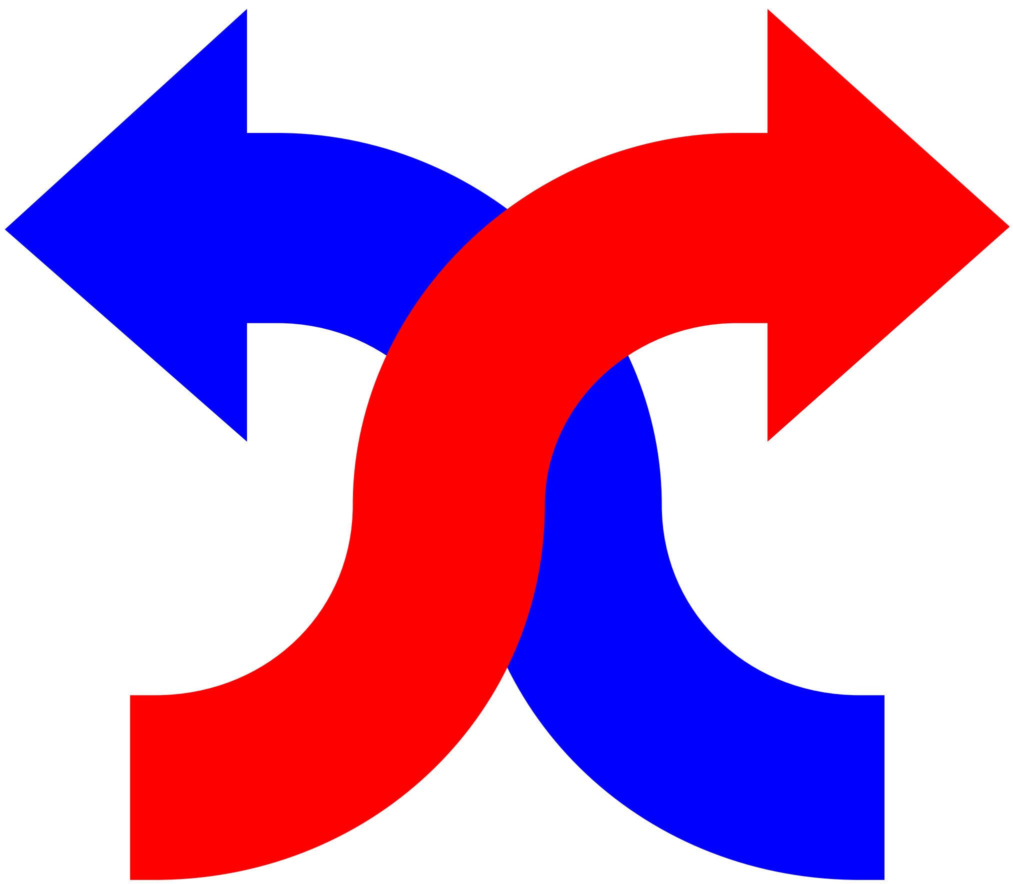
Just Not Thinking Straight

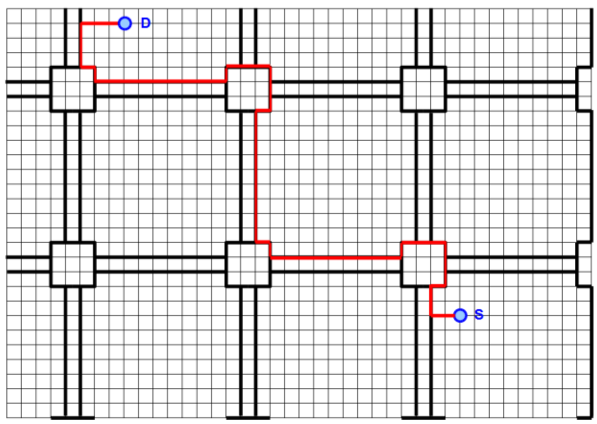
Diagonal Routing to Avoid Stops



Stephen Hamilton | CityTram.org | January 31, 2017

Introduction

In a previous paper (Avoiding Gridlock (Hamilton, 2015)) this author proposed how an existing city road grid implementing a feeder arrangement with trunk roads, could be re-worked to implement large diameter rotary trunk intersections. This would eliminate all traffic light based flow control from the trunk roads, thus providing "continuous motion" corridors through the city on surface streets. Such an arrangement separates the city into "islands" surrounded by free flowing trunk roads. Street intersections within these islands can still be controlled by traffic lights or street signs. But the congestion generating power of street lights is so severe, especially in tightly packed downtown neighborhoods with lots of pedestrian traffic and cargo vehicles transiently blocking lanes, that there is some risk of lights within these islands creating traffic jams that back up to intersections with trunk roads.



