"A Proposed Driver Assistance System in Adverse Weather Conditions"

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"Second runner-up"

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Presentation Outline

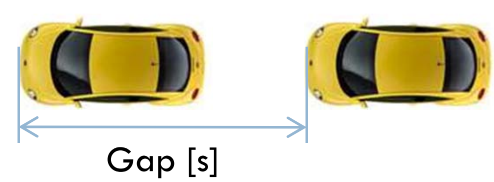
1. Introduction and Research Objective
2. Study Site & Data Reduction
3. Driver Assistance (DA) Systems Overview
4. DA Proposed System “DA-W”
5. Case-Based Reasoning (CBR)
6. Proposed System Validation
7. General Summary and Conclusions

1-Introduction and Research Objective

- Adverse weather conditions negatively affect surface transportation and accordingly impact roadway operating conditions, safety and mobility.
- Most of the literature on the effect of weather have focused on collision risk, traffic volume variations, signal control, travel pattern and traffic flow parameters {*Brilon and Ponzlet (1996), Daniel et al. (2007), Rakha et al. (2008), Datla and Sharma (2010), and Cools (2008)*}; however, few researches studied the drivers' behavior at minor approaches in case of severe weather conditions.

1-Introduction and Research Objective

- For drivers on the minor roadway who are about to enter onto the major roadway, the major task is selecting an adequate gap and then successfully executing the entrance to the roadway "Gap Acceptance/Rejection Behavior"
- Consequently, driver gap acceptance behavior is considered as a decision making traffic process where sometimes the driver could misjudge the offered gap size and crash.
- Therefore, it should be introduced an intelligent system for driver guidance and assistance for preventing crashes; especially during adverse weather conditions: Driver Assistance System

