Autonomous Electric Delivery Vans

Autonomous Electric Vehicle Corporation
Halifax, Nova Scotia

Project Requirements Document

12 September 2023

1 Introduction

The Electric Delivery Vehicle division of the Autonomous Electric Vehicle Corporation is in the process of developing its first generation of autonomous electric delivery vans or AEDVs. The AEDVs are in the process of being designed. They are intended to operate in a compact city environment consisting of a grid of avenues and streets. The AEDVs have a payload of up two tonnes (2,000 kilograms) and a 150-kWh battery. The vehicles will be able to carry goods between buildings.

Autonomous Electric Vehicle Corporation is looking for a software design team to develop a software solution that can control an AEDV to optimally navigate through a city with a dynamically changing streetscape, handling accidents or construction work.

The AEDV software is to support the pickup and deliver of goods. A non-autonomous delivery person will be responsible for physically handling the goods. Trip charges are determined by the weight of the item, the energy required for the shortest route between the source and destination, and a customer charge, regardless of the route taken. Customers will have a customer number which is used for billing purposes.

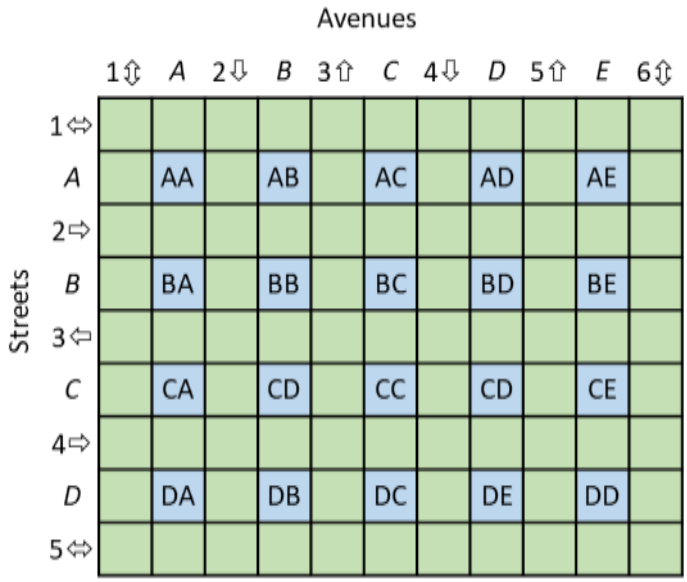
The AEDVs have a finite charge and must know when to seek out the nearest AEDV charging station. A non-autonomous charging station attendant will recharge the vehicle to full capacity. The Autonomous Electric Vehicle Corporation has its own, proprietary super-fast charging system.

This document is intended for software design teams interested in developing a software solution for the AEDVs. The general requirements are described in this document.

Specific software requirements will be outlined at the end of the document.

2 City map

The city consists of a series of Avenues running north-south and Streets running east-west. Buildings are located between avenues and streets. The following graphic shows a sample six Avenue and five Street city grid consisting of 20 buildings (AA through DD):

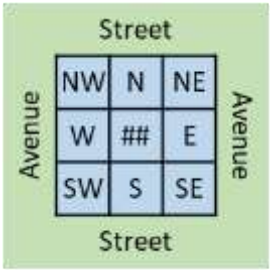


Grid map of sample city (arrows denote one-way or two-way traffic)

All edge avenues and streets (i.e., avenues or streets with buildings only on one side or corner) are bidirectional (that is, they are two-way). However, it is not possible to change direction on a road (i.e., avenue or street), to change direction it is necessary to turn on the next available road.

Non-edge roads are unidirectional or one-way. Changing direction means finding the nearest road (uni- or bidirectional) that will lead to the intended road.

Buildings are situated between avenues and streets and labeled from the upper left (northwest corner) of the map as shown. Locations within buildings are identified as follows:



Common building layout (## denotes the building identifier)

The locations in the building are labeled using traditional compass points (N, E, W, S, NE, NW, SE, and SW). Access to the corner locations of a building can take place from either an Avenue or a Street. Access to the center locations can only be done from streets (N or S) or avenues (E or W).

A location on a building can be a pickup or delivery site, an AEDV charging station, or an AEDV stable.

Each grid on the map is referred to as a cell. There are two types of cell, I-Cell and B-Cell, for intersection cell and block cell, respectively. B-Cells (both avenue and street) are the same length and longer than I-Cells.

