# Strategies to Re-capture Lost Arterial Traffic Carrying Capacities

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Over the years, many arterials that were initially designed to carry tens of thousands of vehicles per day can no longer efficiently carry the desired traffic during the peak hours due to many constraints that curtail arterial traffic carrying capacities. These constraints, or arterial bottlenecks, result from many seemingly innocent enhancements, such as additional traffic signal phases and the installation of new closely spaced traffic signals that were added to provide access to new retail developments.

This article explores in detail strategies that can be employed to increase arterial traffic carrying capacities. Potential challenges along with strategies to overcome them are included. Some of these strategies include:

- Use of Traffic Signal Coordination to Increase Traffic Carrying Capacities
- Traffic Signal Phasing Modifications
- Removal of Split Phasing
- Use of Shared Pedestrian Crossing Time at Split Phased Traffic Signals
- Use of Protected/Permissive Left-Turn Signal Phasing
- Use of Lead-Lag Left-Turn Phasing
- Need for Lengthening of Turn Pockets
- Local Intersection Widening
- Use of Narrow Lanes to Reduce Need for Additional Right-of-Ways
- Understand Impacts Due to Inadequate Left-turn Lanes and Vehicle Queue Storage
- Understand Impacts Due to Outdated Traffic Signal Timing
- Continuous Monitoring of Signal Systems to Effectively Realize Arterial Capacity Gains

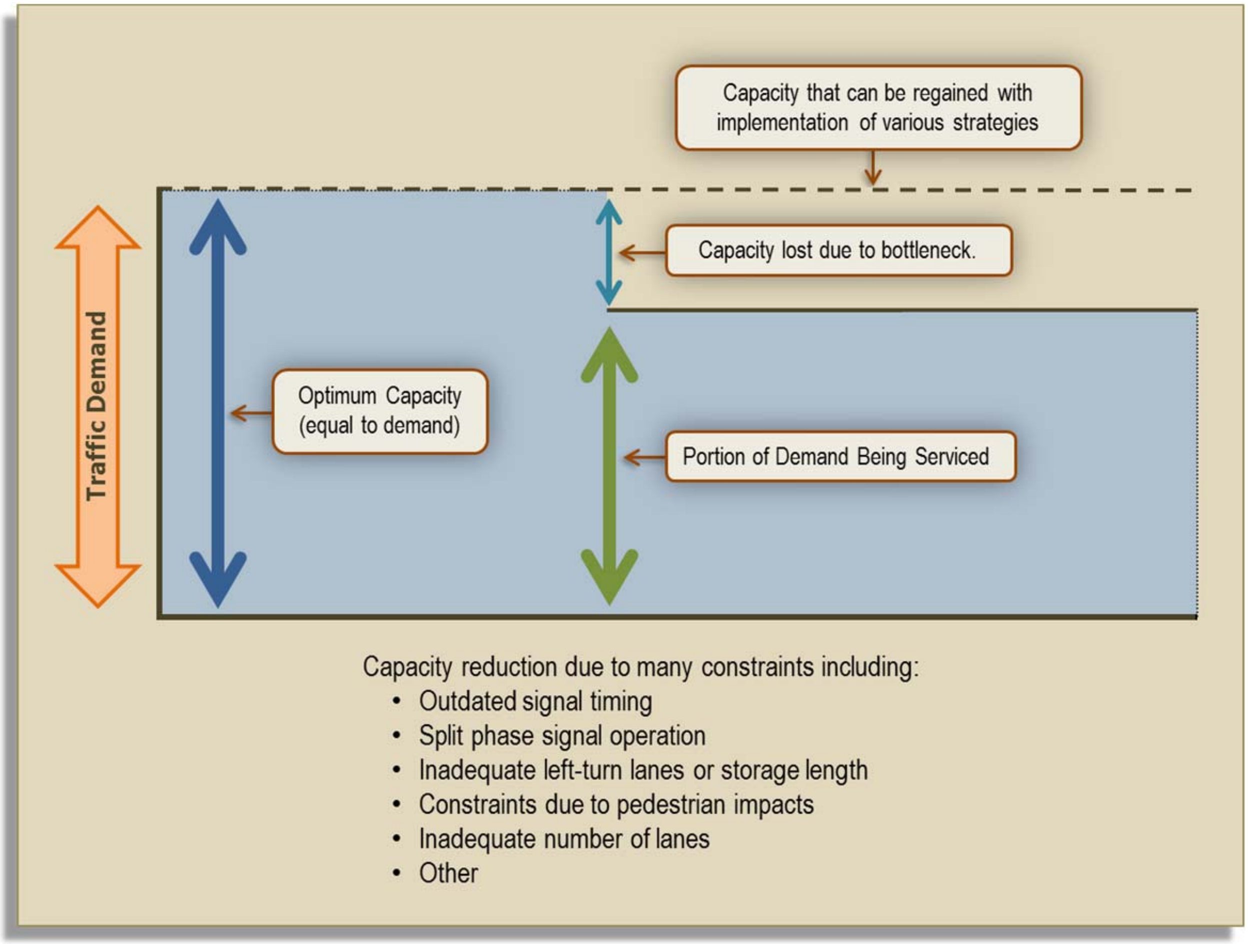
The capacity of an arterial is often defined by the number of lanes in the mid-block section of the roadway. However, in urban areas, the arterial capacity cannot be defined by this criterion alone. In urbanized areas, the arterials are faced with many signalized intersections and crossing arterials with heavy turning volumes. The capacity of arterials in these settings is dependent on the amount of green time that can be allocated to the thru movements at the signalized intersections. The throughput capacity of a travel lane is given by multiplying the saturation flow rate, typically at 1900 vehicles per hour per lane, with the ratio of effective green time (phase split time minus the lost time) and the cycle length. In essence, the throughput capacity is a direct function of green time. The capacity of a certain movement, say the thru movement, can be increased either by increasing the number of lanes, or by increasing the amount of green time or by a combination of both. Likewise, the capacity of the same thru movement may be reduced by providing less green time as would occur with the addition of new left-turn phasing or if the conflicting movements demand more time, be it for cross street traffic volumes, bikes or pedestrians. The capacity of the arterial is also reduced due to ineffective traffic signal system equipment, outdated signal timing or non-coordination of traffic signals.