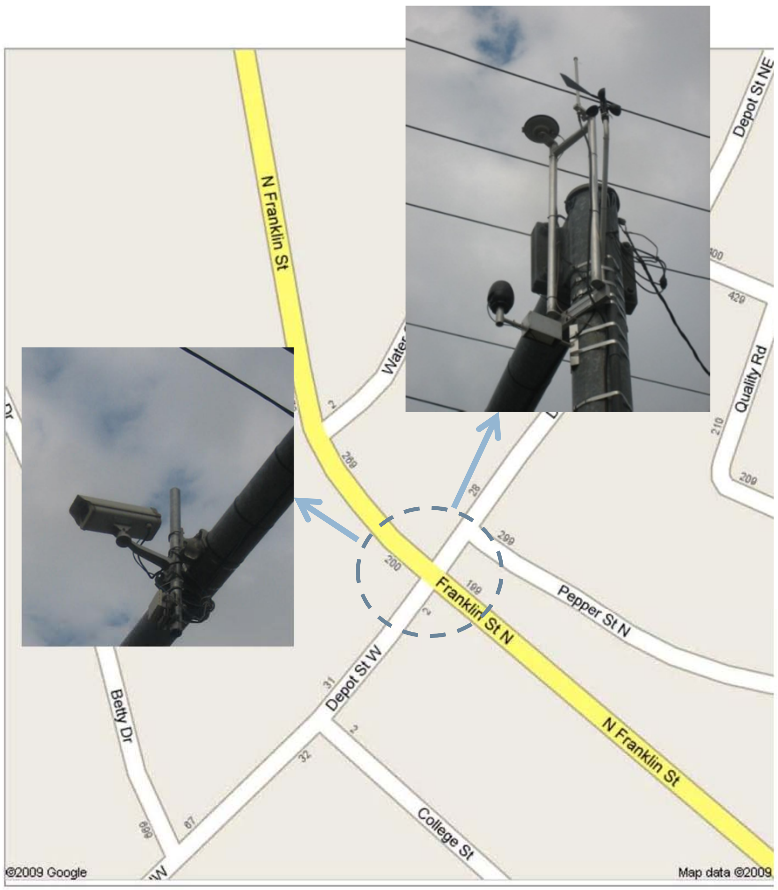


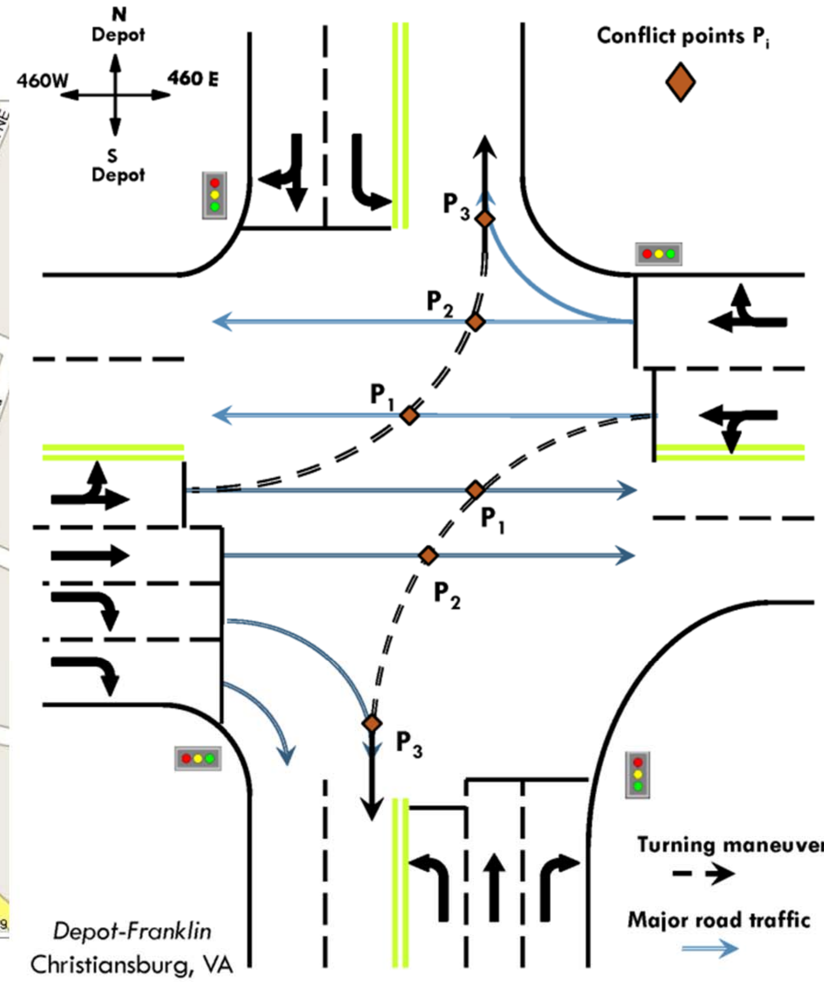
1-Introduction and Research Objective

- The main objective of the study is to propose a new framework for a real time Driver Assistance (DA) system for permissible left turn vehicles in different weather conditions based on collected field data:
  - The proposed system is entitled in this paper a new term: "DA-W" (**D**river **A**ssistance in adverse **W**eather conditions), taking into account the impact of inclement weather, illumination (day or night), gap size and location for the offered gap(lane number).
  - The design logic of the proposed system is based on: Case-Based Reasoning solving algorithm (CBR)

2-Study Site and Data Reduction

- Intersection of Depot St. and North Franklin St. (Business Route 460), Christiansburg, Virginia





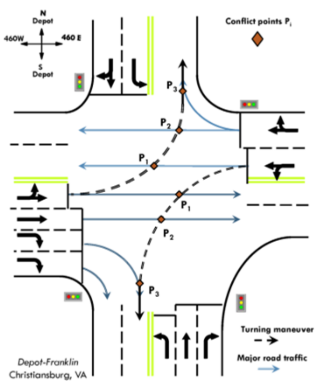
2-Study Site and Data Reduction

•The data were collected over a six-month period

•The data output per day consisted of 15 hourly video files and the corresponding weather measurements.

Screen Shot of a recorded Video

2-Study Site and Data Reduction



- The reduced variables for each observation are :
  - Gap size (s)
  - Weather condition
  - Waiting time corresponding to each offered gap (s)
  - Illumination (day or night)
  - Lane number (location: P1, P2 or P3) of the offered gap
  - Decision of the driver (accept or reject) the gap
- The total dataset consisted of 9,058 gap observations (10.5% accepted gaps and 89.5% rejected gaps). The dataset was divided into three main weather conditions:

  DD, RW and SS

2-Study Site and Data Reduction

DD: Dry Precipitation c

RW: Rain Precipitation and

SS: Snow Precipitation and Snow roadway surface

3-Driver Assistance Systems Overview

- There are several traditional countermeasures for reducing crossing path crashes at controlled intersections.
- Warning or advisory signs are some of the ways to increase drivers' awareness and would help drivers in choosing an appropriate gap to enter the intersection.
- The integration of infrastructure and vehicle systems (VII) offers new possibilities to improve traffic safety and reduce traffic delays.

3-Driver Assistance Systems Overview

- In early 2009, the USDOT re-branded the VII initiative as "IntelliDrive" and changed some of the basic assumptions related to how vehicles and infrastructure components of the system would communicate. One major change relaxed the constraint that all vehicle-to-vehicle and vehicle-to-infrastructure communications would use Dedicated Short Range Communication (DSRC) radios and protocols.
- Thereafter, the US-DOT recently changed the name of "Intellidrive" to "Connected Vehicle Research program"; however, DOT kept the same concepts and motivations of the "IntelliDrive" initiative.

3-Driver Assistance Systems Overview

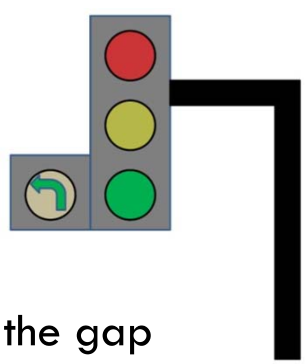
- The main "Connected Vehicle Research program" objectives are to provide the connectivity among vehicles (V2V, V2I, and V2D) for crash prevention, safety, mobility and environmental benefits.
- The safety applications have the potential to reduce crashes through advisories for decision guidance. Consequently, the Driver Assistance (DA) system is considered one of the main aspects of Connected Vehicle Research.
- In general, the concept of left turn vehicle assistant system (i.e. DA) has been addressed in many literatures under varieties of names but with one ultimate goal: "reducing intersection crashes by providing drivers with information to support their crossing decisions".

