Methodology to evaluate the effectiveness of opening a local route as a solution to Bottleneck congestion

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Abstract. The phenomenon of vehicle congestion “Bottleneck”, is a problem that exists in every city focus of trade. The continued increase in vehicle demand is an immediate factor in the emergence of this phenomenon, especially in connections between states. This phenomenon of vehicle congestion may be due to inefficient track design, poorly programmed traffic lights, tight bends and vehicle accidents. The most effective solution for placating this phenomenon is the opening of new parallel collecting or local routes, in order to redistribute the vehicular flow of a pathway affected by the Bottleneck phenomenon. In this research, it was taken as a case of studying an intersection formed by an arterial pathway and a collecting pathway. This crossing is already saturated and without the possibility of increasing lanes, so it was feasible to open a parallel local track through a geometric redesign modelled in Synchro 10.0 software, with the purpose of redistributing the vehicle flow of the congested manifold, without impairing the quality of the transfer of nearby users and intersections. Critical ratio results "v / c" lower than 0.85 were obtained, which is synonymous with admissible capacities according to the criteria of states of the HCM 2010.

1. Introduction
Vehicle congestion continues to grow steadily around the world. Since the current corrective measures and implementations do not effectively reduce the vehicle chaos that is lived on a daily basis. This is due to the excessive population of the motor park and the speed with which it continues to rise due to the exponential growth of technology, and thus the feasibility of purchasing a vehicle. Understanding vehicle traffic flow processes in the vicinity of Bottleneck on motorways is of paramount importance for the study of vehicle capacity. Potentially, bottlenecks are of various types such as upgrades, lane drops, melting areas, and fabric sections [1]. These characteristics are also presented in collecting and arterial pathways where congestion affects the user's mood, and despair and recklessness are the main characteristics that occur daily. In the face of limited road infrastructure, demand exorbitantly exceeds the supply of the tracks, so moving from one point to another will mean greater congestion and therefore higher waits [2]. The contribution of this research is to provide a better vehicular flow to the intersection affected by the vehicle congestion Bottleneck through a methodology that applies the opening of an alternating parallel pathway. This alternate path will be opened under a geometric redesign and modeled in Synchro10.0 for further evaluation of vehicle flow redistribution. In this way, the collecting pathway under study will be able to redistribute the vehicle flow, which causes the Bottleneck (Figure1), to the proposed new route. This methodology will contribute to decision making for future studies related to Bottleneck congestion.
2. Case study
Analyze Velasco Astete Avenue (a route suffering from the Bottleneck effect) and Floresta Avenue (alternate local route). These cross with Primavera Avenue, via arterial, and have been analyzed in order to determine the redistribution of the necessary vehicular flow from Velasco Astete Avenue to Floresta Avenue. The aforementioned redistribution will be generated through a geometric redesign, which consists of opening a semaphore crossing between Primavera Avenue and Floresta Avenue so that the vehicular flow along both collection routes is expedited.

3. Methodology
The methodology used in this research is to establish a series of procedures to know the effectiveness of opening alternate local routes to another route affected by Bottleneck congestion, usually collecting pathways. To do this, an intersection where Bottleneck congestion is manifested through information collection (geometry, signage, vehicular capacity and semaphore cycles) will have to be analyzed. A parallel local route, such as the possible solution, will then be proposed by applying a geometric redesign under the principles of HCM 2010. In addition, the study intersection will have to be modeled through Synchro 10.0 software with the opening of the new parallel local route and the this will allow to analyze the redistribution of the necessary flow in the affected path to the opening path until the critical relationship "v/c" at both intersections allows to obtain reports of delay and optimal service levels. Below is the methodology used through a flowchart (Figure 2).
3.1. Data collection and analysis

It is necessary to collect information from the intersection of interest and the area of influence to know the intensity of the problem and the possibility of opening a parallel local path through a geometric redesign.

i. Vehicular capacity of the intersection of interest (Turn morning, afternoon and night).
ii. Geometry and signaling of the area of influence.
iii. Determine the time interval of greatest congestion or "peak time" for each shift.
iv. Develop flowcharts for the busiest time at each turn.

3.2. Scenario modeling and analysis

A. Actual Situation

Synchro 10 software, which has fewer deviations in result correlation with 95% effectiveness in estimating delays, will be used for modelling, which can result in a saturation degree [6]. Therefore, the following steps were developed for the modeling and analysis of scenarios based on the current situation.

i. With the information collected, the geometry of the study intersection and the area of influence are modeled to establish it as the current situation. This includes signage, semaphoreization and capacity taken in the field.

ii. Factors are coordinated to determine the rate of saturation flow based on HCM 2010 through the "Lane Settings" and "Volume Settings" tables. In addition, the assignment of vehicle and pedestrian routes with priority rules, and control signs.
iii. The v/c ratio, service levels and delays of the current situation are obtained. This point is important since results are obtained when the variable “Growth Factor” has not yet been analyzed (G.F. = 1). It is the starting point to carry out the different scenarios through the G.F.

