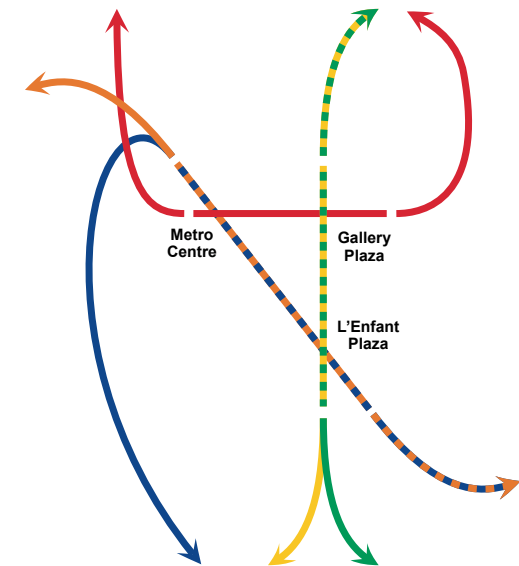
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Preface

This document begins with a brief analysis of the Washington, DC Metro network and its schematic map. Future network amendments will challenge the current design, and a series of prototype replacements are introduced and discussed. Each has the intention of improving on the geometry of the current design, but not at the expense of excessive topographical distortion. There are many ways of achieving this, but most graphic designers are somewhat conservative in their repertoire of solutions.

The current Washington, DC Metro map has a long history and has become almost synonymous with the network itself. It is essential, therefore, that any replacement should be carefully designed and thoroughly researched in order to ensure that it is both usable *and* engaging to both Washington, DC residents and visitors. An iterative, evidence-based methodology is therefore proposed, in which favored designs are refined in consultation with management and in conjunction with user studies at all stages.

The appendices at the end of this document give a detailed discussion of ‘good design’ in the context of schematic maps, and a detailed taxonomy of the different types of angle-rules that are possible, along with their strengths and weaknesses. Examples of maps worldwide are used to illustrate these.

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1. Background: The Washington, DC Metro

The Washington, DC Metro first carried passengers in the 1970s. Conceived of and constructed as a whole, it today comprises over 80 stations on five lines, with steady expansion taking place [4]. Unlike other networks in the USA, such as the New York Subway and the Chicago El, the system does not regimentally follow the City grid structure. Many stations are named after landmarks, attractions, spaces and districts, rather than the more traditional practice of naming after intersecting streets. In many ways, the structure of the network resembles those found in medium-sized European cities rather than the historic networks of the USA. All of these factors need to be taken into account when devising a network map.

1.1 Network map, initial impressions

The map of the Washington, DC Metro dates from the early days of the network. It is distinctive in many ways but, like almost all other networks around the world, reality is simplified by removing most of the details that would otherwise be provided on a standard topographical streetmap. Other than the lines and stations themselves, the only remaining details include rivers, parks, county boundaries, some landmarks, the Washington Beltway and supplementary station information. Like many other networks, this is also a schematic map that follows a frequently-used angle-rule known as *octolinear* [2, 3]. The complex trajectories taken by the lines are simplified by converting them into straight lines; horizontal, vertical, and 45° diagonals (other than the southeastern end of the Green Line) with tightly radiused corners. The intention is that these will be easier to follow than if the routes mirrored topographical reality. The designers undoubtedly hoped that this would result in a usable, engaging map, conveying the implicit message that journeys by Metro would be simple, effortless, and rapid.

The most distinctive feature of the map is its thick Metro lines in relation to the map size and lettering. With future plans envisaging the possibility of up to three line colors along at least one corridor, this design style will not be tenable in the future. Less desirable, station names interrupt the flow of lines in many places. The adverse effect of this will become more pronounced should line



thickness be thinned in the future. These factors alone point towards the need for a fundamental redesign, rather than modifications to the existing version. Station names are also angled in different ways in many places, and font size and spacing is occasionally reduced so that certain stations can be accommodated. Typographically, the overall impression is somewhat chaotic; any implicit message conveyed by this is almost certainly undesirable from a marketing point of view.

A more subtle point to note is that the designer of the map has not taken the opportunity to simplify the trajectories of the lines in many places. This is an essential procedure in optimization because substituting the twisting routes of reality with zigzagging routes on a schematic map does not achieve simplification (see Appendix A).

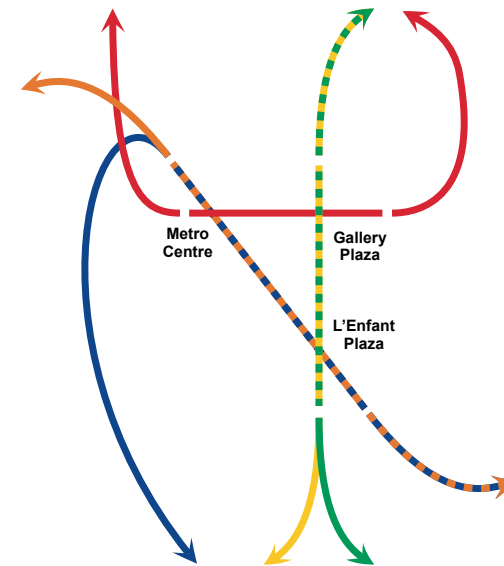
Instead, the shape of complexity is merely changed. For example, the Green Line to the southeast of the city changes direction three times after Waterfront Station. This does not help the user plan a journey, nor choose the most convenient station. The directional information is merely noise, defeating the notional advantage of a schematic map. Journeys by Blue Line appear to be particularly unattractive, with 720° of curvature between L'Enfant Plaza and Franconia-Springfield. Also of note is the twisted route taken by the Green/Yellow Lines north of Shaw. Two right-angled bends and a 45° one imply a circuitous journey for the user, who might make the reasonable assumption that the designer has gone to the effort of implying that Columbia Heights and Dupont Circle are within easy walking distance of each other. This information might be useful in the event of service disruption were it not for the fact that this implication is incorrect.

Overall, there appears to be scope for improvement in this diagram. There is ample opportunity for simplifying the structure of the map and calming its typography, thus enhancing its appeal and usability. Optional travelers need to be given the impression that the network is simple, speedy and effortless to use, and one method of marketing this message is for the map to be likewise.

1.2 Network Topology

Looking at the actual structure of the network, there are a number of properties that constrain the options for the designer who is attempting to create the most usable and aesthetic design possible. It is not a perfectly radial network, and this has implications for how it is mapped.

The current map is roughly square-shaped with supplementary information giving it a portrait-format page. However, the network itself has a strong east-west axis, with the Dulles Airport extension adding to this. Station names can be difficult to place on lines that run horizontally. The preferred UK solution is to alternate station names on either side. Tilted station names are perfectly acceptable in other countries but should be applied neatly if possible. An alternative is to slant the lines, but a slope of around 30° to horizontal is necessary for easy placement of a series of long station names.



Above: Basic Washington, DC Metro central structure and flow

In terms of route trajectories, in the City Centre the lines meet to form a rough triangle, with the need for clear placement of station names limiting how this area can be configured. The Green/Yellow and Red Lines meet, depart, and then meet again further north, and this reduces the potential for straightening these. To the southwest, the trajectory taken by the Blue Line constrains the map enormously; only certain configurations of Yellow and Blue Lines ensure that they will meet at Pentagon without unreasonably elongated gaps between stations.