3-Driver Assistance Systems Overview

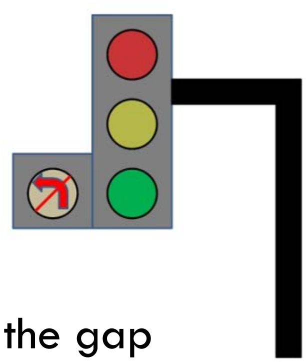
- Examples of researches with <u>ONE</u> concept (DA) but with <u>DIFFERENT</u> titles:
  - The INTERSAFE sub-project within the European research project PReVENT. The INTERSAFE incorporated different kinds of vehicle sensors to track vehicle motions and warn drivers for potential conflicts. {*Fuerstenberg et al. (2007)*}
  - The IRIS (Intelligent coopeRative Intersection Safety system). The IRIS is considered one of the infrastructure-based applications of the European research project SAFESPOT. {*Feenstra et al. (2008)*}
  - The CICAS program (Cooperative Intersection Collision Avoidance Systems) in the U.S. to transmit warnings between the infrastructure and equipped vehicles. {*USDOT's Intelligent Vehicle Initiative (2005)*}
  - Thereafter, it was introduced the concept of "CICAS-SLTA" (CICAS-Signalized Left Turn Assistance) as a part of the California PATH program. { *Misener, et al. (2010)*}

4- DA proposed system “DA-W”

- As mentioned before, it is proposed in this study an Driver Assistance system during adverse Weather conditions: “DA-W”:
  - The system provides the left-turn driver, the appropriate decision (accept or reject the offered gap) taking in consideration the impact of weather condition (dry, rain and snow), gap size, gap location and illumination (i.e. day or night).
  - The advisory (guidance) decision may be displayed as “a green arrow” for accepting the gap and “red arrow” for rejecting the gap, under given assumptions.



Accept the gap



Reject the gap

4- DA proposed system “DA-W”

- The DA-W system features:
  - The DA-W system will provide a driver timely (real time), relevant information regarding unsafe conditions.
  - The DA-W system (infrastructure-based) will be provided with multi-sensors detectors for measuring the gap size offered to each driver and the corresponding weather condition.
  - The DA-W device will process the information gathered from the sensors (input data) in order to estimate the decision guidance (output data), i.e. accepting or rejecting the offered gap, based on collected field dataset.
  - In order to relay between the input, the output and the stored data base, it is anticipated to use “Case-based Reasoning” as a problem solving algorithm (as will be described in the following section).

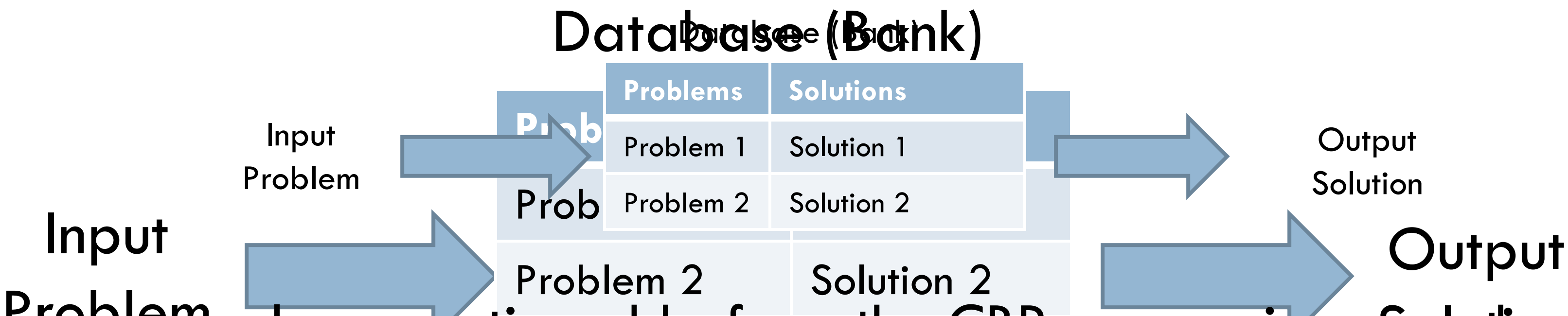
4- DA proposed system “DA-W”

- The infrastructure-based system of DA-W is proposed based on many ASSUMPTIONS which could be listed as follows:
  - The intersection is fully equipped by roadside sensors for detecting the speed of vehicles and have the capabilities of detecting the trajectories of approaching vehicles for gap size estimation;
  - The system should be able to operate under different weather (dry, rain or snow) and illumination (day or night) conditions.
  - The proposed system is anticipated to be applied on the same studied intersection after the collected dataset has been stored;
  - The DA-W display will indicate to driver that it is safe to turn (s/he could proceed into his/her turn), but will leave the turning initiative to the driver;
  - The design logic or problem solving algorithm is suitable for a large fraction of the driving population and the solving process CBR is completed in milliseconds (i.e. a real time system).

