The business case for autonomous deliveries: does it exist?
An economic analysis of the use of autonomous vehicle technology for last mile deliveries

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Urban Population as a Percentage of Total Population

Urban Population (% of total population)

Year

The rise of e-commerce

- Delivery Amount (Unit: Million Box)
- Unit Price (Unit: $/Box)

<table>
<thead>
<tr>
<th>Year</th>
<th>Delivery Amount</th>
<th>Unit Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>52</td>
<td>3.291</td>
</tr>
<tr>
<td>2011</td>
<td>1,299</td>
<td>2.338</td>
</tr>
<tr>
<td>2012</td>
<td>1,460</td>
<td>2.332</td>
</tr>
<tr>
<td>2013</td>
<td>1,560</td>
<td>2.303</td>
</tr>
<tr>
<td>2014</td>
<td>1,612</td>
<td>2.250</td>
</tr>
<tr>
<td>2015</td>
<td>1,816</td>
<td>2.174</td>
</tr>
<tr>
<td>2016</td>
<td>2,047</td>
<td>2.098</td>
</tr>
</tbody>
</table>
Renault, LCVs and AVs

- Groupe Renault manufacturers Light Commercial Vehicles. These
  - are used extensively for Last Mile Deliveries (LMDs).
  - contribute significantly to the revenue of the firm.
- A new technology arises; Autonomous Vehicles (AVs).
  - These vehicles may be used for LMDs.
  - This may impact LCV sales.
- *Do these vehicles have a business case for LMDs?*
  - Removal of driver creates value.
  - Private perspective.
Autonomous Single Delivery Vehicle

ASDVs make a single delivery at a time. Here is Amazon Scout. It goes slow, can use sidewalks.
Autonomous *Multiple* Delivery Vehicle

AMDVs make multiple deliveries in 1 round. Here is Nuro; it makes 4. It goes fast, uses roads.
Methodology

- Prospective analysis
  - A cost structure of last mile deliveries is modelled, and then extended.
- Data was gathered from three sources
  - Academic Literature and Professional Reports
  - Interviews
  - Field Visits
- Operational context/constraints identified, understood and modelled.
Modelling: Overview

A. Warehouse at 30km from Customers

B. Warehouse at 10km from Customers (Densely Packed)

C. Smaller warehouse at 1km from Customers
## Modelling: Summary

<table>
<thead>
<tr>
<th>Distance from Warehouse</th>
<th>Size of Warehouse</th>
<th>Average distance b/w customers</th>
<th>Vehicle Used(^1)</th>
<th>Market Segment</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km</td>
<td>7500 m(^2)</td>
<td>0.5 km</td>
<td>Diesel Van</td>
<td>Parcels</td>
<td></td>
</tr>
<tr>
<td>10 km</td>
<td>15000 m(^2)</td>
<td>0.6 km</td>
<td>Electric Van</td>
<td>Groceries</td>
<td></td>
</tr>
<tr>
<td>30 km</td>
<td>25000 m(^2)</td>
<td>0.7 km</td>
<td>Cargo Bike</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40000 m(^2)</td>
<td>...</td>
<td>ASDV(^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 km</td>
<td>AMDV(^3)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^2\) Assumption: Fleet is unimodal  
\(^3\) Autonomous Single Delivery Vehicle  
\(^4\) Autonomous Multiple Delivery Vehicle  
\(^4\) Business to Business
Literature Overview

- Previous Literature
  - Total Cost of Ownership (TCO) approach for vehicle choice - (Lebeau et al., 2019), (Figenbaum, 2018), (Camilleri, 2017)
  - Warehouse Location - (Combes, 2019)
  - Autonomous Vehicles - (Figliozzi, 2019, 2020)

- Contribution
  - Creation of integrated model (warehouse location AND vehicle choice)
  - Include real world operational constraints
    - Account for heterogeneity of LMDs - different Market Segments
    - Level of service penalty
    - Driver/Deliverer experience
Table: Level of Service Penalty