This paper presents another alternative for managing traffic within these islands. In this alternative traffic lights are not used for coordinating intersections. Instead, contention for roadway at intersections is completely eliminated by simply blocking some paths through the intersections and re-routing traffic following those paths. Traffic lights are then moved and re-introduced for the sole purpose of controlling sharing between cars and pedestrians. The result is a pattern which is easy to synchronize for the benefit of both cars and pedestrians.

Straight Lines and a Compass

As some cities evolved they were strongly influenced by some dominant geographical feature, such as a river on whose banks it grew, or a mountain on whose foothills it grew. In those cases it is likely that many roads are curvy and wandering. But most American cities were not so dominated. In those cities, at some point a commercial or municipal organization took over and "organized" the streets into an "efficient" collection of largely straight parallel roadways. Now "ancient man" would have been aware enough of the sun to have aligned this grid according to the latitude of the city (maximally aligned to the seasonal wanderings of the sun). But "modern and technological western man" was not so aware nor concerned. So they aligned the roads for legal purposes. By aligning to the compass they made surveying easier, which made management of property rights easier.

So this is what we have today. Cities generally have grids produced by intersections of 2 sets of parallel streets at right angles. And most often the 2 sets are aligned to the compass – one with streets running north-south, and one with streets running east-west.   Since most travel within a city is not strictly in the north, south, east, or west directions, but is rather a combination of some of these, we are accustomed to travelling the extra "manhattan" distance (traversing a diagonal as the sum of the two sides).

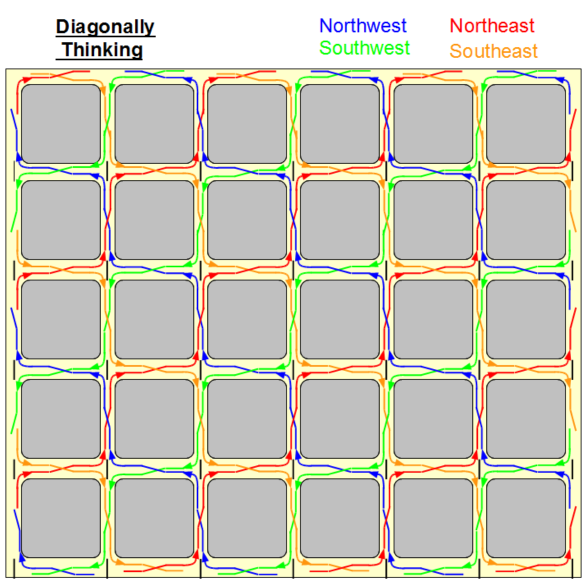
This "manhattan thinking" brings with it the un-avoidable challenge of managing the intersections where these two sets of streets cross.   As explained in the previous paper, sharing the intersection in time – through time-multiplexing – is the American solution, and this is the function of traffic lights. But as also explained in the previous paper, this solution is in-efficient and in-flexible.

Is there a better one ?

Think Manhattan Diagonally

All we have to do to find another answer is to stop thinking in terms of straight lines (between points) that are aligned to the compass. Straight lines that are not aligned to the compass are equally as valid and efficient. So rather than thinking of traffic as running north-south, it could just as well run northeast-southwest.   There would still be a manhattan distance penalty to be paid for non-aligned trips. The only difference is these would be paid for trips that were "on compass" rather than for trips that were "off compass".

Of course, for existing cities with compass aligned grids, diagonal travel would have to be implemented as an "around the block" trip – travel to the northeast would mean 1 block north, then 1 block east. But this provides an interesting opportunity. Since the 2 dimensions that must cross – northeast and southeast – must both be split serially into components, there is the opportunity to match and synchronize those components. A "1 block east" component could be part of a northeast bound path, or a southeast bound path. So those 2 orthogonal paths never need to cross each other in opposition. They cross during the common 1 block component – a merge then split "swap".



Note that we have implemented a 2D orthogonal diagonal grid, where each dimension is a set of interleaved one directional parallel paths. We have implemented it on a 2D orthogonal compass aligned grid. All streets in the compass aligned grid are one-way. All one-way streets have a length of only 1 block. All traffic splits left and right at the end of every block. There is no through traffic at any intersection. Every block starts with a merge.

