Route Signal Systems

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It is quite obvious that a vehicle traveling along a given route can move faster if the electric signals are adjusted so that each signal turns green as the vehicle approaches. However, the setting of the electric signals cannot be based just on the speed limit of that particular street section or route.

The physical features of a traffic route affect the speed at which a vehicle can be expected to move. Signal offset timing adjustments are necessary to compensate for the following features:

1. Horizontal and/or vertical curves which are such that visibility is obscured and/or vehicle operation is affected.
2. Poor geometric design, including inadequate lane widths, lateral clearances, medians, left-turn storage and channelization, which has an adverse effect on vehicle operation.
3. Irregularly or poorly spaced signalized intersections which make it impractical to provide coordination for two-way traffic flow.
4. Poorly located signal indications which affect driver response and ability to move conveniently along the route.

There are also other factors affecting the travel speed of the vehicles which must be considered when timing offsets are established:

1. The percentage of commercial vehicles and buses and their inability to accelerate and maintain a uniform speed, thereby reducing the overall operating speed of all vehicles.
2. Traffic volumes and directional flow characteristics during peak traffic hours. Operating speeds vary directly with the traffic density. High density, midblock frictions, and lack of adequate capacity, particularly at signalized intersections, are general reasons for reduced speeds along any route. The City of St. Louis uses, on most of its pre-timed signal system routes, three offsets and/or cycle splits: (a) offsets to favor inbound traffic during the morning peak traffic period, (b) offsets to favor outbound traffic during the afternoon peak traffic period, and (c) offsets to provide a minimal amount of delay for both directions of traffic flow along the route during the normal period or traffic period other than morning and afternoon peak traffic periods.
3. An underlying consideration in signal coordination is accident potential. When a motorist, leaving or passing through an intersection with the green indication is confronted with an amber at the next intersection, the resulting indecision creates a potential for either rear-end or right-angle accidents, depending upon the action taken by the driver.

DISCUSSION

Before and after studies have been conducted on several route-systems in St. Louis. These studies have entailed speed and delay measurements, accident experience, and volume comparison. Traffic movement along the three route-systems discussed here has been improved by the use of better coordinated signalization and the addition of signalized intersections. However, the number of accidents per year has generally increased on all route-systems.

TABLE 1
NORTH GRAND AVENUE

Item	Year 1962	Year 1967	Change (%)
Average trip time, min and sec:			
A. M. —southbound	10 5	9 13	-8. 6
Normal—southbound	9 41	9 51	+1. 7
Normal—northbound	10 40	7 53	-26. 1
P. M. —northbound	11 17	8 38	-23. 5
Average overall speed, mph:			
A. M. —southbound	17. 3	18. 9	+9. 3
Normal—southbound	18. 0	17. 7	-1. 7
Normal—northbound	16. 3	22. 1	+35. 6
P. M. —northbound	15. 4	20. 2	+31. 2
Average delay, min and sec:			
A. M. —southbound	3 2	2 15	-25. 8
Normal—southbound	3 2	2 40	-12. 1
Normal—northbound	2 47	1 17	-52. 8
P. M. —northbound	3 39	1 57	-46. 6
Volume, ADT	21, 000	25, 000	+16
Accidents at intersections	201[a]	233[b]	+16

[a]1963.
[b]1966.

North Grand Avenue

The North Grand Avenue route-system (Forest Park Boulevard to West Florissant Avenue) is approximately 2. 9 miles long and consists of three basic roadway sections varying in width from 50 to 80 ft.

The 50-ft wide section is 1. 5 miles long, and runs through and north of a highly concentrated midtown commercial, shopping, and office district having relatively high traffic generation. It contains 14 signalized intersections which are closely spaced, preventing coordination for traffic progression in both directions. At heavy left-turn locations, the street surface has been divided into five lanes to provide a left-turn slot. Parking is restricted in these areas.

The second section, where the width varies from 56 to 80 ft, is in a light commercial area (the wider portion of this street section formerly served as the principal ingress and egress to the old Sportsman's Park sports stadium). This section is 0. 3 mile in length and contains three signalized intersections.