All of these factors should be noted when evaluating the prototypes shown in Section 2. Particular configurations are chosen with good reason, and alternatives may be impractical.

1.3 Topographical considerations

Many users complain about topographical distortions on schematic maps, although the difficulties that these cause are probably overstated. Overall, the designer should distort topography where this will improve the flow of the lines, but avoid doing so

excessively. Whether a user is seeking to identify a start or destination station, or alternatives in the event of service disruption, it should always be remembered that a network schematic is a poor substitute for a detailed streetmap, and direction signage and maps of local neighborhoods should ideally be provided at each station.

The Washington, DC Metro has a number of properties that mean that stringent topographical accuracy is less important than for other USA urban rail networks.

- *All stations are uniquely named.* In New York and Chicago, the naming of stations by intersecting street often results in duplicated names. A topographical map is helpful in resolving such ambiguities, but the Washington, DC Metro has none.
- *Almost all likely transfers are catered for within stations.* For some networks, e.g. the London Underground, certain journeys may be completed more quickly by *between-station transfers*; leaving a train at one station and transferring to another station a few hundred yards distant. Planned as a whole, the Washington, DC Metro caters for most possible journeys via its key transfer stations, and so there is no need for the map to indicate nearby stations that could be used for transfer purposes. The only possible exception to this is that a journey from, say, Shady Grove to Clarendon *might* be speeded by transferring from Farragut North to Farragut West, but the time advantage is likely to be small, and this example is probably a rarity.
- *The most appropriate station is clear for most suburban districts.* Many suburbs in London and New York are served by multiple lines at different stations, so that the user may need to be made aware that there are nearby alternatives. In Washington, DC, few suburbs have competing services, and so the map need not highlight these.

Overall, considering topographical fidelity, the designer of the Washington, DC map has more leeway than most USA networks. Gross distortions are to be avoided because these will be resisted by users, but there is little in the way of travel hints and suggestions that need to be communicated via spatial configurations on the map.

2. Prototype designs

Several prototypes have been developed and these are discussed in this section. An explanation of the different angle-rules that schematic maps may follow is given in Appendix B, where the nomenclature adopted is also explained more fully. For the prototypes: size, shape and font are matched to the current design. They have also been matched for basic supplementary information (parks, rivers and landmarks) but more detailed information, such as county boundaries, has not been included. This will be added at future stages of the design process. Design aspects such as line thickness, colors, and (uncontroversial) station and transfer symbols have also been matched so that the maps can be easily compared and evaluated. None of these prototypes should be regarded as a definitive final version. Ideally, a systematic, evidence-based methodology should be adopted, as described in Section 3.

Section 3 explains that the aim of the early design stages (1 to 3) is to create alternative maps and then identify from users the most favored of these. If too much supplementary information is included at this stage, it will be difficult for users to evaluate the basic designs. Subsequently, the most favored alternatives will be refined (Stages 4 and 5) and provision will be made on these to include further supplementary information. However, this will only be added at later stages (6 onwards) once the preferred network configuration is finalized. From here, alternatives for station and transfer symbols, etc., can also be investigated. Hence, in all studies at all stages, users can give their full attention to the key questions under investigation.

For all the prototypes, station names are unabbreviated and none interrupt lines. The Dulles Airport extension is included in full, and the possibility of a separate designation for the proposed service from Franconia-Springfield to Greenbelt is adopted. The prototypes are ordered step by step in increasing complexity of the angle-rules adopted.

2.1 Tetralinear Map: Two angles (horizontal/vertical) rotated by 30°

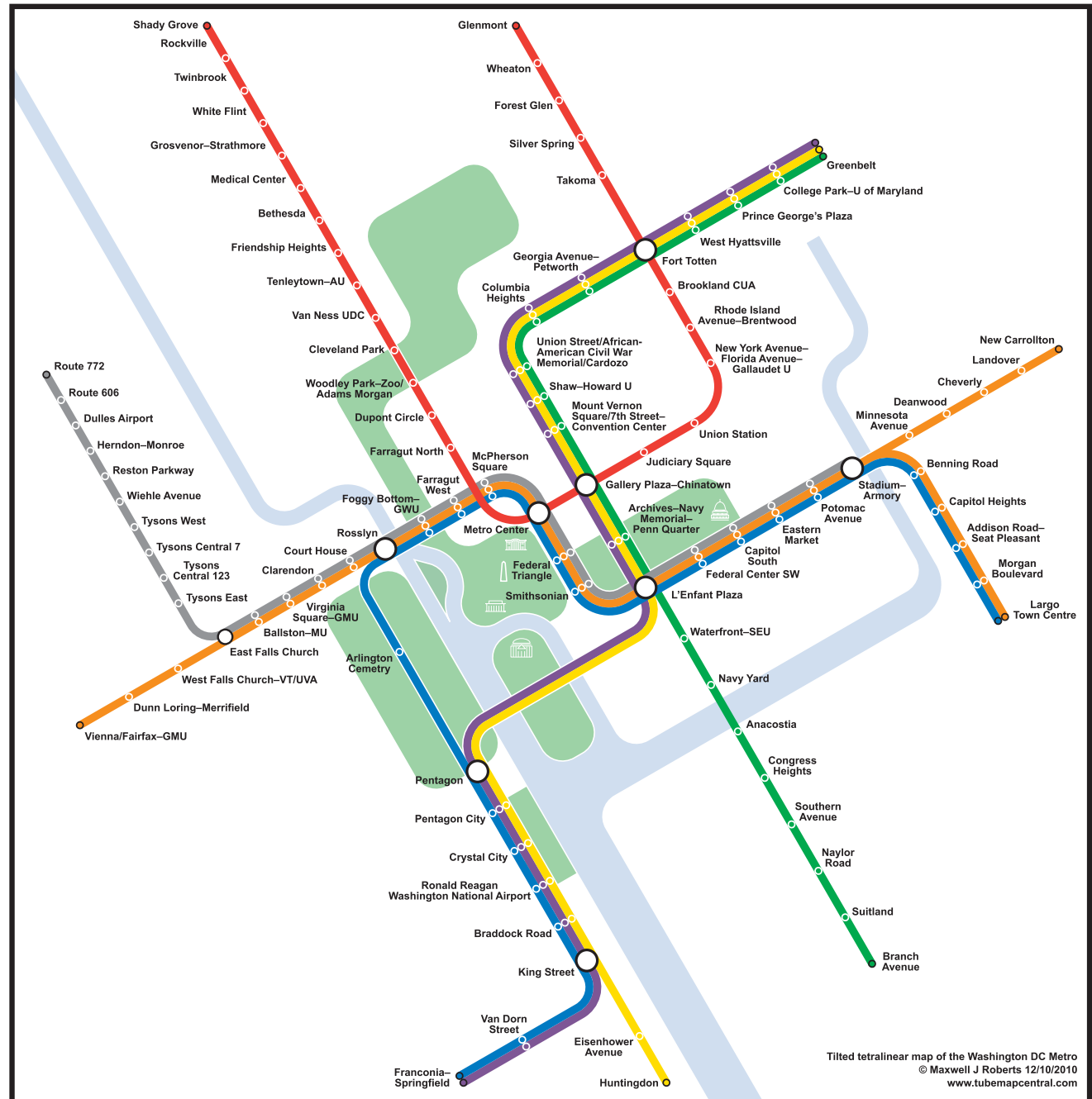
Tetralinear designs are too severe for general use, all too often resulting in many corners, considerable topographical distortion, or both. Occasionally, a rotated design can be visually striking. This is the case for the Washington, DC Metro, where a very distinctive creation is possible. This is the only prototype of the five where none of the station names is tilted.