- ♦ Traffic operational bottlenecks, obsolete signal equipment, lack of staff and funding resources to maintain up-to-date signal timing, and significant traffic growth are the primary factors causing traffic control systems to lose effectiveness.

- ♦ By eliminating operational bottlenecks, replacing obsolete equipment, developing new multi-jurisdictional traffic signal coordination timing plans, and then by devoting the efforts of experienced Traffic Engineers to maintaining up-to-date control strategies, the thru-put capacity of existing roadways can be significantly increased to accommodate the existing traffic demand.

The following traffic operational improvement strategies can be employed to re-capture lost arterial traffic carrying capacities. These must be implemented on an as-needed basis, to be determined via an evaluation of traffic operational restraining bottlenecks, to obtain the required capacities to accommodate traffic demands on major arterials. The network wide evaluation must be conducted in conjunction with the development of system-wide master plan of cycle lengths. While traffic signal-interconnect and coordination is obviously a key to optimizing flow on arterial highways, many other measures must also be utilized to maximize the benefits of traffic signal synchronization.

In developing signal timing plans for arterial networks, it is important to recognize the various factors that influence the optimum traffic flow throughout the arterial network. A critical goal is to end up with as many traffic signals as possible on a common cycle length to minimize the number of sub-systems, thus minimizing stops, delay and vehicle emissions. Additionally, via the cycle length analysis, critical intersections that need spot improvements to increase arterial traffic carrying capacities can be identified. Then mitigations can be implemented via the use of many of the signal coordination enhancement strategies such as the use of protected/permissive left-turn phasing, removal of split phasing, installation of additional turn pockets or extension of existing turn lanes, etc.




As displayed in the figure, arterial traffic carrying capacities can be constrained due to a variety of reasons, many of which can be removed via the implementation of various arterial capacity improvement strategies.

1. **Local Intersection Widening** – Many intersections become bottlenecks for arterial traffic flow simply because a high volume single left turn lane requires a large time allocation and/or a right turn movement (shared with a through lane) becomes blocked by a right turning vehicle waiting for a pedestrian to clear the crosswalk. The typical mitigation for these dilemmas is to provide for dual left turn lanes (thereby reducing the left turn time requirement) and/or providing a separate right-turn-only lane of sufficient length to not block the through lane. These mitigations substantially increase through capacity by providing more time for through traffic and by guaranteeing that all designated through lanes can be free-flowing. If these improvements lead to longer pedestrian time requirements, "Lane Narrowing (Thru an Intersection)", discussed below, may also have to be evaluated.