The third section, 76 ft wide, serves a residential and light commercial area, is 1. 1 miles in length, and contains three signalized intersections. All of the intersection approaches provide three lanes with painted left-turn slots.

The original "Speed and Delay" studies for this area were conducted in 1962, when all of the signalized intersections were pre-timed. Since that time, five signalized intersections have been added. Three of the added signalized intersections are of the traffic-actuated type and contain a background cycle which is used during peak traffic hours to maintain synchronization. These three signals replaced four-way stop intersections, which were in effect at least part-time on normal weekdays. The other two intersections are pre-timed signals and were established to improve traffic flow and pedestrian movement across North Grand Avenue. No significant roadway changes took place during the study period. Signal indications along the route were improved at many locations by the addition of mast arm signal indications. Signalization along this street is uniform, with far-right, far-left indications.

Table 1 gives trip time, speed, delay, volume and accident data for North Grand Avenue. While traffic volumes and accidents have increased, the average travel time has generally decreased. The decrease in travel time and delay can be attributed to signal timing changes, improved visibility, and the addition of signalized intersections, as shown in Figure 1.

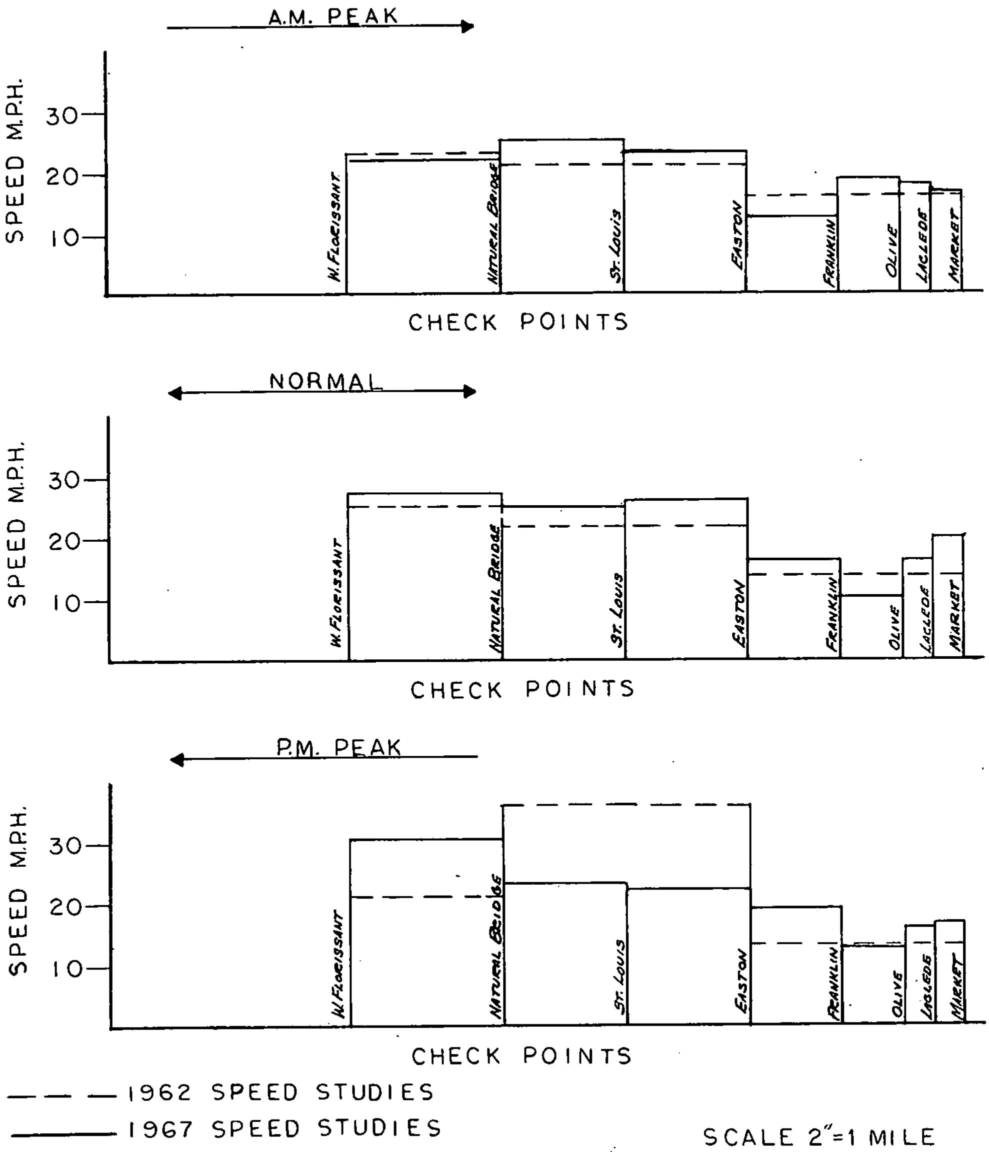

Figure 1. Average speed between check points, Grand—north.

McCausland Avenue

The McCausland Avenue route-system (Daniel Boone Expressway to Arsenal Street) encompasses a distance of approximately 1.33 miles and consists of two roadway sections.

The first section is 40 ft wide and is located in a residential area. Peak-hour parking restrictions permit the use of the entire roadway surface which is marked for four lanes of traffic. The section is approximately 0.87 mile long and has three signalized intersections.

TABLE 2

McCAUSLAND AVENUE

Item	Year 1962	Year 1967	Change (%)
Average trip time, min and sec:			
A. M. —northbound	3 29	3 27	-1. 0
Normal—northbound	3 29	4 1	+15. 3
Normal—southbound	3 41	3 7	-15. 4
P. M. —southbound	3 59	3 53	-2. 5
Average overall speed, mph:			
A. M. —northbound	22. 8	23. 1	+1. 3
Normal—northbound	22. 8	19. 8	-13. 2
Normal—southbound	21. 6	25. 6	+18. 5
P. M. —southbound	20. 0	20. 5	+2. 5
Average delay, sec:			
A. M. —northbound	21	22	+4. 8
Normal—northbound	28	56	+50
Normal—southbound	23	18	-21. 7
P. M. —southbound	48	48	0