It is possible to start at any point in this grid, and drive to any other point in the grid, without stopping, and without your path being orthogonally crossed. So there is **no need for street lights to coordinate traffic among cars !** Every street around every block can be accessed from any direction. This is a VERY efficient way to keep cars moving through a dense grid.

This scheme does come with a route distance penalty. Diagonal trips are exactly the same length as in the compass aligned grid – the manhattan distance. But compass aligned trips of point to point distance L are converted into 2 diagonal trips of distance L/2, with the manhattan distance for each of those diagonals being L. So the total travel distance is 2*L, a 100% penalty. For example, suppose you are travelling 4 blocks straight east. This would be done by going 2 blocks northeast, then 2 blocks southeast. Each of those diagonals would cover 2 blocks east and 2 blocks north or south. So a total of 8 blocks would be covered for the 4 block point to point trip.

The duty cycle for traffic lights in a normal compass aligned grid will be less than 50%. So for the same travel velocity, the 2*L trip without stopping will require less travel time than the L trip with stops. So commute times are shortened, and since starts and stops are eliminated, fuel economy is improved and air pollution is reduced.

Pedestrian Protection

Since cars travel without stopping through this network, and since the drivers are focused on merging on every block, pedestrian crossings would be dangerous and difficult. One option is to build grade separated pedestrian crossings on every block. But this option may be too expensive and/or aesthetically un-appealing. Since this network is intended for those islands between trunk roads, a more appropriate answer might be to compromise a bit on the car dominance.

Re-introducing street lights is a way to safely support road sharing between cars and pedestrians. Because the lights are solely for pedestrian crossing, they should be less disruptive to the flow of cars than car-vs-car sharing lights are. For most of the day there is only occasional demand for pedestrian crossing. During peak periods – morning work start, evening work end, and lunch time – the sharing must be managed.

Strict synchronization of all lights should be maintained. A sharing cycle is enforced at single "anchor" light. Cycles at all other lights are slaved to the anchor, and phase offset in time to compensate for car travel from the anchor point. It is as if the anchor point emits a wave which radiates in all directions out from that anchor point. In that way it should be true that once a car is stopped by one light and then the green light allows it to proceed, that car should encounter a large number of subsequent lights in the green condition. Thus cars attempting to traverse the neighborhood should encounter a minimum delay due to red light periods.

All pedestrian crossing lights are “demand enabled” rather than “demand driven”. That is they never turn red unless there is pedestrian demand, and they do not turn red immediately upon registering that demand, but rather wait until the proper point in the cycle and then turn red. This will cause some pedestrian delay for a safe crossing. However, as long as the cycle period is relatively short, this delay will be acceptable.

There is roughly a 10:1 ratio between car and pedestrian velocities. Cars in this environment may proceed at approximately 30 mph, while a reasonable walking velocity is about 3 mph. A typical city street density is 12 per mile. So a city block is approximately 440 ft. Thus a car will travel 1 block in around 10 seconds, while a pedestrian will require about 100 seconds for the same distance.

Allowing approximately 20 seconds for pedestrian crossing yields a light cycle time of about 110 seconds. The worst case first crossing delay for a randomly arriving pedestrian will be 90 (110 – 20) seconds. The typical first delay will be 45 seconds (90/2).

But this long delay will only be encountered for the first crossing. A typical pedestrian will cross in about 10 seconds, spend 100 seconds walking to the light at the next block, register his request at the next light, wait 10 seconds, and then continue. So car traffic interferes only minimally with a multi-block walk.