These improvements can be relatively costly and should only be implemented where problems have been properly identified. The identification process is itself complex and must include identification of a potential problem and then a very extensive and detailed intersection operational level of service analysis (via delay methodology), followed by evaluation of feasible corrective action alternatives.

2. **Signal Phasing Modifications** – This can include adding or removing left turn phasing, changing the type of phasing (see Protected-Permissive Left Turn Phasing discussed below), or eliminating cross street "split phasing." Split phasing is a type of signal phasing wherein left-turns, through traffic and right turns all are provided green while the opposing movements are stopped. The "split phasing" elimination may involve widening of the cross street, which is often a narrow driveway to a shopping center. Unfortunately, shopping centers have been allowed to develop with inadequate driveway width and, as such, "split phasing" has been allowed to accommodate driveway design. The problem is that this results in extra time being allocated to the cross traffic, thereby reducing the arterial/main street capacity. Main street capacity is not just a function of the number of lanes, but also the amount of green time available for those lanes. Therefore, arterial capacity can often be significantly improved by doing minor side street/driveway widening in order to increase the green time allocation for the main street. The widening of side street/driveways avoids shared lanes (e.g., left and through movements shared from the same lane), which often requires the need for split phase signal operation.

3. **Length of Turn Pockets** – Here again, substantial area-wide investigations are required to locate problem left turn pockets. This issue is simply that overflow of a left turn pocket will restrict the through traffic flow of the adjacent through lane, and sometimes the next lane also, due to erratic lane changes to avoid the blockage. Careful operational analysis of queuing is required to determine proper left turn pocket lengths for a variety of traffic conditions. Use of protected/permissive left-turn phasing, discussed below, can substantially reduce left-turn queuing.

4. **Two-Way Left Turn Lanes** – Two-way left-turn lanes are median areas for left-turning vehicles. The two-way left-turn lane allows for storage of vehicles until an acceptable gap in opposing traffic becomes available. These have been well proven as safe and effective. They can increase both mid-block and intersection capacity. Mid-block capacity is increased because turning vehicles will not block through lanes. Intersection capacity is improved because fewer vehicles will need to make U-turns to return to a mid-block destination. Determining where to use two-way left turn lanes is not easy and may involve intersection capacity evaluation and then an economic analysis of alternatives, if an existing raised median is in place. Re-striping painted medians is relatively simple and inexpensive.

5. **Protected/Permissive Left Turn Phasing** – Protected/Permissive Left Turn phasing (PPLT), whereby motorists are allowed to make safe left turns during the green ("green ball") time of through traffic, in addition to protected-only periods of displaying a green left turn arrow. This has become a proven and desirable means to dramatically reduce vehicle delays. However, for safety reasons, traditional PPLT must always have the protected arrows occur as a leading phase, (i.e., no lead-lag phasing) which can be detrimental to arterial signal coordination as discussed in "Lead-Lag Left Turn Phasing" below. In order to reduce left turn delay and enhance coordination by allowing lead/lag left turns (see description below), the Flashing Yellow Arrow (FYA) type PPLT must be implemented. Besides enhancing arterial coordination, the FYA alternative for PPLT has also proven to be much safer than the standard PPLT, thereby allowing its use at nearly all intersections, unless there are sight distance issues that cannot be mitigated or speed issues resulting in collisions involving left-turning vehicles.

   PPLT can increase left turn capacity from 30% to 100% or even more due to vehicles turning during gaps in opposing through traffic and during the through phase yellow clearance time. PPLT is typically much more effective than dual left turn lanes by being considerably less expensive to implement and by minimizing the length of crosswalks. Longer crosswalks, resulting from adding a second turn lane, require longer time periods for pedestrians to cross and would result in less time (meaning less capacity) for main street vehicles.

   Any PPLT installation requires careful traffic engineering evaluation and design before implementation.