Volume, ADT	22, 000	23, 000	+4
Accidents at intersections	51[a]	71[b]	+39

[a]1963.
[b]1966.

The second section is 70 ft wide, with two 33-ft wide driving areas and a 4-ft wide median; it serves a light commercial area. It is approximately 0. 46 mile long and contains three signalized intersections.

Off-peak hour or normal period signal coordination is not maintained along McCausland Avenue, since five of the six signalized intersections are traffic actuated. However, background cycles are used during peak morning and afternoon periods to provide signal coordination during these periods. These background cycles were added during the period between the two speed and delay studies.

From the time of the 1962 studies, until the present studies were conducted, no new intersections were signalized and no significant roadway changes were accomplished along the McCausland Avenue route-system (Table 2). Figure 2 shows speed variation.

North Kingshighway Boulevard

The North Kingshighway route-system (Lindell Boulevard to West Florissant Avenue) encompasses a distance of approximately 3. 75 miles and consists of two roadway sections.

The first section is 60 ft wide and serves the West End hotel complex, several churches, residences, light commercial area, and a large department store. This section is 1. 25 miles in length and contains eight signalized intersections.

The second roadway section is composed of two driving areas, each approximately 27 ft, separated by a parkway median of 50 ft. This section is 2. 5 miles in length and contains eight signalized intersections. This section includes a volume-density signalized intersection at the full-diamond interchange with the Mark Twain Expressway. This volume-density signalized intersection voids any coordination with the one pre-timed signalized intersection to the north.

No significant roadway changes have been made along Kingshighway Boulevard during the study period. Three new signalized intersections have been added—all actuated with background cycles for peak-hour operation. One of the three signals replaced a part-time stop sign, and one a four-way stop intersection. Extensive signal indication improvement work has been accomplished, such as changing from near-right signal indications to uniform far-right indications, and addition of mast arms. Data for this route are given in Table 3. If adjusted for difference caused by two intersections where it was necessary to allow left-turn movements (previously not allowed), the accident data would be 166 and 208 and the percent change 25. 2. Figure 3 shows speed variation.