5- Case-Based Reasoning (CBR)

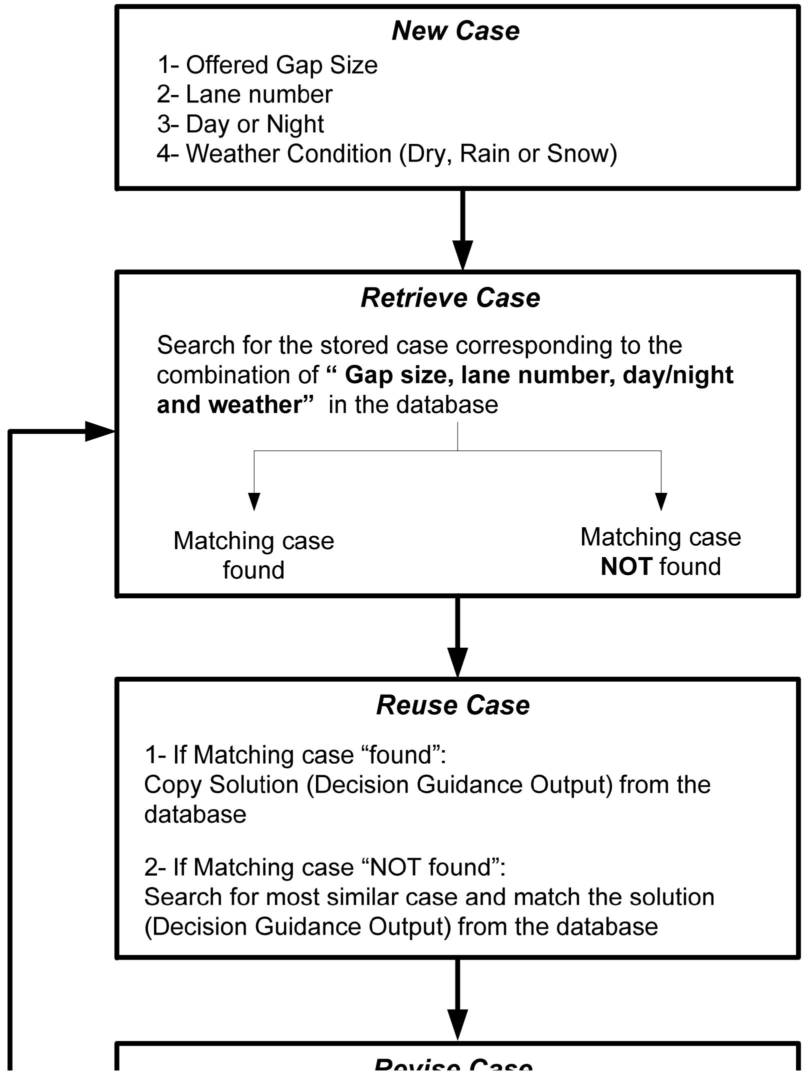
- The Case-based reasoning (CBR) is a problem solving paradigm that has been used in many disciplines over the past years (e.g. philosophy and psychology, diagnostic systems and real-time control problems).
- CBR has been also applied in many transportation problems-solving research (e.g. Intelligent transportation assessment, freeway traffic routing and traffic network management); ***however, this paper presents a novel application for the CBR algorithm in the DA system for left-turn vehicles.***
- In general, there is no consistent CBR method suitable for every domain of application; however the main concept of CBR is to solve a problem (case) by remembering previous similar cases and by reusing the corresponding information.

5- Case-Based Reasoning (CBR)