6. **Lead-Lag Left-Turn Phasing** – Lead-lag left-turn phasing is basically a type of signal phase sequencing that staggers the left-turns alongside parallel through movements to allow for better coordination of traffic signals i.e., the leading left-turn occurs concurrently with the parallel through during the beginning of arterial green, and the lagging left-turn occurs during the ending portion of arterial green. This is one of the easiest capacity enhancements to implement since all signal control equipment allows it. Its effectiveness results from allowing for more time allocation to opposing through movements. Additionally, this phasing allows for left turn traffic to be coordinated with upstream signals, which typically does not occur if the opposing left turns occur together (i.e., leading). There are some issues in that drivers may complain about lagging, and the yellow clearance time for lagging left-turns has to be longer than normal to match the through yellow, or there will be wasted red time delaying at least one left-turning vehicle per cycle (equivalent to 30 or more vehicles per hour for a 120 second cycle system).

Traffic engineers will need to be able to fully explain and defend lead-lag phasing in order to better educate the public. Also, the controller manufacturing industry needs to be directed (if not mandated) to modify their software/firmware to more efficiently accommodate lead-lag phasing to make it more efficient relative to the lagging left-turn yellow clearance issue stated above and easier for Traffic Engineers to defend.

7. **One-Way Couplets** – There is no expectation that this strategy will ever be wide spread, but wherever it can be implemented, it will result in an increase of coordination capacity because of fewer conflicting movements at intersections, resulting in a higher percentage of green time for through traffic. Business leaders need to be educated that this does not diminish access and, in fact, may attract more business due to improved traffic flow/ circulation.

8. **Lane Narrowing (Thru an Intersection)** – Contrary to common belief, the narrowing of lanes can increase capacity at intersections. This is because capacity is dramatically impacted by the amount of green time available. Thus, when through, left, or right turn lanes are added, the addition may be ineffective because crosswalks become longer, requiring more green time for the cross street (to safely accommodate pedestrians). This means that the lane capacity of all lanes (existing and new) will be reduced because of less time availability. This can be easily evaluated by calculating before and after capacity, recognizing the changes in green time.

   Negative impacts of adding lanes can be reduced or eliminated by such things as:

   a. Using narrow lanes through the intersection, such as 11' for through and 10' for left and right turn lanes.
   b. Using pedestrian refuge islands between a right-turn-only lane and the through lanes, in addition to lane narrowing
   c. Eliminating selected crosswalks and narrowing lanes when more lanes are needed
   d. Using pedestrian bridges.

9. **Effective Traffic Signal Coordination** – A truly effective traffic signal coordination program consists of appropriate traffic signal infrastructure (communications, signal controllers, vehicle detection, etc.,), optimum intersection capacity (with appropriate signal phasing, lane geometrics and alleviation of any physical bottlenecks that curtail arterial capacity) and coordinated signal timing (cycle/split/offset), including the proper implementation and fine-tuning of the coordination timing. Also required are the maintenance, upkeep and surveillance/ monitoring of this integrated system to ensure

that the capacity gained with the initial inter-jurisdictional coordinated system is continued on a long-term basis.

Additionally, multi-jurisdictional traffic signal coordination provides the benefits of reduced travel time, stops and delays on arterial streets within large urbanized areas without regard for jurisdictional boundaries. Typically, with some exceptions, local, county and state agencies only focus on coordinating traffic signals within their own jurisdiction without regard for progression across adjacent boundaries or crossing arterial streets. Agencies need to work together and implement multi-jurisdictional projects.