Additional accident data are given in Table 4. After installation of the progressive timing systems, accidents generally increased. However, with only one exception (Kingshighway signals), these accident increases were less than the overall city average change.

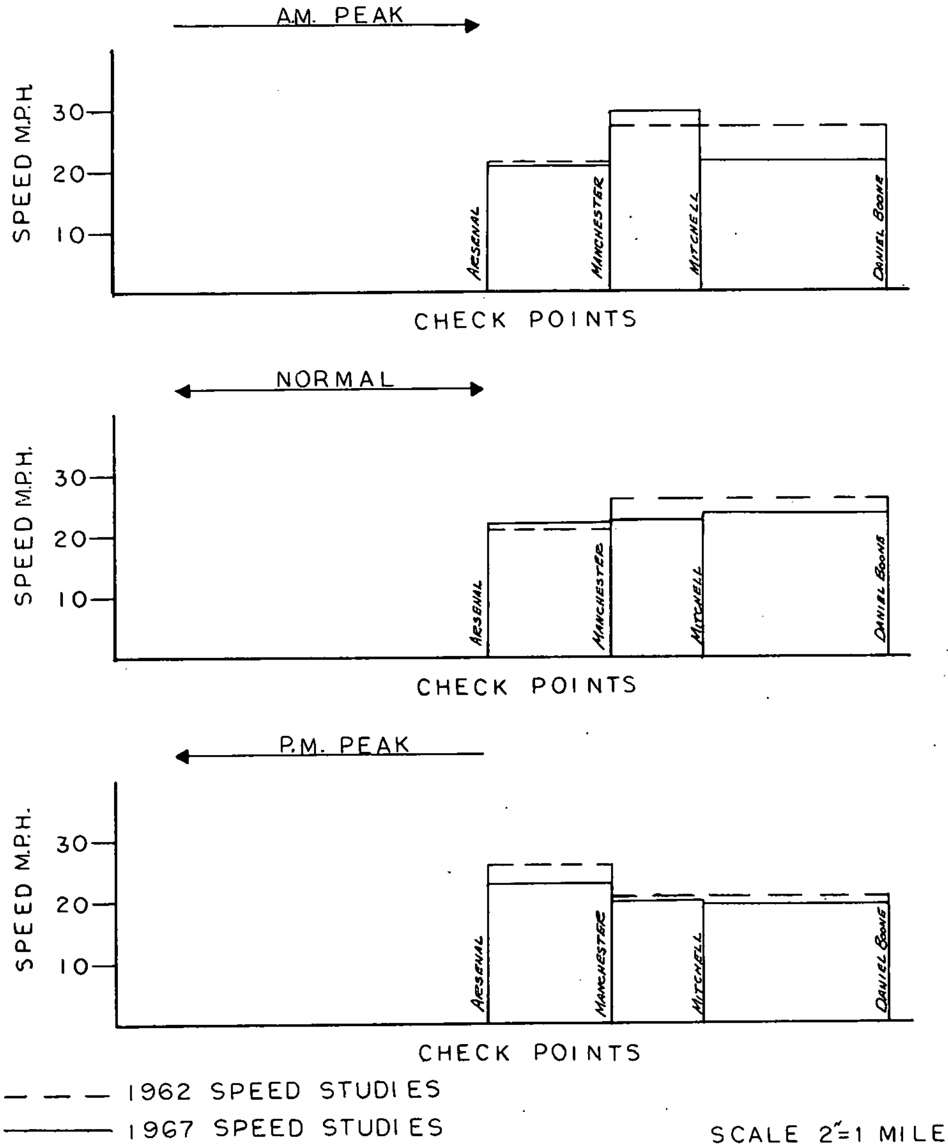

Figure 2. Average speed between check points, McCausland—south.

Table 5 summarizes data on newly signalized locations along the routes. While none of the intersections are truly high-accident locations, the trend on Kingshighway was an increase in accidents, while no statistically significant changes were noted on Grand Avenue.