<table>
<thead>
<tr>
<th></th>
<th>Task</th>
<th>Handled by in Conventional Delivery</th>
<th>Handled by in Autonomous Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Navigating</td>
<td>Driver</td>
<td>Vehicle</td>
</tr>
<tr>
<td>2.</td>
<td>Calling and notifying customer of arrival</td>
<td>Driver</td>
<td>Vehicle</td>
</tr>
<tr>
<td>3.</td>
<td>Locating merchandise in storage</td>
<td>Driver</td>
<td>Customer</td>
</tr>
<tr>
<td>4.</td>
<td>Unloading merchandise</td>
<td>Driver</td>
<td>Customer</td>
</tr>
<tr>
<td>5.</td>
<td>Delivering merchandise to end customer</td>
<td>Driver</td>
<td>Customer (collects it himself)</td>
</tr>
<tr>
<td>6.</td>
<td>Getting proof of successful delivery from customer</td>
<td>Driver</td>
<td>Vehicle (registers opening/closing of door)</td>
</tr>
</tbody>
</table>
### Market Segments

**Table**: Market Segments considered for Analysis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Unit</th>
<th>Parcels</th>
<th>Groceries</th>
<th>B2B&lt;sup&gt;5&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deliveries per Round</td>
<td>-</td>
<td>100+</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Avg. Weight/Delivery</td>
<td>Kg</td>
<td>0.3</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>Time per Delivery</td>
<td>Minutes</td>
<td>3</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Vehicle Refrigerated</td>
<td>-</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Level of Service Penalty</strong>&lt;sup&gt;6&lt;/sup&gt;</td>
<td>€/Delivery</td>
<td>1.5</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Values above for Diesel Van.

---

<sup>5</sup> Business to Business  
<sup>6</sup> iff AVs used
Modelling: Math

\[
\text{Cost/Delivery} = \left( \frac{\text{Costs/Week}_{\text{warehouse}} + \text{Costs/Week}_{\text{fleet}}}{\text{Deliveries/Week}} \right) \tag{1}
\]

\[
\text{Costs/Week}_{\text{warehouse}} = f(\text{size}, \text{distancefromcitycenter}) \tag{2}
\]

\[
\text{Costs/Week}_{\text{fleet}} = (\text{tco}_{\text{vehicle}} + \text{wage}_{\text{driver}}) \times \text{numberofvehicles}_{\text{fleet}} \tag{3}
\]

\[
\text{Deliveries/Week} = f(\text{Vehicle}, \text{MarketSegment}, \text{CustomerDensity}, \text{SpeedBetweenDeliveries}, \text{LocationofWarehouse}, \text{ApproachSpeed}) \tag{4}
\]
## Results: Scenarios

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Purchase Costs (Euros)</th>
<th>Losses Linked to Driver Experience</th>
<th>Costs Linked to Remote Operators</th>
<th>Level of Service Penalty</th>
<th>Driver Wage per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>SDAV = 250,000</td>
<td>MDAV = 300,000</td>
<td>None</td>
<td>None</td>
<td>11.17 €</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>SDAV = 250,000</td>
<td>MDAV = 300,000</td>
<td>20% loss of deliveries per day</td>
<td>1 remote operator for 20 vehicles</td>
<td>1.5, 3 and 5 Euros acc. to Market Segment</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>SDAV = Price of Cargo Bike (7,890)</td>
<td>MDAV = Price of Electric Van (64,643)</td>
<td>20% loss of deliveries per day</td>
<td>1 remote operator for 20 vehicles</td>
<td>1.5, 3 and 5 Euros acc. to Market Segment</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>SDAV = Price of Cargo Bike (7,890)</td>
<td>MDAV = Price of Electric Van (64,643)</td>
<td>20% loss of deliveries per day</td>
<td>1 remote operator for 20 vehicles</td>
<td>None</td>
</tr>
<tr>
<td>Scenario 5</td>
<td>SDAV = Price of Cargo Bike (7,890)</td>
<td>MDAV = Price of Electric Van (64,643)</td>
<td>20% loss of deliveries per day</td>
<td>1 remote operator for 20 vehicles</td>
<td>None</td>
</tr>
<tr>
<td>Scenario 6 (Green Vehicles Only)</td>
<td>SDAV = Price of Cargo Bike (7,890)</td>
<td>MDAV = Price of Electric Van (64,643)</td>
<td>20% loss of deliveries per day</td>
<td>1 remote operator for 20 vehicles</td>
<td>None</td>
</tr>
</tbody>
</table>

**Table: Scenarios**
Cost per delivery: S1, Parcels

![Graph showing cost per delivery as a function of distance between deliveries (Market Segment = Parcel)].