Advantages

Clean, visually striking, good typography. Good trajectories for Red and Green Lines.

Disadvantages

Topographical distortion, users may resist such an abstract design. Corners are severe (90° turns).



2.2 Hexalinear Map: Three angles (horizontal, 60° left to right, and 60° right to left)

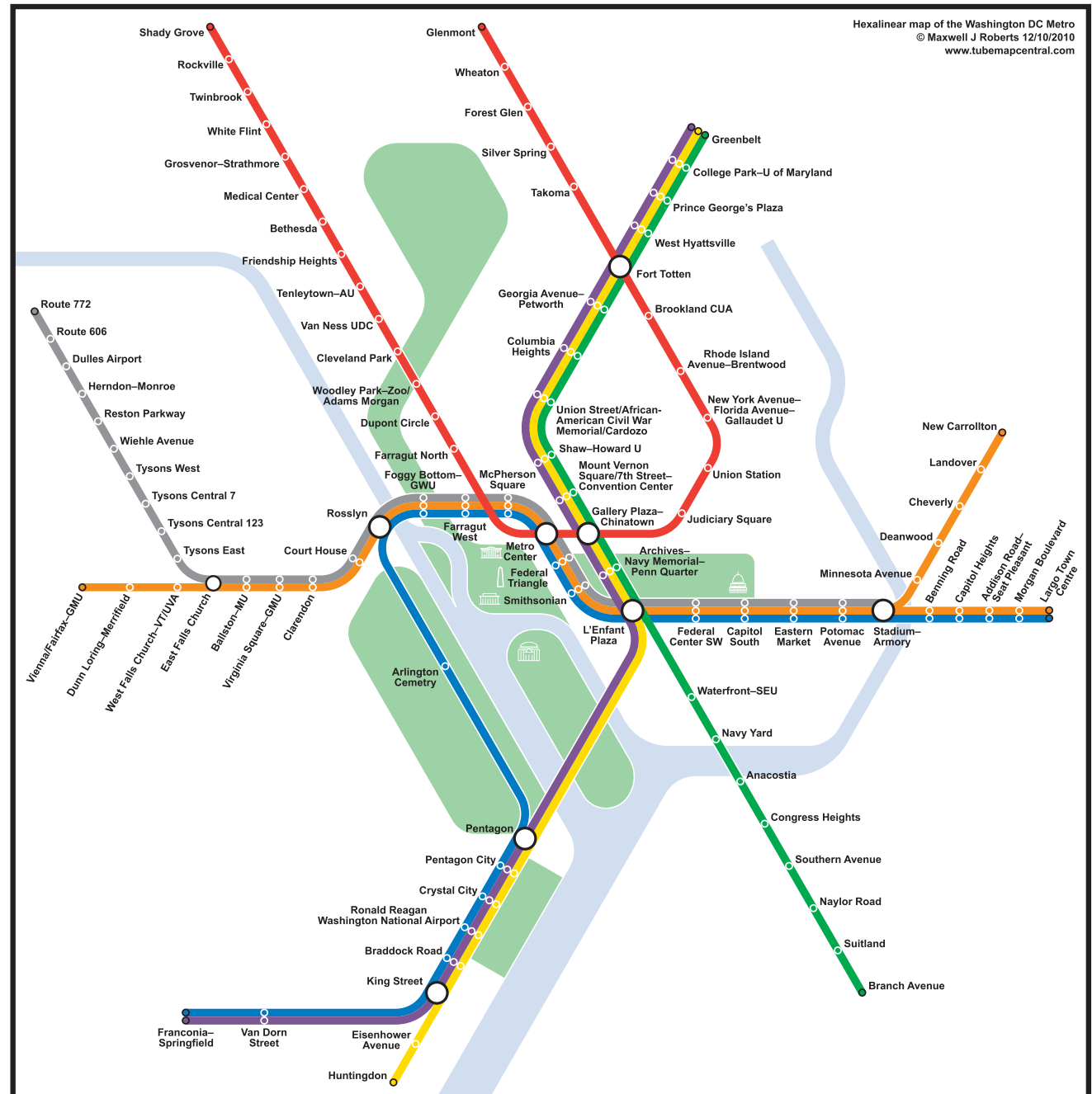
Hexalinear maps can look very dynamic when matched to the right network. For Washington, DC, the steep angle results in some difficulties in meeting the Blue and Yellow Lines, hence the 'hump' at Rosslyn. On the other hand, the lines fan into the suburbs in a satisfactory way, and the inherent compactness of 60° angles enables the Dulles airport extension to be shown cleanly.

Advantages

Lines fan cleanly into SE suburbs, Yellow/Purple/Green and Red Lines have excellent trajectories. Design is reasonably compact horizontally. Hexalinear angles unlikely to surprise or be resisted by users.

Disadvantages

Angles do not quite fit the W/SW part of the network.



2.3 Octolinear Map: Four angles (horizontal, vertical, and 45° diagonals x2)

The traditional angle-rule for a schematic map fits the Washington, DC Metro reasonably well, and considerable improvements are possible over the current official map in terms of geometry, particularly for the east-west lines. However, the Red Line fares less well, and the lack of compactness forces a bend in the Dulles Airport extension.

Advantages

Standard design technique, therefore likely to be widely accepted by users. East-west and Blue Lines have good trajectories. Low levels of topographical distortion.

Disadvantages

Extra corners required elsewhere,
little overall advantage over the
hexalinear map in this respect.
Dulles Airport extension suffers.