METHODS OF INTERCONNECTION

After a route-system has been established, some method must be provided to insure that the proper relationship between signalized intersections is maintained. In St. Louis, two methods are used.

TABLE 3

NORTH KINGSHIGHWAY BOULEVARD

Item	Year 1962	Year 1967	Change (%)
Average trip time, min and sec:			
A. M. —southbound	11 56	13 4	+9.5
Normal—southbound	12 26	11 10	-10.0
Normal—northbound	12 34	12 0	-4.5
P. M. —northbound	13 33	11 52	-12.5
Average overall speed, mph:			
A. M. —southbound	18.9	17.2	-9.0
Normal—southbound	18.1	20.2	+11.6
Normal—northbound	17.9	18.8	+5.0
P. M. —northbound	16.6	19.0	+14.5
Average delay, min and sec:			
A. M. —southbound	2 54	3 34	+21.6
Normal—southbound	3 1	2 38	-12.7
Normal—northbound	2 50	2 28	-13.0
P. M. —northbound	4 9	2 33	-38.5
Volume, ADT	28,000	31,000	+10.7
Accidents at intersections	166[a]	254[b]	+53

[a]1963.
[b]1966.

Non-Interconnected Offsets

This system depends on the power company to furnish constant frequency electric service, and St. Louis has had considerable success with this system. Of course, power failures can destroy a signal offset timing program. If this occurs over a large area, a great deal of time may be required to retime the system.

The major traffic arterials where this system is used are patrolled daily, and secondary streets are checked a minimum of twice each week. To minimize the amount of

TABLE 4

ACCIDENT SUMMARY

Location	Before 1963	After 1966	Change (%)
(a) North Grand Avenue			
Signalized intersections	201	233	+16
Non-signalized intersections	64	52	-19
Between intersections	48	51	+6
All accidents	313	336	+7
(b) North Kingshighway Boulevard			
Signalized intersections	166	254	+53
Non-signalized intersections	105	135	+29
Between intersections	78	75	+4
All accidents	349	464	+33
(c) McCausland Avenue			
Signalized intersections	51	71	+28
Non-signalized intersections	16	22	+37
Between intersections	23	16	-30
All accidents	90	109	+21
(d) City-wide Accidents (approx. 700,000 population)			
All locations	15,248	21,347	+40