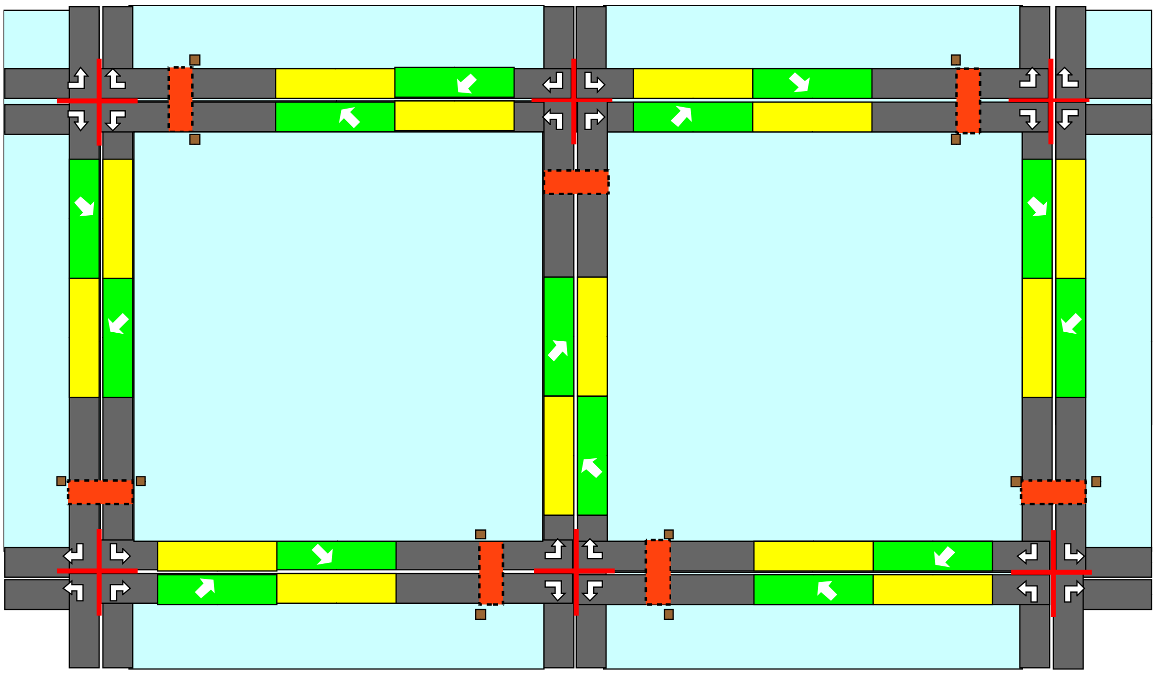
Meanwhile, a stopped car waiting for that pedestrian, when the light turns green (at 20/110 in the anchor cycle) can proceed taking about 10/110 cycles per block, but gaining about 10/110 cycles per block due to the phase shift. So the car should be able to travel nearly indefinitely without being stopped a second time by a red light. Effectively the car’s duty cycle at shared points (pedestrian lights) is 100 % (after the first probabilistic delay).

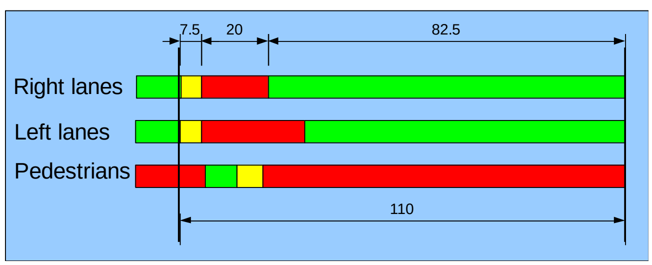
Restricting the purpose of traffic lights solely to car-vs-pedestrian sharing greatly simplifies things. It makes effective synchronization of the light system not only simple, but also very effective, and very inexpensive.

Since cars will be turning at each corner, visibility of pedestrians will be poorest there. It is safest to move the location of street lights away from the corner and more toward mid-block. Shortly after turning onto the street cars will be merging with cars coming from the opposing direction, and may be swapping lanes to prepare for the next corner. So early in the block drivers eyes and attention will be focused on other cars. It is safest not to introduce pedestrians at this point. So placing the pedestrian crossings later in the block (in the final third or quarter), but prior to the end of the block (where drivers may make last minute panicked corrections) is safest.

It likely would also be useful for the green lights for left and right lanes to be staggered just slightly. This would facility easier merging on the next block just after the corner. Street painting is used to promote merging to the left first (since cars already on the left will have best visibility of cars in front, and this clears the way for the more blind merge to the right).

The figures below depict this arrangement.





Conclusion

It has been shown how an existing city neighborhood – especially an inner urban core neighborhood – with a gridded street system where traffic flow is governed by street lights can be converted. The converted system has safer all one-way streets; provides for safe and less intrusive sharing between cars and pedestrians; results in shorter car travel times; has flow (both cars and pedestrians) that is far more resilient against demand loading; and is simpler and cheaper to regulate.

This treatment can be applied to any gridded system. But it is well suited to support the "islands" created by the ground level urban throughways created via large radius rotaries (as described in "Avoiding Gridlock).

About the Author

Stephen Hamilton is a newly retired individual who just concluded a 40 year career as a computer and integrated circuit designer. He has had a lifelong interest in physics, cars, and transit technology in general. Believing that climate change is a species threatening reality, and that governments have failed to face it, he has decided to spend his remaining time and talents trying to use commerce to impact it. Stephen has decided that personal travel in America is the area where his impact can be greatest. He has spent the past 36 months studying this area, and thinking about its challenges and possible/likely solutions. CityTram.org was created to encapsulate these efforts.