2.1 Building locations

As previously mentioned, a building consists of eight locations identified by its building identifier. Each location can be one of:

- A pickup or delivery location. All pickup locations are allocated to different AEDVs at the start of their run or dynamically as the day progresses. The weight of each pickup is known beforehand as is the delivery location. Other than weight, there is no limit on the number of items that can be picked up from a location (i.e., some locations are warehouses). The AEDV must determine the best route based on weight and distance. Routes can change dynamically if accidents or construction occurs.
- AEDV charging station. AEDVs need recharging when their battery is nearing depletion. To avoid depleting the battery, the AEDV must make its way to the nearest charging station. All charging stations broadcast their state whenever a vehicle arrives or departs. All AEDVs receive the message to they know which stations are potentially available when they are nearing depletion.

  A charging station can simultaneously charge two vehicles. If both chargers are busy, the AEDV should wait until one is available or find another charging location.

  If an AEDV runs out of charge before reaching a station, the recovery vehicle must be dispatched from the nearest AEDV stable. The AEDV software must be designed to put vehicle into the nearest corner building location (i.e., NE, NW, SE, or SW) just prior to running out of charge. This ensures that that roadways are not blocked.
- AEDV stable. An AEDV stable has room for four AEDVs and has two chargers. AEDVs must be fully charged starting their delivery runs for the day.

3 Rules of the road

To minimize the likelihood of collisions, the AEDVs are subject to a series of traffic rules. These rules might need to be expanded as experience is gained.

AEDVs on streets have the right-of-way and will not stop, even if the I-Cell is occupied. This can result in accidents.

An AEDV on an avenue B-Cell has the right-of-way only if the I-Cell is clear and there are no moving AEDVs in the adjacent, on-coming B-Cell.

When turning a corner, the AEDV must ensure that the intersection is clear and there are no on-coming AEDVs in the adjacent B-Cells.

4 Accidents

An accident can occur in any cell (intersection or block). The AEDV software must be designed to avoid accidents. Accidents will occur between two or possibly more AEDVs.

If an accident occurs, a recovery vehicle must be dispatched from the nearest AEDV stable to collected the damaged AEDVs. The recovery vehicle picks up both vehicles and returns to its stable. Any undelivered goods must be loaded onto and delivered by the AEDVs that come of the stable.

Recovery vehicles follow the same rules of the road that AEDVs do. The Recovery vehicle is electric. It consumes 0.2 kWh per clock tick when dispatched to an accident and 1 kWh per clock tick when returning to the stable with a damaged AEDV. The recovery vehicle's battery capacity is 100 kWh.

5 AEDV characteristics

AEDVs are either moving throughout the city or are idle performing a pickup or delivery, charging, waiting to cross an I-Cell, or parked in a stable waiting to be sent out.

AEDVs are identified by a unique EVIN (Electric Vehicle Identification Number). EVINs are five digits long, starting at 10000. EVINs increase by 1.

The AEDV must order its deliveries and routes so that it takes the minimum amount of travel time and energy between pickup and delivery. Routes time might need to be adjusted should an accident or construction occur along an intended route.

There are a limited number of charging locations located throughout the city. The locations are known and identified on the map.

AEDVs consume energy according to the following rules:

- AEDVs in idle mode consume 0.001 kWh each clock tick. This powers the communication system to allow it to respond to requests that can occur periodically.
- An AEDV consumes 0.1 kWh each clock tick when moving.
- It takes one tick clock to move through an I-Cell.
- It takes three clock ticks to move through a B-Cell.
- Every package the AEDV is carrying consumes 10^{-4} kWh per tick for every 1 kilogram carried. An AEDV can carry up to 2 tonnes or 2,000 kilograms. A full load (2,000 kilograms) consumes 0.2 kWh per tick.

The AEDV recharge rate (kWh per tick) and battery capacity are maintained by Autonomous Electric Vehicle Corporation.

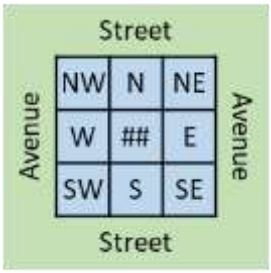
5.1 AEDV information

The state of each AEDV is to maintained throughout its life by Autonomous Electric Vehicle Corporation. At a minimum this is the vehicle's EVIN, its total operational time (in ticks), the number of recharges, the battery capacity, the total weight carried, and the number of accidents it has been involved in.