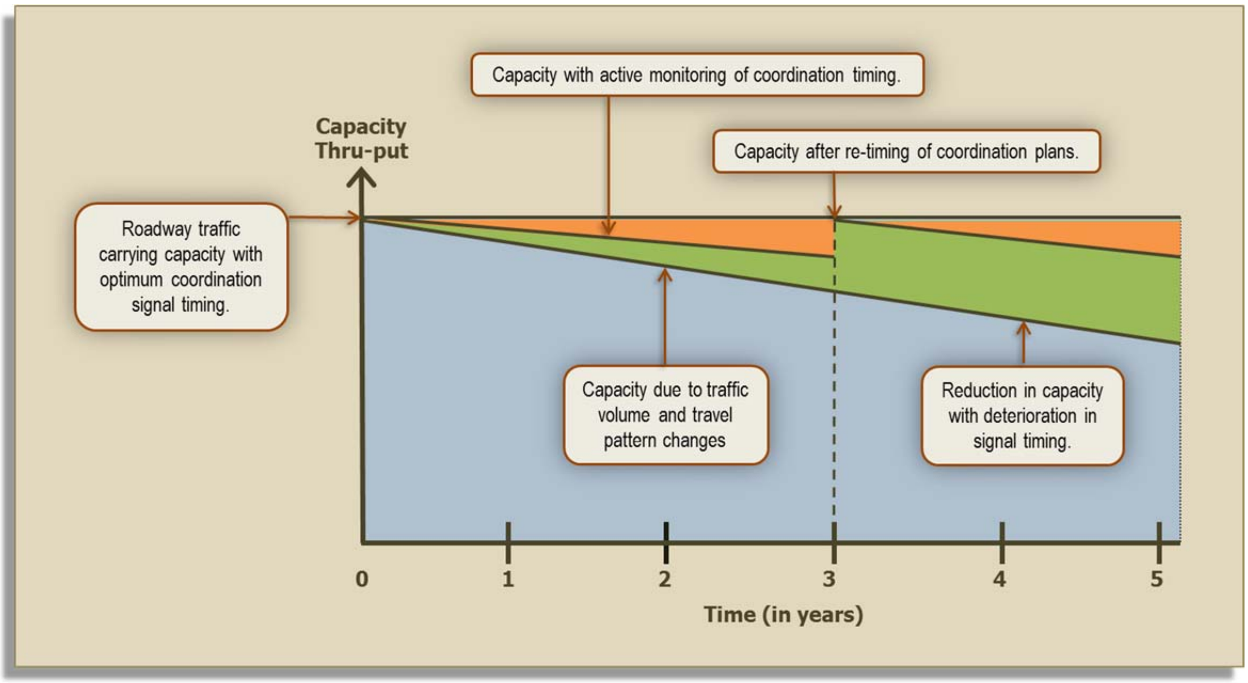
10. **Signal System Monitoring and Maintenance –** Traffic signal systems and coordination timing allow for optimization of roadway capacity, but only with added manpower costs. The use of modern systems and up-to-date timing is vital to achieving utilization of available roadway capacity. Unlike physical widening only, the allocation of proper green time to fully optimize roadway capacity requires ongoing oversight at an experienced professional level. This professional Traffic Engineering oversight has become the "de facto" definition of traffic signal monitoring. This professional activity does not include the physical maintenance of traffic signals traditionally accomplished by either in-house technicians or by contract signal maintenance companies. The traditional signal maintenance process may have to be streamlined to effectively handle modern highly computerized components but will always need to be responsive to problems independently identified by the monitoring professionals. Key items include vehicle detection and signal system communications.

    Experience has revealed that the traffic engineering monitoring effort requires both traffic engineering expertise and traffic signal/system technical expertise. Effective monitoring will determine that traffic flow is being disrupted, and then identify the cause, such as traffic demand changes, failed controller equipment or erratic communications. Based on 2014 salary levels, the cost to provide adequate monitoring is in the range of $100-$125 per signal per month. This cost varies significantly depending on the complexity of systems and volume of traffic being dealt with.

    Typical traffic signal system monitoring functions include:

    - ✓ Daily/weekly remote viewing of system functions.
    - ✓ Periodic driving of the system signals to visually review the coordination effectiveness.
    - ✓ Communicating with responsible maintenance technicians.
    - ✓ Minor modifications of splits and offsets to respond to traffic fluctuations.

- ✓ Maintaining up-to-date signal timing charts.
- ✓ Reports on system effectiveness.




As demonstrated in the figure, arterial thru-put capacity can be regained with active monitoring of coordinated traffic signal system and periodic re-timing.

In summary, with today's increasing traffic demands on both freeways and arterial highways, it has become important to identify traffic operational improvements that can be implemented so as to increase the traffic carrying capacities of the existing highway network. In addition, coordination of traffic signals results in the reduction of vehicle stops, delays, travel times and emissions, and provides relief to congested corridors by capitalizing and building on existing arterial transportation infrastructure.

The following critical components are necessary to achieve optimal performance of the arterial highway system:

- ➢ Elimination of minor traffic operational bottlenecks.
- ➢ Optimization of traffic signal coordination systems.
- ➢ Ongoing monitoring and updating of such coordination systems on an inter-jurisdictional basis.

While traffic signal coordination provides various benefits as noted above, the non-coordination of traffic signals could actually reduce arterial traffic carrying capacities as signal timing may be inefficiently allocated, resulting in unnecessary stops and delays. The operation of signals on a coordinated basis results in fewer stops, reduced travel times, improved fuel economy and, in general, a much more efficient and pleasant driving situation along the arterial.