2.4 Higher-Order Linear Map: Based upon 22.5° increments, technically Hexadecalinear

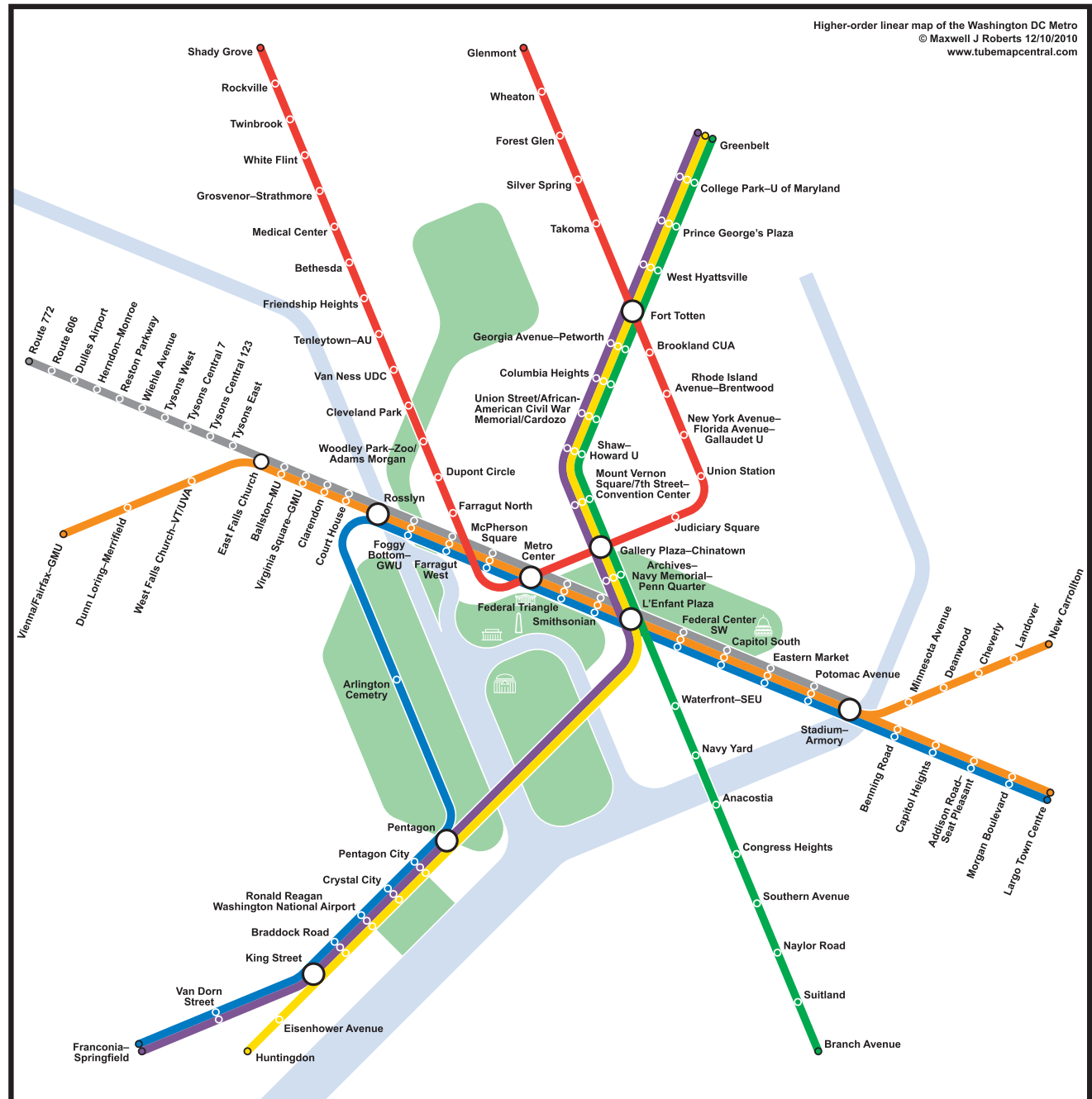
Higher-order linear maps are difficult to design and should only be attempted if there is a clear objective that may be achieved in doing so. Even so, results can be disorientating for users. In this case, the objective was to ‘force’ a perfectly straight route from Dulles Airport to the city center. The minimum tilt to permit this is around 22.5° (shallower angles result in difficulties placing central stations). Overall, the city is now slanted, which some users might object to, although the lines themselves have the best trajectories of the four prototypes so far.

Advantages

Fewest corners, new extension is on a straight line with clear publicity value.

Disadvantages

Unusual design might meet with resistance. Largest number of tilted station names of all prototypes, although these are arranged neatly.



2.5 Curvilinear Map: No straight lines permitted

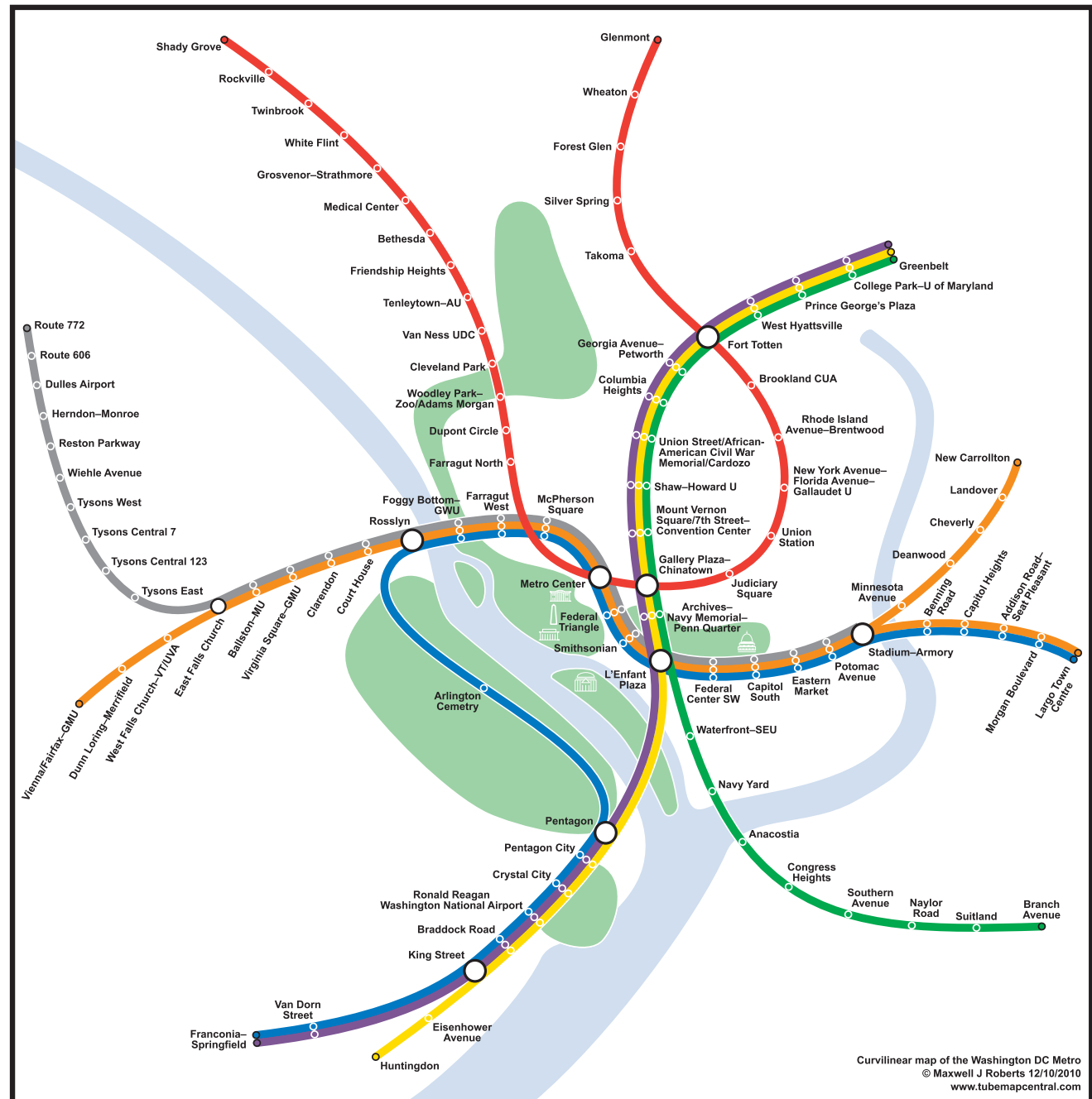
Curvilinear maps enable harsh corners to be smoothed away, replaced by gentle curves. Some users initially find this style unsettling, although many see an immediate appeal. In general, this type of design has the greatest advantage over traditional schematics for very complicated networks, but the Washington, DC Metro version demonstrates its potential well.