B. Scenario analysis
At this stage, different scenarios will be analyzed until the appropriate flow distribution is achieved to have a Low Capacity (U.C.) or Capacity (A.C.) path.

iv. G.F. with values less than the unit is used to observe the proportion with which the v/c ratio decreases and associate it as different scenarios that can take the intersection. The value assigned for G.F. analysis means the amount of flow that must be spread between the two pathways in order to achieve the improvement of the flow through the v/c ratio.

v. The values obtained in key figure v/c should be evaluated according to the categories established by HCM 2010. In order to achieve results within the Under Capacity (U.C.) or Near Capacity (N.C.) category [5]. The categories relative to the v/c ratio that HCM 2010 sets are shown in Table 1.

Table 1: Intersection status criteria for the planning analysis of signaled intersections. Source: HCM 2010.

| Critical v/c Ratio (Xcm) | Relationship to Capacity       |
|-------------------------|--------------------------------|
| Xcm ≤ 0.85              | Under Capacity (U.C.)          |
| > 0.85 – 0.95           | Near Capacity (N.C.)           |
| > 0.95 – 1.00           | At Capacity (A.C.)             |
| Xcm > 1.00              | Over Capacity (O.C.)           |

C. Proposed Situation
At this stage the intersection with the opening path and its respective synchronized semaphoreization should be modeled to determine the number of openings required and the feasibility of that solution.

vi. Once the results have been obtained in the U.C. or N.C. categories, it should be analyzed whether the flow to be distributed to obtain these results is feasible according to the geometry of the area and the proposal of the redesign. At this point it will identify whether there is a need to open one or more local roads parallel to the crossing under study [4].

vii. These results can be validated through surveys of driver users to know the percentage of acceptance of the proposed alternate route.

Finally, you can determine whether there is a need to open one or more parallel routes based on the receive capacity that a geometric redesign can grant and mitigate the BottleNeck effect [3].

3.3. Validation and Simulation
To validate the methodology, this criterion was used, following the steps mentioned in stages A and B to model one of the most congested intersections in our country. The crossing of Av. Velasco Astete with Av. Primavera presents the Bottleneck phenomenon due to the existence of a single collection route (Av. Velasco Astete) that receives the flow of local roads. So it was decided to use the solution measurement, through a geometric redesign on the Av. From the Floresta, local and parallel route to Av. Velasco Astete, to mitigate the aforementioned phenomenon. The flow was distributed proportionally to the path opened based on the scenarios analyzed.
4. Discussion of the results

4.1. Results with intersection modeling without solution proposal (Current Situation).
Following the steps in stage A, of scenario modeling and analysis, the following results were obtained in Table 2.

| Morning Shift (GF-1) | Late Shift (GF-1) | Night Shift (GF-1) |
|----------------------|-------------------|--------------------|
| Knot 1   | Knot 2 | Knot 3 | Knot 1   | Knot 2 | Knot 3 | Knot 1   | Knot 2 | Knot 3 |
| L.O.S.       | D      | C      | D       | E      | C      | D       | F      | D      |
| Delays       | 39.1   | 46.5   | 29.1    | 51.5   | 65.7   | 25.1    | 41.8   | 120.9  | 38.9   |
| v/c ratio    | 0.86   | 0.86   | 0.86    | 1.2    | 1.2    | 1.2     | 1.78   | 1.78   | 1.78   |

The three shifts in which data were taken in the field are presented. For each knot, the level of service, delays, and degree of saturation at peak time is determined to more clearly obtain the situation in which the study area is located.

4.2 Results of scenario analysis with intersection model without solution proposal.
Continuing with the steps set in stage B, from point 3.2, five new scenarios were chosen for each turn (Morning, Afternoon and Night) through values assigned to the "Growth Factor" shown in Table 3.

| Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 |
|------------|------------|------------|------------|------------|------------|
| Gf v/c     | Gf v/c     | Gf v/c     | Gf v/c     | Gf v/c     | Gf v/c     |
| Morning Shift | Late Shift | Night Shift | Morning Shift | Late Shift | Night Shift |
| 1 | 0.86 | 1 | 1.2 | 1 | 1.78 |
| 0.98 | 0.84 | 0.95 | 1.14 | 0.8 | 1.43 |
| 0.95 | 0.82 | 0.9 | 1.08 | 0.7 | 1.25 |
| 0.9 | 0.77 | 0.85 | 1.02 | 0.6 | 1.07 |
| 0.87 | 0.75 | 0.8 | 0.96 | 0.55 | 0.98 |
| 0.84 | 0.72 | 0.7 | 0.84 | 0.5 | 0.89 |

Six scenarios were required to obtain optimal v/c ratio values. For the morning shift, an intersection state was obtained within the Low Capacity (U.C.) range with a ratio value of "v/c" of 0.72 when the "Growth Factor" was 0.84. On the other hand, for the night shift a state of intersection was obtained within the range Near Capacity (N.C.) with a ratio value of "v/c" of 0.89 when the "Growth Factor" was 0.5. This shows that to obtain significant improvements based on the most critical shift, night shift, a fifty percent redistribution of the vehicle flow of the affected collecting pathway must be achieved.