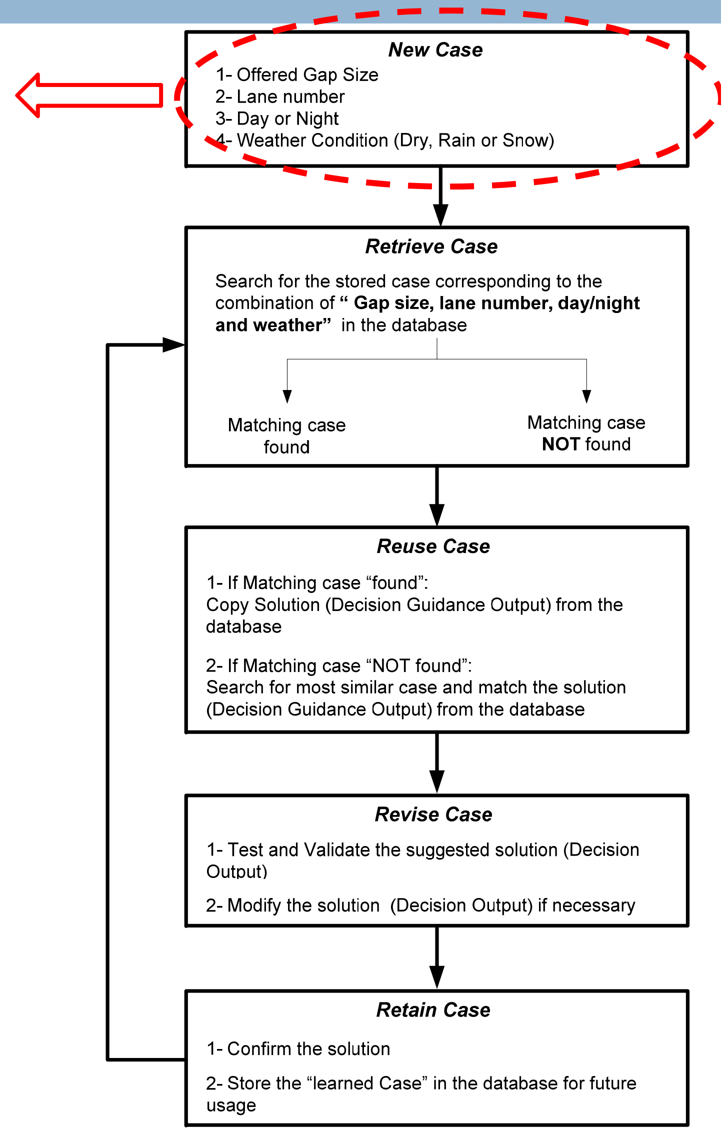
- In general, as mentioned before, the CBR process is a case base that stores previous instances of problems and their derived solutions. The CBR cycle starts with entering a new case (input) followed by four main steps:
  1. *Retrieve* the most similar case or cases,
  2. *Reuse* the information and knowledge in that case to solve the problem,
  3. *Revise* the proposed solution and
  4. *Retain* the parts of this experience likely to be useful for future problem solving.

5- Case-Based Reasoning (CBR)



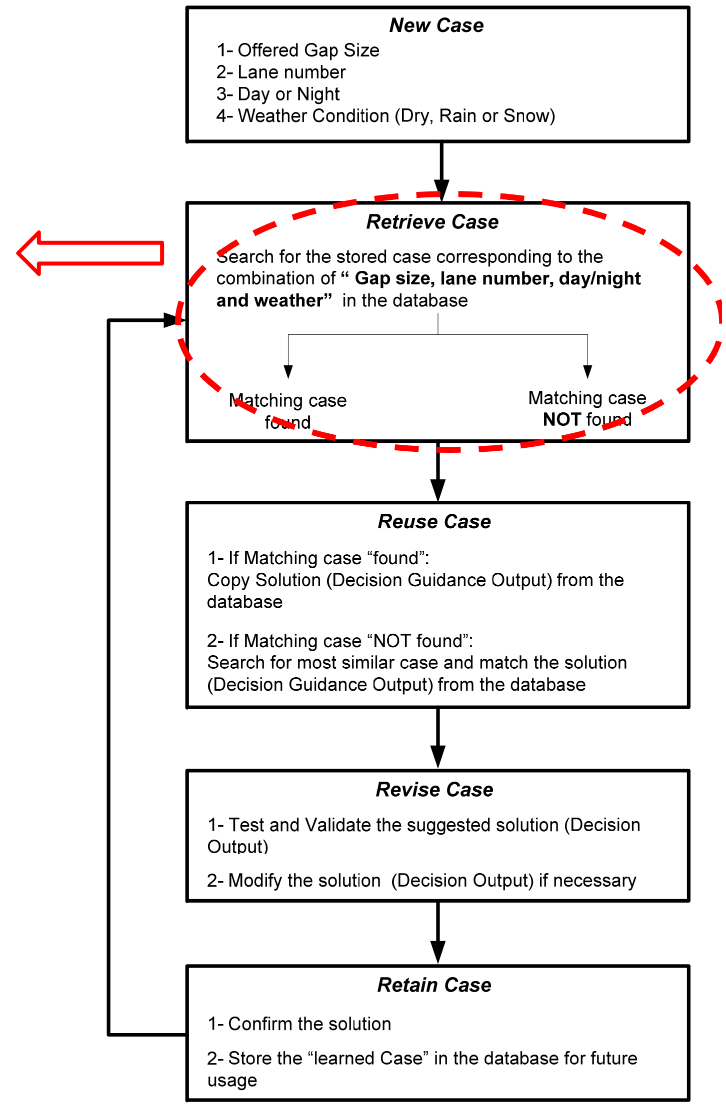
5- Case-Based Reasoning (CBR)

- NEW CASE: For this study, the case is defined as the gap size offered to the left turn vehicle with its corresponding variables.
- The input information for each case in the CBR cycle consists of:
  - the offered gap size,
  - the lane number (location) of the offered gap,
  - day or night (for visibility indication) and
  - the corresponding weather category (as explained before: DD, RW or SS).