Advantages

Novel design. Corners smoothed away without excessive topographical distortion. Appeals to those users who find strict geometry harsh and intimidating.

Disadvantages

Many users (around 40–50% in the UK) prefer strict geometry, although this proportion will be greatest where the tradition of octilinear schematic designs is greatest, such as London.



3. Proposed methodology

As shown in Section 2, there are many different angle-rules that a designer can use to create a network schematic, each with advantages and disadvantages that vary by network. It is therefore important that the designer takes a systematic approach. Different angle-rules must be explored and used to devise prototypes. In the process of this, the designer can identify any points of difficulty, along with particular angle-rules that assist or exacerbate these.

User studies are also important, and cost-effective to conduct in relation to the entire design process. A number of these have been conducted at the University of Essex and London South Bank University in the UK (e.g., [3]). One major finding is that subjective ratings of designs (e.g., an estimation of how easily lines can be followed) have no relationship with objective usability measures (such as speed of planning a journey between two stations). Essentially, *map engagement* is entirely separate from *map usability*, so that an individual may dislike a map that he/she finds easy to use, or like a map that he/she finds difficult to use. Of course, a skilled designer will aim for an engaging, usable design, but it is important that user studies evaluate both aspects of behavior.

The overall plan is to design a map in stages, weed out the least liked prototypes, optimize the basic structure of the remainder, establish the most favored design and then determine fine details such as station/transfer symbols and supplementary information. The sequence of stages would be as follows.

3.1 Preliminary stages

The designer should survey the network if possible, and consult with users and management concerning the strengths and weaknesses of existing designs. Requirements such as font/font size, dimensions, colors, and priorities such as keeping certain lines straight but not others, should be established early if possible.

3.2 Rapid prototyping

A range of prototypes following different angle-rules should be produced. These will be intended to be well-optimized designs, but subject to future refinement. At least four should be created: traditional octolinear, curvilinear, and two others based upon those angle-rules that match the particular network well.

3.3 Preference studies

In order to narrow down the options, users will be asked to rank-order designs for preference, and describe the perceived strengths and weaknesses for each. To assess the wider impact of different designs, ideally at least three groups of users should be consulted: (a) City experts, (b) Transit experts who are not familiar with the particular city, and (c) transit/city novices.

3.4 Refinement

On the basis of user ratings, no more than the two most favored designs should be selected for further optimization. Different options can be explored, and final network configurations will be aimed for. If any prerequisites concerning supplementary information, etc., are known, the designs should be made ready to accommodate these, although they would not be displayed on the test designs until 3.6.

3.5 User testing

Usability studies should be conducted on different groups to ensure that the refined designs are usable and have no pitfalls (modifications are possible in the light of this). Assuming that they are evenly matched for usability, further preference studies will determine the most favored design.

3.6 Embellishment

Once the basic network configuration is finalized for the most favored option, further choices need to be made concerning station/transfer symbols and supplementary information. If necessary, these can be evaluated via further preference studies (which are straightforward to conduct).

3.7 Adoption of final design

Consultation with users and management at all stages, along with a systematic evidence-based approach, should ensure the widespread acceptance of the new design by the general public and the media.

4. Conclusions

A series of prototypes has been created, intended to optimize the line trajectories on the Washington, DC Metro schematic, and therefore usability and appearance. Each is intended to be possible candidate for the basis of a future official map, and to demonstrate the level of improvement that is possible. Ideally, the next step is to evaluate user preferences. An evidence-based, consultative, iterative methodology is proposed. By developing the favored designs in this way, continuing to engage users throughout the design process via journey planning, preference, and subjective evaluation studies, a distinctive, attractive usable design will result. This will gain widespread acceptance soon after introduction.

APPENDIX A: Good design for schematic maps

Since the 1930s, transport undertakings around the world have been displaying their networks by using simplified diagrammatic depictions. Such *schematic maps* are intended to enable people to plan journeys without having to contend with irrelevant distractions. They are also important publicity devices, encouraging system usage. To attract people for whom travel is optional, it is important that schematic maps communicate the overall impression that a journey will be simple, effortless and rapid. The difference between a good and a bad design will contribute a great deal to first impressions formed by the potential user.

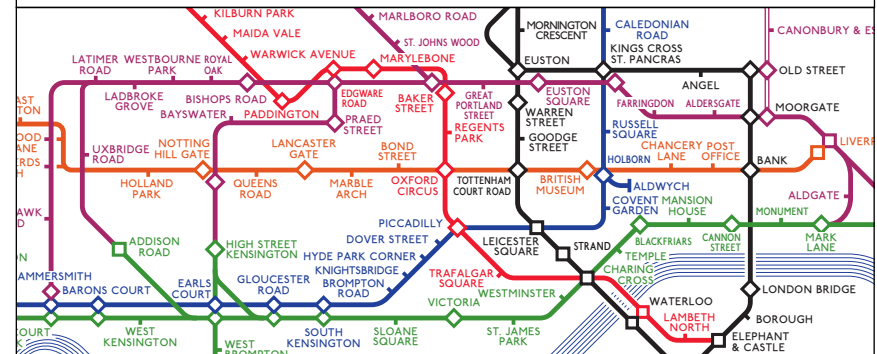
Simplification

A precise definition of a schematic map is difficult to identify, but a browse through a selection of network maps [1] will reveal some clear patterns across the world. Many undertakings use a *topographical map*. This might simplify reality to some degree, for example by omitting all but the most important landmarks, but the locations of stations, and sometimes even the trajectories of the lines themselves will mimic reality as much as is possible on a scale drawing. The problem with such maps is that the complex twisting of lines adds information that is irrelevant to journey planning (*what is the best way to get from Station A to Station B?*) and can mask the overall structure of the network, so that the underlying routes of the lines are harder to identify and learn.

The alternative to a topographical map, a *schematic map* seeks to simplify reality further by converting the complex trajectories of routes into simple straight lines. Similar to the design used by the London Underground for over 75 years, corners are tightly radiused, and a limited number of angles is permitted, almost always horizontal/vertical lines along with diagonals at 45° (this particular combination of angles, or *angle-rule* is known as *octolinear*, see Appendix B). There the similarity ends, and there is a bewildering variety of techniques for grouping services and showing stations, transfers, and other information [1]. However, the basic octolinear straight-line technique for showing the routes of the network remains dominant.



Above: Topographical map of the London Underground in the style issued before 1933. Below: The schematic map of the London Underground designed by Henry Beck (1933) simplifies the trajectories taken by the lines, making the routes easier to follow and the underlying structure of the network easier to identify and learn.