4.3. Scenario results with the intersection model with alternating track opening (Solution Proposal).

New scenarios have been proposed and it has been validated with a simulation with the viable proposal, verifying that the delays in the study intersection were reduced. In addition, it is verified that on the alternate road, the traffic flow redistributed towards it causes an increase in congestion to "acceptable" service levels, with operating speeds above 80 km / h.
You have the results of modeling the intersection with the path opened according to the steps indicated in stage C. These were grouped into Tables 4, 5 and 6; and consist of the redistribution of the flow of manifold (Av. Velasco) to the local road (Av. From the can) with the GF values of the scenarios established in stage B.

**Table 4:** Values and categories of key figure v/c for each scenario set at stage B in the morning shift.

| Scenario | Gf  | v/c | Category | Gf  | v/c | Category |
|----------|-----|-----|----------|-----|-----|----------|
| Scenario 1 | 1   | 0.86 | N.C.     | 0   | 0   | -        |
| Scenario 2 | 0.98 | 0.84 | U.C.     | 0.02 | 0.50 | U.C.     |
| Scenario 3 | 0.95 | 0.82 | U.C.     | 0.05 | 0.51 | U.C.     |
| Scenario 4 | 0.9  | 0.77 | U.C.     | 0.1  | 0.53 | U.C.     |
| Scenario 5 | 0.87 | 0.75 | U.C.     | 0.13 | 0.56 | U.C.     |
| Scenario 6 | 0.84 | 0.72 | U.C.     | 0.16 | 0.55 | U.C.     |

In scenario six of the morning shift, it is observed that by applying a sixteen percent redistribution of the vehicular flow of Av. Velasco Astete towards Av. From the Floresta you can get an intersection state within the Low Capacity (U.C.) range for both intersections. However, it was sufficient to apply the two percent redistribution of vehicle flow, as shown in scenario two, to obtain Low Capacity (U.C.) intersection states at both intersections.

**Table 5:** Values and categories of key figure v/c for each scenario set at stage B in the afternoon shift.

| Scenario | Gf  | v/c | Category | Gf  | v/c | Category |
|----------|-----|-----|----------|-----|-----|----------|
| Scenario 1 | 1   | 1.2 | O.C.     | 0   | 0   | -        |
| Scenario 2 | 0.95 | 1.14 | O.C.     | 0.02 | 0.42 | U.C.     |
| Scenario 3 | 0.9  | 1.08 | O.C.     | 0.05 | 0.49 | U.C.     |
| Scenario 4 | 0.85 | 1.02 | O.C.     | 0.15 | 0.55 | U.C.     |
| Scenario 5 | 0.8  | 0.96 | A.C.     | 0.2  | 0.6  | U.C.     |
| Scenario 6 | 0.7  | 0.84 | U.C.     | 0.3  | 0.72 | U.C.     |

In scenario six of the late shift, it is observed that by applying a thirty percent redistribution of the vehicular flow of Av. Velasco Astete towards Av. From the Floresta you can get an intersection state within the Low Capacity (U.C.) range for both intersections being this being the best of the scenarios for the late shift.

**Table 6:** Values and categories of key figure v/c for each scenario set at stage B in the afternoon shift.

| Scenario | Gf  | v/c | Category | Gf  | v/c | Category |
|----------|-----|-----|----------|-----|-----|----------|
| Scenario 1 | 1   | 1.78 | O.C.     | 0   | 0   | -        |
| Scenario | O.C. | U.C. | N.C. | A.C. | O.C. |
|----------|------|------|------|------|------|
| 2        | 0.8  | 1.43 |      |      | 0.2  |
| 3        | 0.7  | 1.25 |      |      | 0.3  |
| 4        | 0.6  | 1.07 |      |      | 0.4  |
| 5        | 0.55 | 0.98 |      |      | 0.45 |
| 6        | 0.5  | 0.89 |      |      | 0.5  |

In scenario five of the night shift, it is observed that by applying a redistribution of forty-five percent of the vehicular flow of Av. Velasco Astete towards Av. From the Floresta you can get an intersection state within the range to Capacity (A.C.) for both intersections being this the best of the scenarios for the night shift.

5. Conclusions
Bottleneck congestion has become a severe problem for urban intersections, especially those used as interdistrict connections. From the collection of information, input data was obtained for modeling in Synchro 10.0 software and the actual condition of the intersection expressed in Service Levels, Delays and "v/c" ratio. In addition, the opening of an alternate and parallel local track was the best option for placating vehicle congestion at the study intersection. Finally, this methodology was able to evaluate the redistribution of flows necessary for efficient geometric redesign through scenarios modeled in Synchro 10.0 software. As a vision for the future, we want to use this methodology at various intersections under the effects of Bottleneck congestion at an international level.

6. References
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