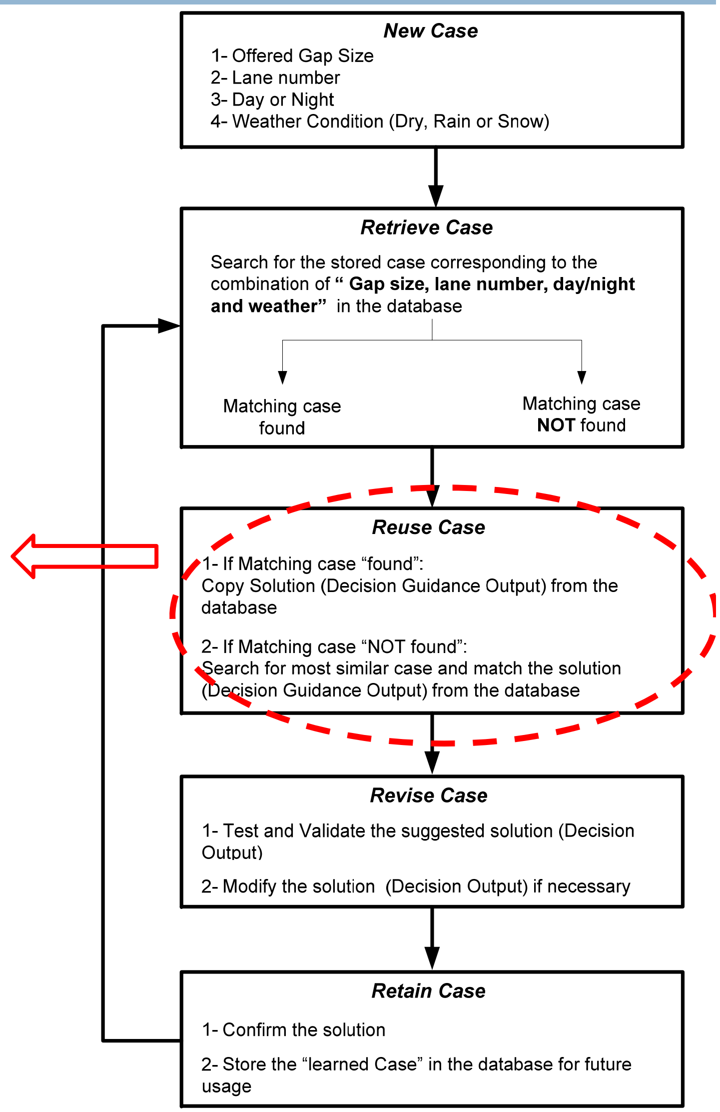
5- Case-Based Reasoning (CBR)

- RETRIEVE CASE: The CBR system compares the new problem with the stored cases in the collected field data, and the result will be:
  - Matching case “found” or
  - Matching case “not found”.



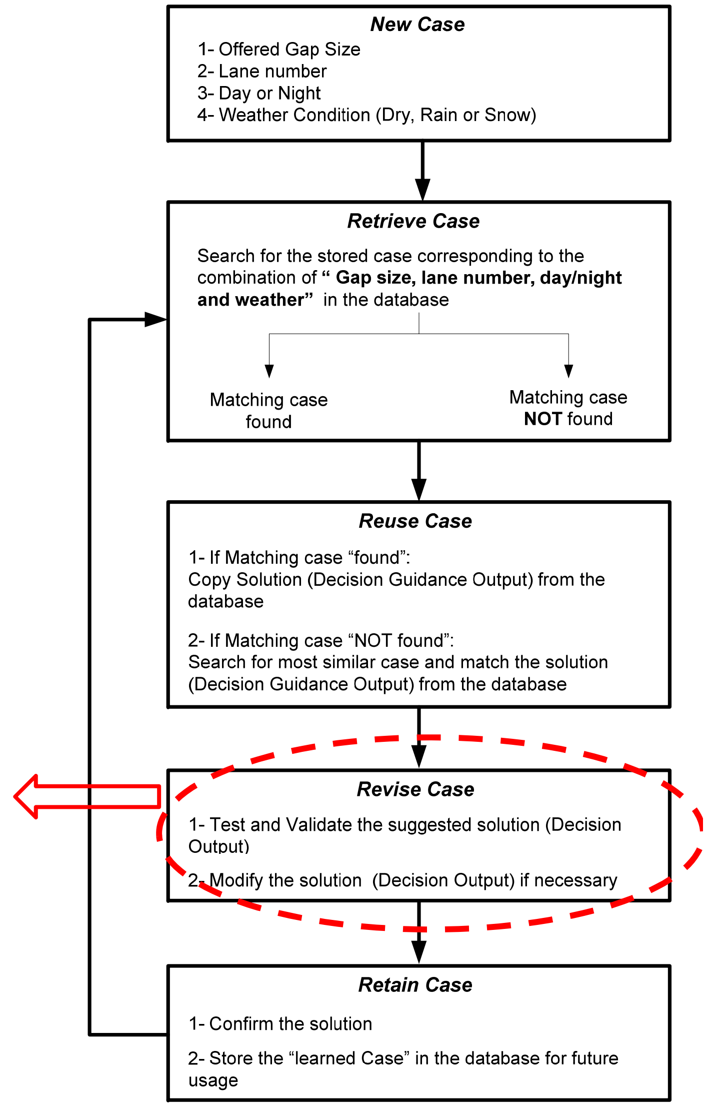
5- Case-Based Reasoning (CBR)