Design rules versus design objectives

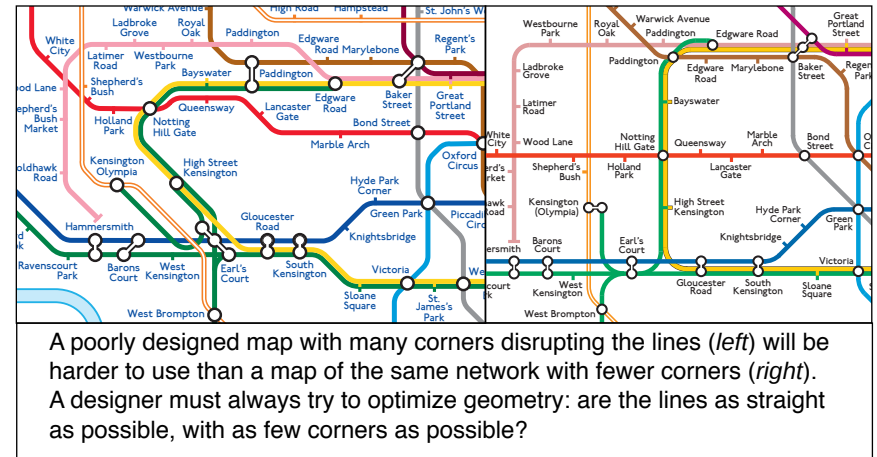
A schematic map can assist the user if the complexities of reality are genuinely simplified. This is important because there is a misconception amongst graphic designers that *octolinear* by itself constitutes some sort of cartographical gold standard, such that maps designed using this angle-rule will automatically be easy-to-use, and that maps that fail to use this will inevitably have a usability disadvantage. This belief is easy to refute both theoretically and empirically. If we consider that the goal of the designer is simplicity, then bad implementation will turn the meandering curves of reality into zigzagging corners on a map. Reality has not been simplified,

instead the shape of the complexity has merely been changed, and the underlying structure of the network is buried just as much as before. In usability studies, maps of the same network with more corners tend to be harder to use than maps with fewer corners [2,3].

We need to make the distinction between *the angle-rule* chosen to depict a network, and *the quality of implementation* using a given angle-rule. With skill, a reasonably effective design is likely irrespective of angle-rule, but without skill, an unusable design is all too likely. Fundamentally, we do not have rules for arbitrary reasons, rules exist so that objectives may be attained. The *objective* in producing a transport schematic is an attractive, simple, engaging, usable design that encourages people to travel and enables them to plan quickly without making mistakes. Adopting the traditional octolinear angle-rule provides a tool by which this objective may be reached, but if the tool is used inappropriately then the designer will fail to attain the objective. Conversely, given the objective of an effective map, there may be other tools available to enable this to be met. As shown in Appendix B, octolinear is just one of many possible angle-rules, and different angle-rules are suited to different networks.

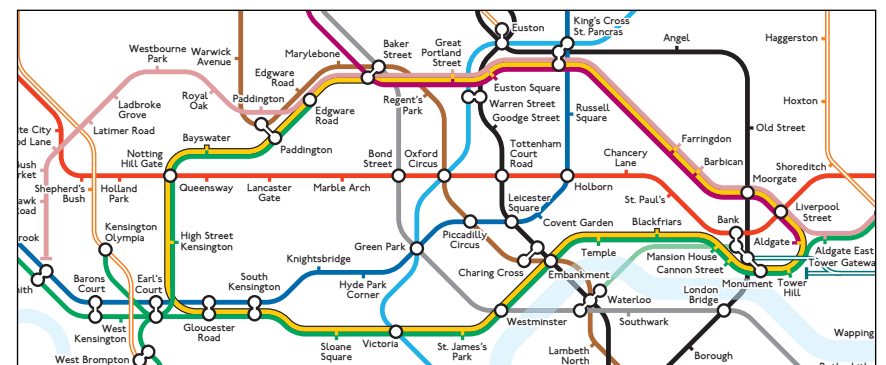
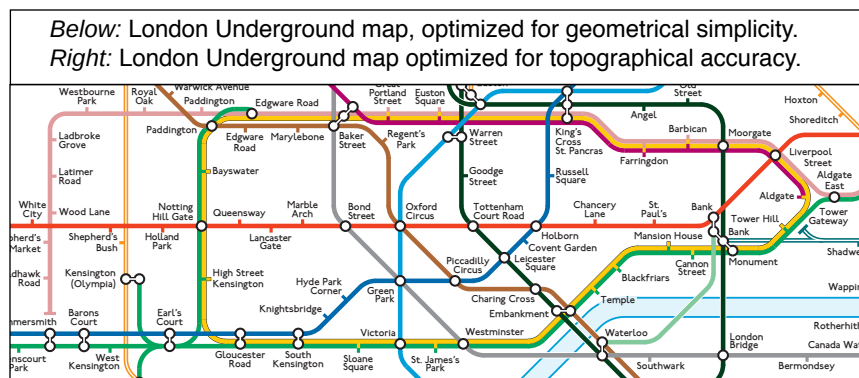
Preservation of topography

The goal of a designer is to optimize the geometry of a map by converting the complexities of reality into simple straight lines. However, in opposition to this is the perceived, or real need to limit topographical distortion. Optimizing the two can be a very difficult



balancing act, and it is worth considering whether topographical information on a journey planner does serve a useful purpose.

- *Identification of start or destination stations.* Technically, the purpose of a journey-planner is to assist the user who *already* knows the start and destination stations. Typically, tourist attractions and other important destinations in most cities will advertise their most convenient stations in their publicity. Users familiar with their locale will know their choice of starting stations. For people who do not know either of these, and who do not possess a scale streetmap, it is unlikely that a schematic map can assist. Identifying key stations by their position on a relatively small-scale schematic that is bereft of



street and other details is a skill that could only be displayed by a user with considerable city expertise.

- *Identification of alternative stations.* At times of service disruption, topographical information on a schematic might be useful for identifying a nearby alternative station that could be used instead, although announcements, signs and neighborhood maps may fulfill this function more effectively.
- *Disambiguation of similarly-named stations.* Where networks name stations after intersecting streets, topographical information on a schematic provides a way of disambiguating them. For example, with five subway stations named *23rd Street* in Manhattan, an accurate topographical map might help the user to identify the target station. The Chicago El is another example, with four stations named *Pulaski*.
- *Identifying and locating between-station transfers.* For older networks, originally constructed or operated by competing companies, potential transfers between rivals were given little consideration. In many cities, London included, certain journeys may be completed faster by leaving a train at one station, and walking a few hundred yards to another station for a new train. Some of these transfers now have official status, and are recommended on the London Underground map. The introduction of electronic ticketing has led to others that are not officially recommended. Even so, novice users may be reluctant to venture into unknown neighborhoods, and without clear signposting, they may have difficulty locating even recommended between-station transfers.
- *Minimizing conflict with users' mental models of the city.* Some users have very low levels of distortion-tolerance: any topographical disruption will lead to complaints, although it is not clear that this will damage their journey planning. Indeed, the people who tend to complain the most are users who are the most expert, and therefore have least need of topographical maps. Novice users are unlikely to notice even quite high levels of distortion, especially in suburbs.

The above points indicate that topographical information, even on a schematic map, may be of some use, although its importance is probably overstated. If such information is to guide the configuration of a map, it is important that it is consistently applied. This is because, from the point of view of a novice user, in the absence of further information, it is impossible to know which configurations on a map constitute travel hints, and which are unintended byproducts of the schematization process. Even where topography is impeccably accurate, such information is not always usable. For example, consider one station that is exactly north of another by a few blocks. This information can only be used for navigation if the direction that the station exit is facing is known, otherwise, a compass will be required.