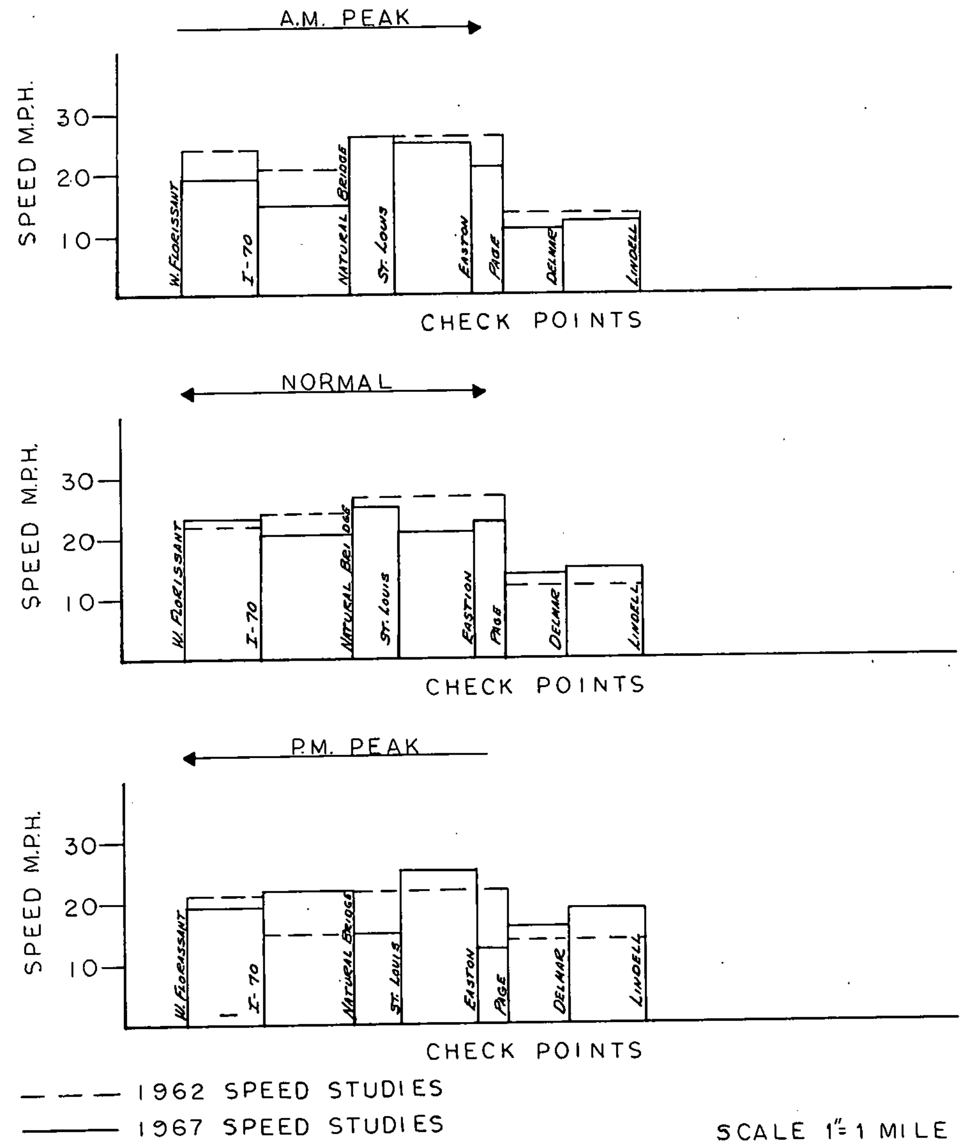

Figure 3. Average speed between check points, Kingshighway—north.

deviation, the city uses master cycle dials located in the radio room, with all signal timing referenced to these master cycle dials via the two-way radio in the electrician's truck.

Direct Wire Interconnect

St. Louis has underground ducts available which can be used in many locations to provide direct-wire interconnection. Single conductor wires in the required number are pulled where needed to provide the interconnection. This is usually 5 to 7 wires, depending on the number of functions to be controlled.

TABLE 5

ACCIDENT RELATED TO INSTALLATION OF NEW SIGNALS

Location	Before Signalization 1963	After Signalization 1966
(a) North Kingshighway Boulevard		
Cote Brilliante Ave.	5	10
Maffitt Ave.	3	9
Penrose Ave.	5	9
Total	13	28
(b) North Grand Avenue		
Franklin-Enright	15	12
Bell Ave.	9	7
Cook Ave.	10	8
North Market St.	14	16
Hebert St.	7	9
Total	55	52

There are other methods of interconnection which sometimes are feasible because of the great distance to be covered and/or the expense of installing underground cables. A radio interconnect system requires the installation of a base radio transmitting station near the master controller and a receiver at each local controller to receive instructions. A leased telephone system uses telephone pairs leased from the telephone company. It usually requires complicated tone-phase systems to transmit and receive the needed information between the master and the local controller.

CONCLUSIONS

Traffic flow along a traffic route-system can be expedited if the traffic signals are adjusted to provide a coordinated system with timing at each signalized intersection adjusted to minimize delay.

To provide maximum efficiency, some type of interconnect or offset relation should be provided and maintained, to insure the proper relationship of signalized intersections along the route at all times.

Addenda

PHOENIX, ARIZ.

Phoenix made an extensive study in comparing costs of radio, telephone lease line, and city-owned line. The cheapest installation was found by use of lease telephone interconnect. Cost data are given in the following 1962 material obtained from Charles E. Haley, City Traffic Engineer of Phoenix.