- REUSE CASE: Since the retrieved case is likely to be somewhat different from the current case, a CBR system typically adapts the retrieved solution to closely suit the new problem during the *reuse* step, by searching the closest case (least gap difference case).
  - It could be found many observations for the same gap size and sometimes with inconsistent decisions (accept and reject). Therefore, to overcome this problem, it is assumed to use the 85th percentile of the stored decision list then round it to the nearest integer (0 or 1).



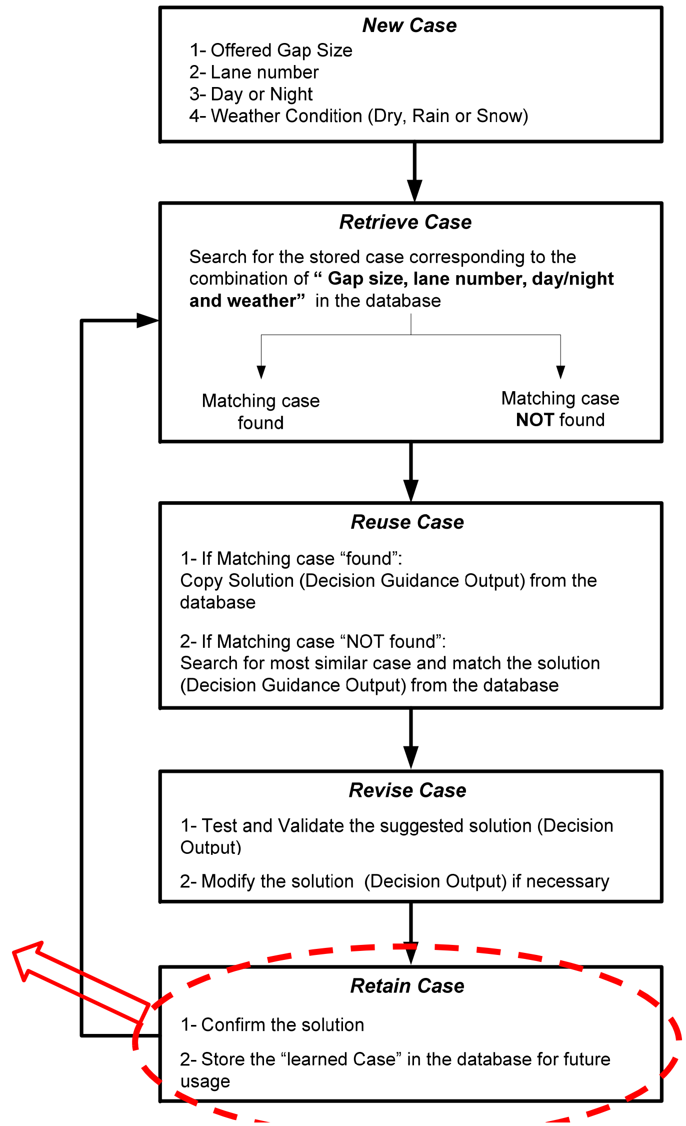
5- Case-Based Reasoning (CBR)

- REVISE CASE: In this step, the decision output is validated and tested to overcome irrational outputs using the following rules.
  - If the decision output for the input case is “accept” and the decision corresponding to any larger gap in the stored database is “reject”, the final decision output would be changed to “reject”.
  - Similarly, for the case of “reject” as an initial decision and the decision for a smaller gap is the opposite, the final decision will change to “accept the gap”.
  - In all other cases, the initial decision will remain the same.



5- Case-Based Reasoning (CBR)