- Warehouse located at 1, 10, or 30 km away from customers.

Y-axis scaled to log base 10; values are real. Avg parcel volume (Parcel) = 0.0031 m³; Time per delivery = 0.05 hrs or 0.2 hrs (4W).

Legend:
- Vehicles
  - Diesel Van
  - Electric Van
  - Cargo Bike
  - Autonomous Single Delivery Vehicle
  - Autonomous Multiple Delivery Vehicle

Overview:
- Parcels
- Service Penalty
- Market Segments
- Math

Table:

<table>
<thead>
<tr>
<th>Distance Between Deliveries (km)</th>
<th>Cost per Delivery (€/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
</tr>
</tbody>
</table>

Cost per Delivery Results:
- Winning Combination

Conclusion:
- Appendixes
Cost per delivery: S1, Groceries
Cost per delivery: S1, B2B
Optimal Warehouse Location/Vehicle Combination

- Warehouse location and vehicle choice are not independent:
  - Some vehicles - ex. Cargo Bikes - are severely limited by their autonomy
  - Comparing TCO over different vehicles is not appropriate if some vehicles have different operational constraints
- A logistics firm will choose a combination of warehouse location/vehicle type that offers the least cost per delivery.
Optimal Warehouse Location/Vehicle type: S1
Optimal Warehouse Location/Vehicle type: S4
Optimal Warehouse Location/Vehicle type: Low Wage regions

Most competitive vehicle-warehouse location combination per market segment. Scenario: Low Wage Geographical Regions. Three warehouse locations are compared: 1km, 10km, and 30km from the first delivery.

Market Segment = Parcels

Market Segment = Groceries

Market Segment = B2B

Note: Displayed are delivery costs for different market segments. The optimal combination varies depending on the market segment and distance between deliveries.
Conclusion

- Model which compares cost per delivery over different vehicles, warehouse locations, size, customer densities and market segments is developed.
- Competitiveness domains for different vehicles are determined.
  - Conventional vehicles extremely efficient under current operating scenario.
  - If AVs become cheaper, and service penalty is borne by customers, AVs are competitive for certain market segments, under certain conditions.
- Future work: Model to be extended to mixed fleets, question of lead time to be addressed.
Thanks for your time and insights!

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In this thesis, a microeconomic model of *cost per delivery* is developed. Its components are:

- Warehouse
- Vehicles
- Elements specific to the use of AECS vehicles
Appendix 1: Warehouse Costs

A warehouse consists of
- A physical structure at a location
- Employees
- Equipment, Electricity, Maintenance etc.

\[
\text{warehouse}_{\text{costs}} = \text{warehouse}_{\text{rent}} + \text{warehouse}_{\text{employeecost}} + \text{warehouse}_{\text{othercosts}}
\]  

The following assumptions are made;
- A logistic firm requires a warehouse for its cross-docking operations.
- This warehouse is rented.
- Firm operates only 1 warehouse with unimodal fleet.
- Equipment, Electricity, Maintenance and other costs are assumed to be dependant on Market segment to which warehouse caters.
Warehouse Rent: Size, Location

The rent of a warehouse depends on two criteria;

- its size and,
- its distance from the city center.

Based on data from property rental sites, this can be expressed as;

\[
\text{warehouse}_{\text{rent}} = (0.0003 \times \text{wh}_d^4) - 0.04 \times \text{wh}_d^3 + 2.15 \times \text{wh}_d^2 - 43.1 \times \text{wh}_d + 392.3 \quad (6)
\]

Where \(\text{warehouse}_{\text{rent}}\) is the rent per square meter and \(wh_d\) is the distance of the warehouse from city center.
Warehouse Rent: Size, Location (contd.)
Based on available (limited) data, the number of employees as a function of the size of the warehouse follows a linear relation.

\[ \text{warehouse}_{\text{employees}} = \text{warehouse}_{\text{size}} \times \text{employees}_{m2} \times \text{cost}_{\text{employee}} \]  

(7)
Apart from rental costs, and wage costs to employees, there are other costs in running a warehouse. These include, but are not limited to;