Interconnection of Traffic Signals, Re: Agreement With Local Telephone Company

The Division of Traffic Engineering, after extensive study, recommends the City of Phoenix enter into an agreement for interconnection of all the traffic signals with the local telephone company. The purpose of providing the single pair of telephone wires to each signal is to electrically interconnect the traffic signals so that the time relationship between signals will be maintained for progressive traffic movement.

At the present time the majority of signals must be checked manually each week. An employee of the electrical division must spend approximately a full day each week checking these signals. Because of power failures signals can be out of synchronization for as much as a weeks time. By interconnecting electrically, better transportation and service to the public will result. Interconnection is also the first step in the modernization of the traffic signal system. Through interconnection, by installing a computing-type of control system, we can send information out to individual controllers adjusting the amount of green time and their relationship one with another depending upon the traffic flow. This, however, is the next step in the modernization of our signal system and will require additional monies in the future.

The cost for this service, which is in the 1962-63 budget, is:

1. First year capital outlay $4600 (one time cost)
2. Tariff for remainder of budget year $3700
3. Tariff for each additional year $5700

The Division compared these costs with the costs of other methods of interconnect; i. e., city-owned and installed wire and radio interconnect. City-owned and installed wire would cost twice as much as leasing from the telephone company, interconnection by radio would cost three times as much as leasing this service from the telephone company. These prices quoted by the telephone company are considerably less than prices quoted in previous years. We understand this is a national reduction in price as the telephone company is energetically seeking leased wire business for data transmission.

The installation of a complete electric interconnect system is the first step in the creation of a completely electronically controlled, traffic sensitive, modern, flexible type of traffic signal system.

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Agreement

The City Council of the City of Phoenix has authorized the City Manager to enter into an agreement with the telephone company for the purpose of providing telephone wire service to interconnect traffic signals in the City of Phoenix.

The agreement, which was negotiated and agreed upon as to form and content by both parties, is as follows:

The company agrees to furnish and maintain one pair of telephone wires to each signal location requested by the City of Phoenix according to the following terms:

Construction

No new construction will be required of the telephone company. The maximum overhead run from the company terminal facility to the City of Phoenix signals will be 180 feet. If spans of greater length are encountered, the City of Phoenix will furnish and install the necessary poles. Service runs will be made by the company to a point on either a wooden or steel signal pole, a minimum of 40 inches below secondary power lines. Where attachment points are made on steel poles, the City of Phoenix will furnish a point of attachment for telephone wire connection and insure that the resistance from the pole to ground shall not exceed 25 ohms. Any termination equipment other than point of attachment will be furnished and installed by the telephone company.

The City of Phoenix will be permitted a load of 2. 5 mils per signal to a maximum of 60 mils per pair of wires.

Reconstruction

In the event the company modifies its plant from overhead to underground, the City of Phoenix will provide an underground conduit from a manhole to the signal controller or point of attachment location. The company will furnish and install the necessary cable in the conduit run. Any change in repeater station locations by the City of Phoenix may require the City of Phoenix to rent extra cable necessary to reach the new locations.

Service

In the event the company does not have telephone cable available for any signal location, it shall provide service to the City of Phoenix as soon as possible. The company shall provide 24 hours a day, 7 days a week, service to the City of Phoenix to repair and maintain wires leased by the City of Phoenix.

Tariff

The company shall bill the City of Phoenix monthly for rental of leased wire at the rate for intra-exchange channels as filed with the Arizona Corporation Commission. The current rate is:

First ¼ mile or fraction thereof \$3. 00
Each additional ¼ mile or fraction thereof \$0. 625

The rates stated in this contract are subject to change upon filing and acceptance by the Arizona Corporation Commission of tariffs providing different rates.

Mileage of lines in use by the City of Phoenix shall be determined as the direct air-line distance between all signal locations connected, starting at the intersection of Central Avenue and McDowell Road and measured so as to produce the lowest total intra-exchange mileage charge. The mileage will be computed separately in ¼ mile multiples (fractional ¼ miles being considered as full ¼ miles) between each pair of signals. The interconnection of the City of Phoenix signals shall be considered as one continuous channel and the charge of $3.00 for the first ¼ mile, or fraction thereof, shall apply only once to the channel.