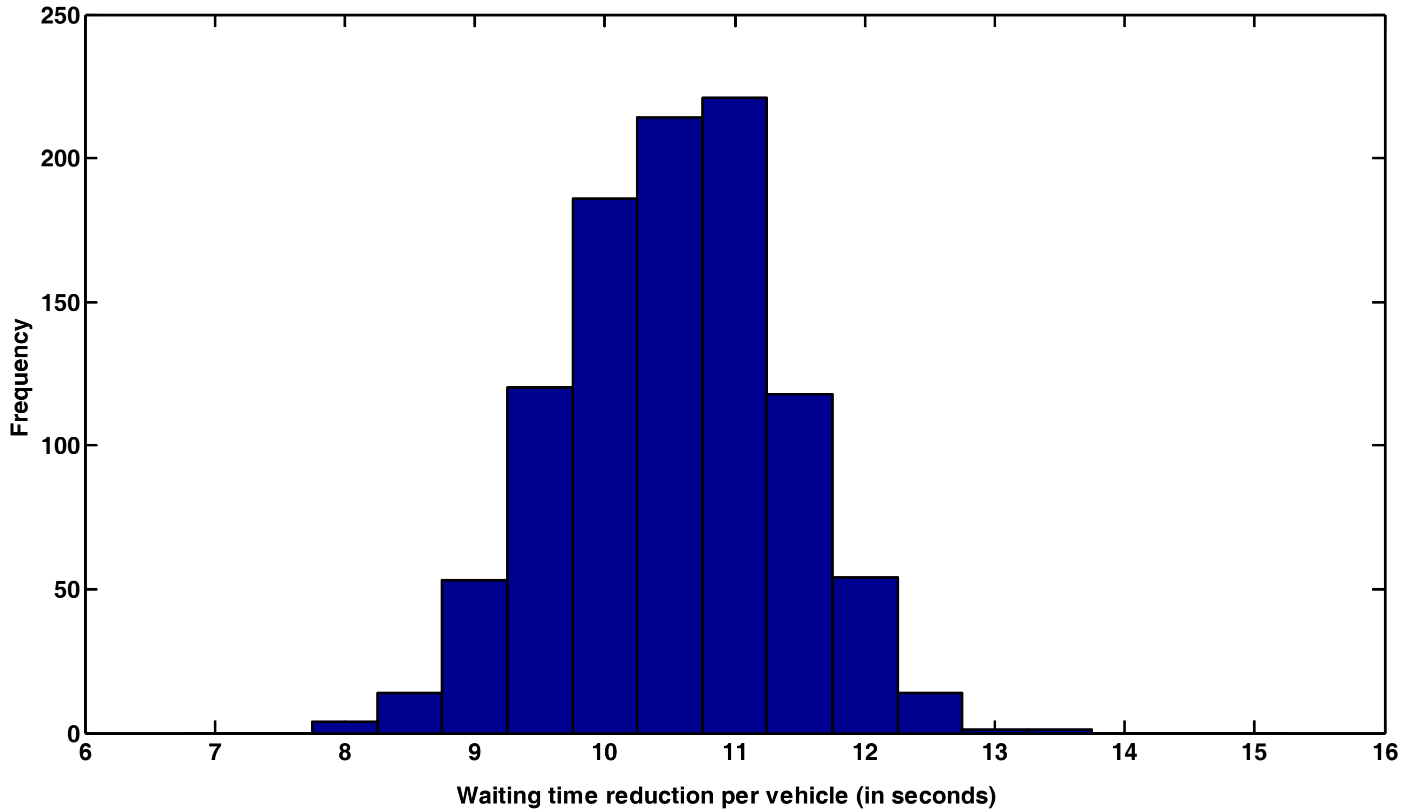
- RETAIN (STORE) CASE: After revising the initial decision and estimating the final output, the *retain* case in the final stage confirm the output and store the case as a "learned case" in the database for future usage.
  - At the end, as mentioned before, it is assumed that the CBR cycle will be accomplished in milliseconds for providing the driver a real time decision guidance.



6- Proposed System Validation

- In order to validate the DA-W system framework, it is anticipated to use 80% of the collected field data (randomly selected) as stored cases database and apply the proposed framework on the remaining of the data as new cases.
- This step is repeated 1000 times using Monte Carlo Simulation and the waiting time is recorded at each time and compared to the original waiting time stored in the dataset.
- The difference between the new recorded waiting time (with DA-W system) and the observed waiting time in the original dataset (without DA-W system) is considered "**the waiting time reduction**" for each vehicle.

6- Proposed System Validation



- It is observable that the average waiting time reduction for each vehicle ranges between 7.9 seconds and 13.3 seconds after applying the DA-W system.

7- Summary and Conclusions

- Adverse weather conditions negatively affect surface transportation and accordingly impact roadway operating conditions, safety and mobility and usually lead to erroneous decision making by the driver.
- This paper addressed the decision making guidance for left turn vehicles at signalized intersections under different weather conditions as sometimes the driver could misjudge the offered gap size and crash.
- This paper proposed a new framework for real time intersection driver assistance (DA) system for left turn vehicles using collected field data for different weather conditions entitled a new term: "DA-W".

7- Summary and Conclusions

- The DA-W system (infrastructure-based) is expected to be provided with multi-sensors detectors for measuring the gap size offered to each driver and the corresponding weather condition.
- The DA-W device would process the information gathered from the sensors (input data) in order to estimate the decision guidance (output data), i.e. accepting or rejecting the offered gap, using the collected field data and (CBR) as a problem solving algorithm.
- It was found that after applying the DA-W system, the waiting time reduction for each driver (vehicle ID) ranges between 7.9 and 13.3 seconds on average.
- It is anticipated that these findings will be used to develop weather-specific traffic signal timings and also for the future of intelligent assistance systems for drivers.

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THANK YOU

Questions??

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