- Equipment costs
- Electricity costs
- Maintenance costs

Equipment costs include the costs of sorting machines, or Automated Storage and Retrieval Machine, which are extremely expensive.
All other costs, not indicated by rent or employment costs are represented by the greek letter $\delta$.

$$\text{warehouse_{othercosts}} = \delta$$

In this model it is assumed that for a given market segment, for a given warehouse size, these other costs are the same. These costs are not known. This creates a problem that can be tackled in at least two ways:

1. calibrate model such that cost/delivery reflect real world values.$^7$

2. subtract the min. cost/delivery from all other costs/delivery for each configuration such that $\delta$ is removed.

$^7$These values are known through field visits.
Method 2 can be represented as:

\[
\text{warehouse}^{\text{configuration}_1} \text{costs} = \text{warehouse}^{\text{configuration}_1} \text{rent} + \text{warehouse}^{\text{configuration}_1} \text{employeecost} + \text{warehouse}^{\text{configuration}_1} \text{othercosts} \tag{9}
\]

\[
\text{warehouse}^{\text{configuration}_2} \text{costs} = \text{warehouse}^{\text{configuration}_2} \text{rent} + \text{warehouse}^{\text{configuration}_2} \text{employeecost} + \text{warehouse}^{\text{configuration}_2} \text{othercosts} \tag{10}
\]
As for a given configuration (warehouse location, warehouse size, customer density, vehicle, market segment),

\[
\text{warehouse}_{\text{configuration}_1}^{\text{othercosts}} = \text{warehouse}_{\text{configuration}_2}^{\text{othercosts}} = \delta \quad (11)
\]

From 9, 10 and 11 we have;

\[
\text{warehouse}_{\text{costs}}^{\text{configuration}_1} - \text{warehouse}_{\text{costs}}^{\text{configuration}_2} = \\
\text{warehouse}_{\text{rent}}^{\text{configuration}_1} - \text{warehouse}_{\text{rent}}^{\text{configuration}_2} + \\
\text{warehouse}_{\text{employeecost}}^{\text{configuration}_1} - \text{warehouse}_{\text{employeecost}}^{\text{configuration}_2} \quad (12)
\]
Throughput of a warehouse is assumed proportional to its size.

\[ \text{warehouse}_{\text{throughput}} \propto \text{warehouse}_{\text{size}} \quad (13) \]

\[ \text{warehouse}_{\text{throughput}} \propto \text{fleet}_{\text{size}} \quad (14) \]

\[ \text{warehouse}_{\text{size}} \propto \text{fleet}_{\text{size}} \quad (15) \]

\[ \text{warehouse}_{\text{size}} = k \times \text{fleet}_{\text{size}} \quad (16) \]

- Width and number of bays are determined using Google Maps.
- Area of warehouse is determined using Google Maps.
- Number of vehicles per square meter is thus calculated.
From above images;

- Area of building = 48m*248m = 11904m²
- Length required by 1 vehicle = 3m
- Length of warehouse = 248*2 = 496m
- No. of vehicles = 496/3 = 165.33
- No. of vehicles/m² = 165.33/11904 = 0.014 vans/m²
- No. of vehicles/m² (only 1 side) = 0.007
Warehouse Size and Throughput (contd.)

- No. vehicles/m² depends on the type of vehicle.
- An ASDV is not as wide as a Cargo Bike is not as wide as an AMDV is not as wide as a Van.
- Area reqd(ASDV) = 0.5*Area reqd(Van)
- Area reqd(Cargo Bike) = 0.7*Area reqd(Van)
- Area reqd(AMDV) = 0.8*Area reqd(Van)
The TCO is a widely used approach to compare different cost structures over differing vehicle technologies. It involves comparing actualised costs for each period over the life of a vehicle. These costs include:
- Costs independent of distance travelled
  - Purchase, resale, insurance, subsidies
- Costs dependent on distance travelled
  - Fuel, maintenance
Vehicles Compared for TCO Analysis