Other information might be required.

6 Pickups and deliveries

Pickups and deliveries are to one of eight locations in a building:



Common building layout

The locations in the building are labeled using traditional compass points (N, E, W, S, NE, NW, SE, and SW). Deliveries to the corner locations of a building can take place from either an Avenue or a Street.

Deliveries to the center locations can only be done from streets (N or S location) or avenues (E or W location).

Each location has two parking spots on its street side or avenue side, or both in the case of corner locations for pickup and delivery. Parking spots do not exist in I-Cells.

A pickup consumes 0.01 kWh every clock tick for every 100 kilograms or fraction thereof collected.

A delivery takes 1 clock tick for every 50 kilograms or fraction thereof delivered. The motor shuts down but the control systems and lighting consume 0.05 kWh per tick. For example, a 100-kilogram package takes two ticks or 0.1 kWh.

When a pickup or delivery occurs, the AEDV parks beside the building's location, allowing other AEDVs to pass.

An AEDV can return to the road (i.e., avenue or street) only if there is no AEDV in the cell to be entered or the adjacent cell.

When departing from a corner, the AEDV can enter the either the adjacent avenue or street, subject to AEDV rules-of-the-road. AEDVs leaving from a corner must ensure that there is no traffic approaching from B-Cells from the intersection.

7 Billing information

Customers are billed for the pickup and delivery of goods. The bill is expressed in terms of the energy consumed, which is obtained from: the weight of the goods, the best route distance (regardless of the route taken), and the actual energy required. There is a customer charge, but that is not of concern. The customer supplies a customer number (if invalid, the pickup does not occur). The AEDV is to update the delivery file with the weight, best route, and the actual energy consumed.

The AEDV must determine the best route based on weight and distance. Routes can change dynamically as pickups occur or if accidents or construction is encountered.

Billing information is to be recorded in the following format (the Data Dictionary format is required by Autonomous Electric Vehicle Corporation):

```
Bill = Customer-Id + Date + Source + Destination + P-Time + D-
Time + Weight + Best-Distance
Customer-Id = * Customer id – format specified elsewhere *
Date = DDMMYYYY
Source = Address * Source address *
Destination = Address * Destination address *
Weight = * Weight in kilograms *
Address = Building-Id + Quadrant
Building-Id = * Encoding of building's avenue-street location *
Quadrant = [N | S | E | W | NE | NW | SE | SW]
P-Time = * Pickup time in ticks *
D-Time = * Delivery time in ticks *
Best-Distance = * Distance in metres *
```

The format of the Customer-Id is:

```
Customer-Id = Alphabetic + Digit
Alphabetic = [A .. Z]
Digit = [0 .. 9]
```

Note that A9 is followed by B0.

8 Changes to map and pickup requests

Periodically, construction activities can start and stop. When construction starts, the avenue-street combination is broadcast to all AEDVs. If a section of a street is under construction, the street number is sent, along with the numbers of the adjacent avenues; however, if a section of an avenue is under construction, the avenue number is sent, along with the adjacent streets. When the construction is finished, the section of street or avenue in question is sent to all active AEDVs.

Pickup requests can occur dynamically on clock ticks; multiple requests can occur on the same tick. If two or more AEDVs respond to a request, the following rules apply:

1) The request must not exceed the AEDVs weight limitations.
2) The AEDV closest to the pickup location can proceed to the location.
3) The AEDV must have sufficient energy to complete the delivery.
4) If all things are equal, the AEDV with the lowest EVIN performs the pickup.
5) Other rules might be required.

A delivery request is formatted as follows:

```
Request = Customer-Id + Source + Destination + Weight
Source = Address * Source address *
Destination = Address * Destination address *
Weight = * Weight in kilograms *
Address = Building-Id + Quadrant
Building-Id = * Encoding of building's avenue-street location *
Quadrant = [N | S | E | W | NE | NW | SE | SW]
```

9 Solution requirements

Your solution is to design, implement, and test a system to control AEDVs. The system is to support the requirements specified in this document.

To demonstrate the system, it must be able to emulate any number of AEDVs operating at a time.

Vehicle location must be shown on a city map. The map is to be updated on each clock tick.

Further design requirements will be made from Autonomous Electric Vehicle Corporation over the following weeks.

An emulation of the solution must be no later than 10 December 2023.

For further details on the project, contact your Autonomous Electric Vehicle Corporation representative.