Overall, although schematic maps can be configured to show topographical information precisely, this can be at the expense of an attractive usable diagram and, in any case, it is not clear that the user will be able to take advantage of such information without a scale streetmap for additional guidance. In which case the streetmap should be consulted for full guidance rather than the schematic. From the point of view of the designer, the best strategy is to optimize geometry on the schematic as much as possible, taking advantage of topographical distortion in order to do so, but not distorting reality to the point at which typical users are taken out of their comfort zones. Certainly, it is necessary to avoid conveying any information that could be misleading if taken literally by a user.

Conclusions

Blind adherence to traditional design rules is unlikely to lead to a usable map. The designer must take care to optimize its geometry, ensuring that reality has genuinely been simplified. The aim is to take the complex line trajectories, and convert them, where possible, into memorable, easy to follow straight lines. Changes of direction – corners – should be minimized: nothing will be gained if complex twisting curves are converted into complex twisting zigzags. In the process of optimizing geometry, some topographical distortion is inevitable. Although complaints about topographical distortion are probably overstated, the designer must have some sensitivity of the issues so as not to go beyond people's comfort zones.

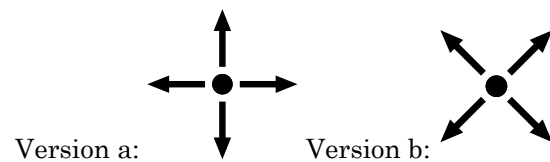
Appendix B: Taxonomy of schematic angle-rules

There are many ways in which to design a schematic map. The traditional way, an *octolinear* map, with four possible angles (horizontal, vertical, 45° left to right, 45° right to left) is just one of a family of *angle-rules* that could be adopted, and have been adopted round the world by various transport undertakings. What is notable is that different networks have different structures, and that these are suited to different angle-rules [2,3].

The basic categories are outlined in this section, along with brief notes on their advantages and disadvantages. It is difficult to know in advance which angle-rules will suit which networks because this research is still in its infancy. Only the simplest cases are named, but this list provides a useful starting point for any designer, irrespective of network.

This analysis has recent origins and, unfortunately, looks set to inherit mathematical terminology. The angle combinations available for a particular map are categorized by their *linearity*. Imagine a design that will have just vertical and horizontal lines (two angles). With a blank sheet, the designer has a choice of *four* directions in which to draw a line (up/down/left/right). Hence, a *two-angle* map is *tetralinear*. The traditional schematic angle-rule (horizontal/vertical lines and 45° diagonals) gives the designer a choice of eight different directions, hence the map is *four-angle* or *octolinear*, and so on.

B.1 Tetralinear/Two angles



Advantages

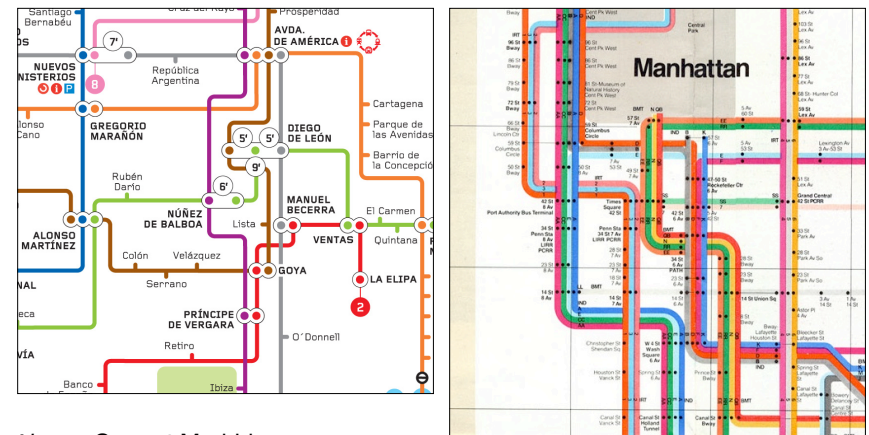
Relatively compact

Disadvantages

Can lead to excessive topographical distortion, or many corners, sometimes both.

Examples

The current Madrid Metro map. Many designers seek to use as few diagonals as possible. For example, in the 1970s the Vignelli New York Subway map was effectively tetralinear in Manhattan.



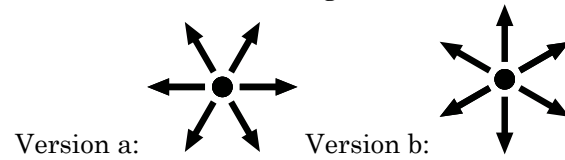
Above: Current Madrid
Above right: New York, 1972

Comment

Too severe for most cities, both of the above maps are controversial, and the Madrid map demonstrates the difficulty in configuring transfers with this type of design. However, a *rotated* tetralinear map can be very striking, and is essentially the design used by Montreal (right).



B.2 Hexalinear/Three angles



Advantages

Fits many networks surprisingly well. Version (a) is inherently compact horizontally. 60° angles can give a dynamic appearance to a map.

Disadvantages

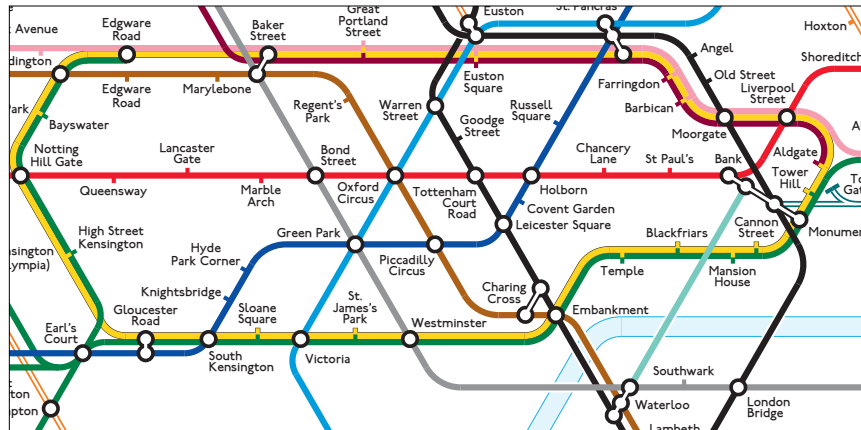
More restrictive than octolinear, the designer must abandon *either* horizontal *or* vertical lines.

Examples

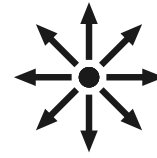
None currently in use.

Comment

A very subtle style, unlikely to conflict with users' expectations regarding map design. For some networks, such as the London Underground, it can result in pleasing geometric effects such as equilateral triangles (below).



B.3 Octolinear/Four angles



Advantages

Ostensibly a design gold standard. Well-known and well-understood by designers worldwide. Versatile and flexible. Computer software presets make this easy to implement.