- Maximum number of deliveries a vehicle can accomplish in a day is determined.
- This is used to determine - using TCO, Warehouse Costs and Driver Wages - the Cost per Delivery
- The following vehicles are compared:
  - Diesel Vans (often the base case)
  - Electric Vans
  - Electric Cargo Bikes
  - Single Delivery Autonomous Vehicles (SDAV)
  - Multiple Delivery Autonomous Vehicles (MDAV)
Vehicles Compared: TCO Data I
Vehicles Compared: TCO Data II

- Analysis based on data of 50 Vans of differing energy source, capacity, manufacturer, etc.
- Vans of different volume capacities used in different market segments. Parcels use van with capacity of 3.5 m³, Groceries and B2B of 8 m³.
- Purchase and Energy costs for Grocery Market Segments are 1.2 times that of B2B segment due to refrigeration.
- ASDVs cost 2x, and AMDVs cost 3x diesel vans.\(^8\)

\(^8\) arbitrary choice, will soon change it to 2x,3x of Electric Vans.
Methodology: determining Number of Deliveries per day

**Table: Variables used**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>number of deliveries in a day</td>
<td>-</td>
</tr>
<tr>
<td>( t_{lod} )</td>
<td>length of day</td>
<td>hours</td>
</tr>
<tr>
<td>( t_{loading} )</td>
<td>time to load vehicle</td>
<td>hours</td>
</tr>
<tr>
<td>( t_{delivery} )</td>
<td>time per delivery</td>
<td>hours</td>
</tr>
<tr>
<td>( d_{wfd} )</td>
<td>distance of warehouse to first delivery</td>
<td>kilometers</td>
</tr>
<tr>
<td>( d_{bd} )</td>
<td>average distance between deliveries</td>
<td>kilometers</td>
</tr>
<tr>
<td>( s_{wfd} )</td>
<td>average speed between warehouse and delivery area</td>
<td>kilometers per hour</td>
</tr>
<tr>
<td>( s_{bd} )</td>
<td>average speed between deliveries</td>
<td>kilometers per hour</td>
</tr>
<tr>
<td>( dps )</td>
<td>deliveries per stop</td>
<td>-</td>
</tr>
<tr>
<td>( dps_{coeff} )</td>
<td>time coefficient if more than 1 deliveries per stop</td>
<td>-</td>
</tr>
<tr>
<td>( V_{autonomy} )</td>
<td>vehicle autonomy</td>
<td>kilometers</td>
</tr>
<tr>
<td>( V_{volume capacity} )</td>
<td>vehicle volume capacity</td>
<td>cubic meters</td>
</tr>
<tr>
<td>( V_{weight capacity} )</td>
<td>vehicle weight capacity</td>
<td>kilograms</td>
</tr>
<tr>
<td>( p_{vol} )</td>
<td>average parcel volume</td>
<td>cubic meters</td>
</tr>
<tr>
<td>( p_{wt} )</td>
<td>average parcel weight</td>
<td>kilograms</td>
</tr>
</tbody>
</table>
Methodology: Equations - Number of Deliveries per day

To find number of deliveries per day, the following steps are implemented:

1. Solve for \( n \) subject to

   **Time constraint**
   
   \[
   n_1 = \left( \frac{t_{lod} - \frac{2 \cdot d_{wfd}}{s_{wfd}} + \frac{d_{bd}}{s_{bd}} - t_{loading}}{d_{bd} + \left( 1 + (d_{ps} - 1) \cdot d_{ps_{coeff}} \right) \cdot t_{pd}} \right) \cdot d_{ps} \]
   \tag{17}

2. **Autonomy Constraint**

   \[
   n_2 = \left( v_{autonomy} - \frac{2 \cdot d_{wfd}}{s_{wfd}} \right) \cdot \frac{d_{bd}}{s_{bd}} + 1 \]
   \tag{18}

3. **Volume Constraint**

   \[
   n_3 = \frac{V_{\text{volume\_capacity}}}{p_{vol}} \]
   \tag{19}
Methodology: Equations - Number of Deliveries per day II

**4. Weight Constraint**

\[ n_4 = \frac{v_{weight\ capacity}}{p_{wt}} \]  \hspace{1cm} (20)

**5. Choose min from 17,18,19,20**

\[ n_{round1} = \min(n_1, n_2, n_3, n_4) \]  \hspace{1cm} (21)

**2. Determine time of round with \( n_{round1} \)**

\[ t_{round1} = 2 \frac{d_{wfd}}{s_{wfd}} + \left( n_{round1} \frac{d_{ps}}{s_{bd}} - 1 \right) \frac{d_{bd}}{s_{bd}} + \left( n_{round1} \frac{d_{ps}}{s_{bd}} \right) \left( 1 + (d_{ps} - 1) d_{ps_{coeff}} \right) t_{delivery} + t_{loading} \]  \hspace{1cm} (22)

**3. Determine no. of 'complete' rounds per day**

\[ r_n = \left\lfloor \frac{t_{lod}}{t_{round1}} \right\rfloor \]  \hspace{1cm} (23)
Methodology: Equations - Number of Deliveries per day III

4 Determine time left

\[ t_{left} = t_{lod} - r_n \times t_{round1} \]  \hspace{1cm} (24)

5 Determine number of other deliveries

1 Time constraint

\[ n_5 = \left( \frac{t_{left} - \frac{2 \times d_{wfd}}{s_{wfd}} + \frac{d_{bd}}{s_{bd}} - t_{loading}}{d_{bd} - \frac{s_{bd}}{s_{bd}} + ((1 + (d_{ps} - 1) \times d_{ps}_{coeff}) \times t_{pd})} \right) \times d_{ps} \]  \hspace{1cm} (25)

2 Autonomy Constraint will be same as 18
3 Volume Constraint will be same as 19
4 Weight Constraint will be same as 20
5 Choose min from 25,18,19,20

\[ n_{other} = min(n_5, n_2, n_3, n_4) \]  \hspace{1cm} (26)
Thus, from 23, 21,26, total deliveries in a day are given as:

\[ d_{total} = r_n \times n_{round1} + n_{other} \]  \hspace{1cm} (27)

- From \( d_{total} \), \( d_{total}^{week} \) is determined.
- This is applied across whole fleet to determine \( dfleet_{total}^{week} \).
- This is used to determine cost/delivery.
The Driver/Deliverer

- In conventional deliveries, the driver/deliverer accomplishes the last meters of the last mile and obtains a confirmation of delivery from the end customer.
- He is paid an hourly wage of 11 euros/hour. He works 40 hours/week.
- In deliveries using autonomous vehicles, the driver wage is zero.
**Table: Latent Knowledge in Drivers**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Skill/Knowledge</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Personal relationships with various inhabitants</td>
<td>- Alternate delivery possibilities (ex. If customer is not available, driver delivers to neighbour, based on previous agreements)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Accommodating non prepared return on other rounds (Especially true for business deliveries, If a return form a customer is not prepared, s/he can call the driver and inform them, making the round more efficient)</td>
</tr>
</tbody>
</table>
### Latent Knowledge II

| 2. | Knowledge of Parking spaces | - Concierge  
|    |                           |  
|    |                           | - Reduction of time spent to look for a parking space  
|    |                           | - Knowledge of parking time restrictions  
|    |                           | - Alternate parking spots  
| 3. | Knowledge of traffic conditions and trends | Ex. Higher traffic in a specific repeated delivery address at a particular time (commercial center)  
|    |                           | - Reordering delivery order to achieve faster overall delivery  

### Latent Knowledge III

<table>
<thead>
<tr>
<th>4.</th>
<th>Knowledge of geographical quirks</th>
<th>Ex. Access codes, GPS Map Failures : Dead Ends</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>- Driver saves a lot of time by already knowing the access code, or the requirement of it.</td>
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<tr>
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<td>- Driver aware of GPS failures in certain specific scenarios, ex. Dead ends, and avoids them.</td>
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</tbody>
</table>
An experienced driver can be 40% more effective during his/her rounds. “the difference between two of our drivers (D22 and D24) with similar round sizes and parcel volumes shows a considerable variation in effectiveness, with D22 driving 44% less distance, spending 35% less time per parcel, 29% less driving time per parcel, and 39% less parking time per parcel. The variation in effectiveness of our drivers relates to better route planning, exploitation of accumulated knowledge of the round, personal relationships with other stakeholders, the amount of time spent at the curbside and the influence of walking. These statistics show that more effective drivers achieve higher rate of delivery of parcels per minute while spending less time driving and parking in the van”. (Bates et al., 2018)