Disadvantages

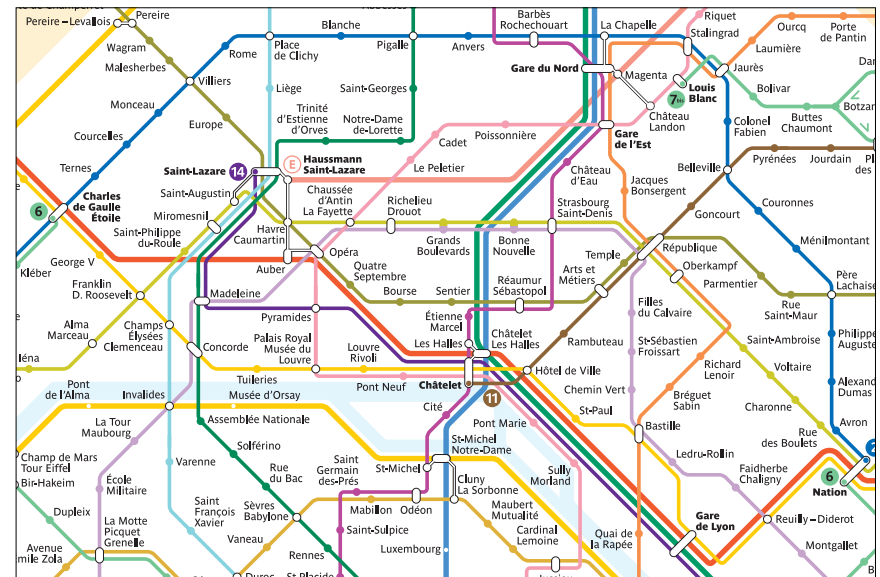
Frequently abused by careless designers. 45° diagonals are inherently wasteful of space.

Examples

Approximately 1/3 to 1/2 of world urban rail maps are octolinear [1].

Comment

The first choice for many designers, but often misunderstood. The Paris Metro (below) is a good example where the complexity of the network means that an octolinear map is hard-pressed to offer any benefits over a topographical map, Tokyo is another.



B.4 Higher-Order Linearity (e.g. five angles: decalinear; six angles: dodecalinear, etc.)

Advantages

A skilled designer can reduce the number of corners on a map *without* sacrificing topographical accuracy. Best suited for very complicated networks or strongly radial networks.

Disadvantages

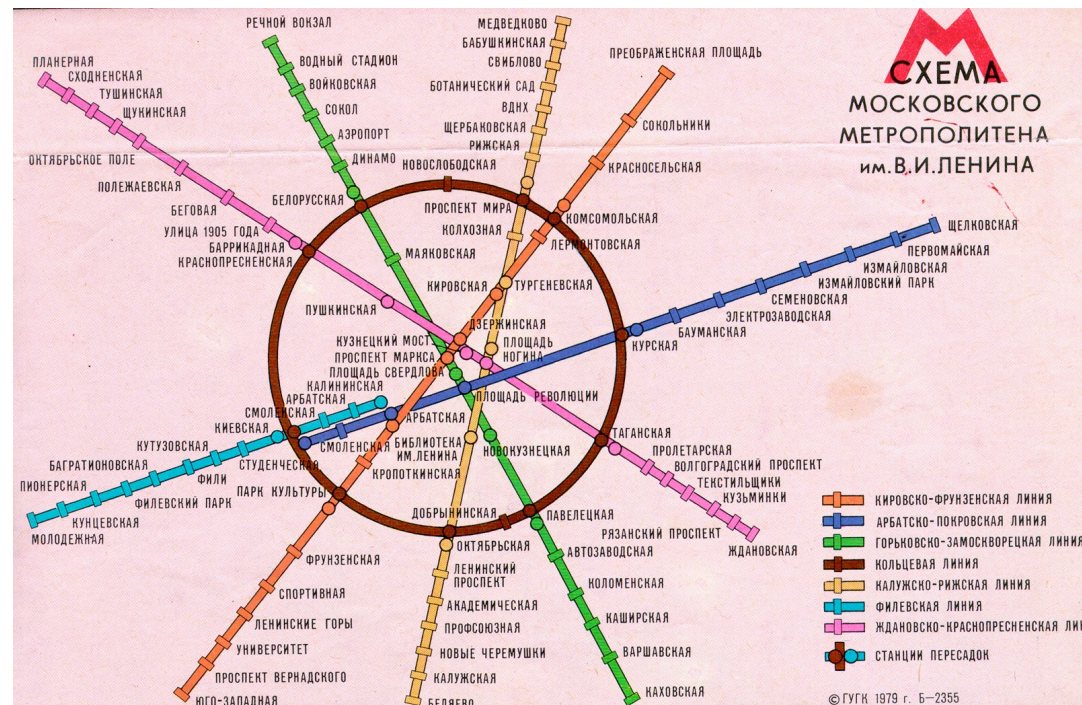
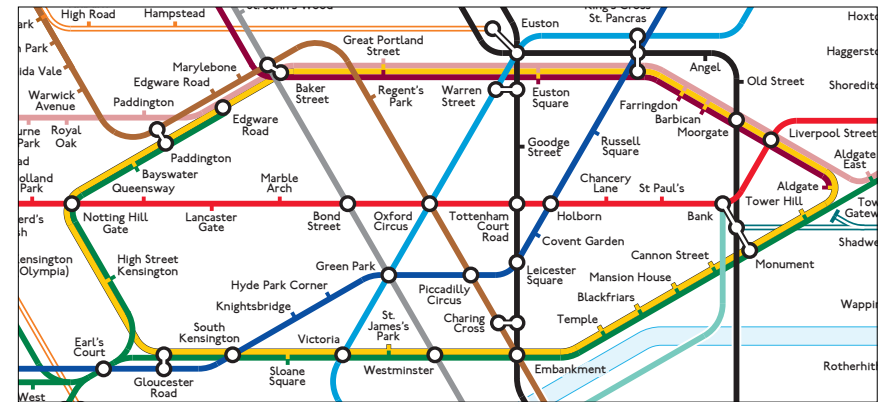
Very difficult to implement well, needs practice. Poor designs can lack visual coherence. Users may resist. Very poor designs can shock.

Examples

Famously used to good effect on Moscow Metro maps in the 1970s (below). Has been tried from time to time in Paris.

Comment

Should only be attempted by a designer who has clear objectives that cannot be satisfied by using lower linearity. For example, considerably reduced numbers of corners in Central London are possible (below).



B.5 Curvilinear (No straight lines permitted)

Advantages

Can tame the most complex networks where the only alternative is a maze of zigzags. Excessive topographical distortion can be avoided. For around 40% of users, a well-implemented design is flowing, organic and engaging.

Disadvantages

Open to abuse by poor designers. Needs care to implement well and there are no established aesthetic standards. Resisted by those users who prefer regular geometry.

Examples

Not currently adopted, but designs have been produced with significant usability benefits compared with official maps in Madrid and Paris (right) [2,3].

Comment

Although this style shows the most benefits for complex networks, pleasing designs can result for simple ones too. The intention of the designer should be to replace the zigzags on a conventional map with almost-imperceptible changes in curvature as the eye follows the lines.



Key bibliography

[1] Ovenden, M. (2007). Transit maps of the world. New York: Penguin.

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[4] Schrag, Z. M. (2006). The great society subway. A history of the Washington Metro. Baltimore: Johns Hopkins University Press.