Side-walk robots as mobile parcel lockers – Helsingbotica project

Aim: A pilot in a suburb with robots replacing vans the last part of the trip

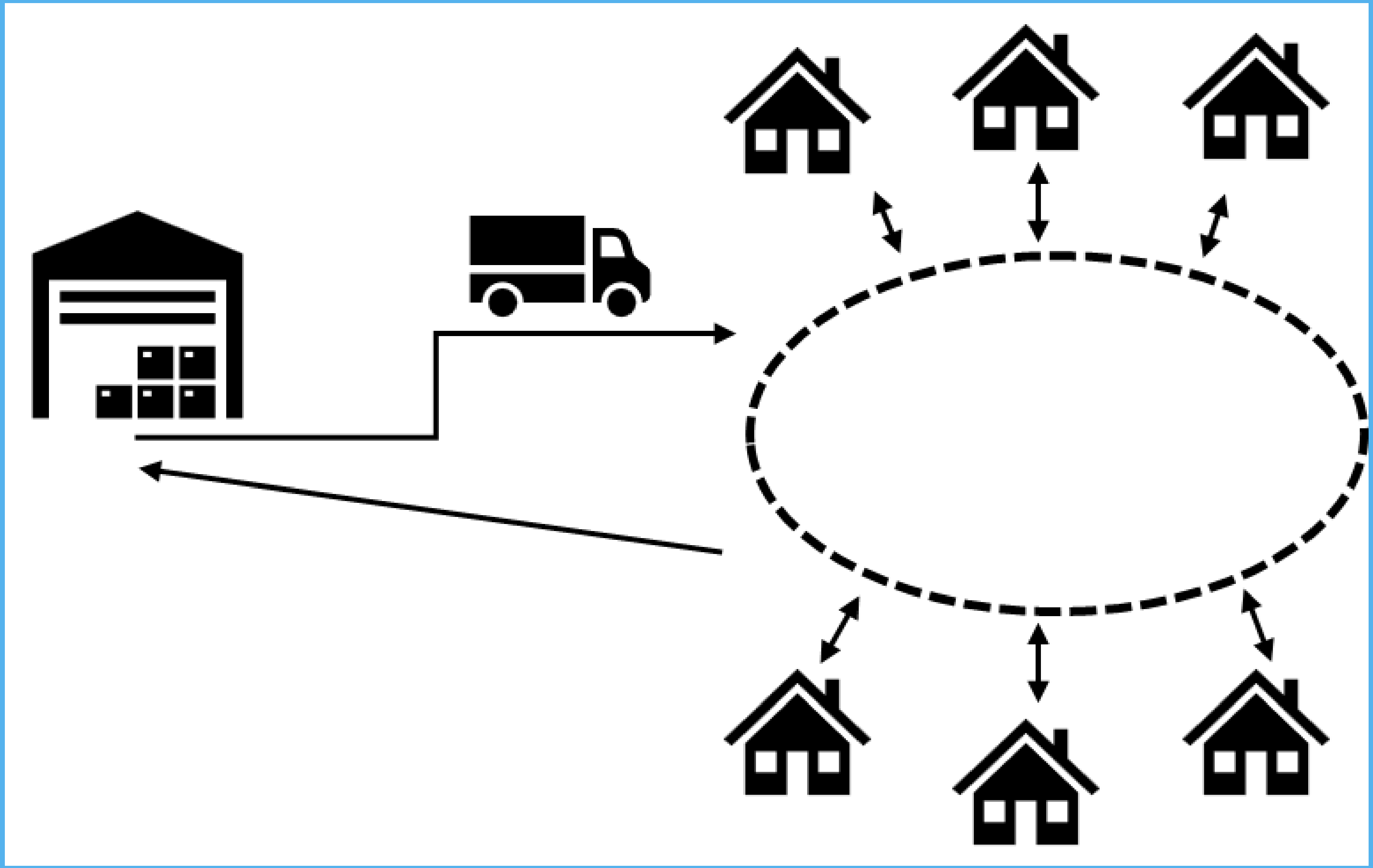
Partners:

- Hugo Delivery AB
- Helsingborgs Stad
- Apotea AB
- BEST Transport AB

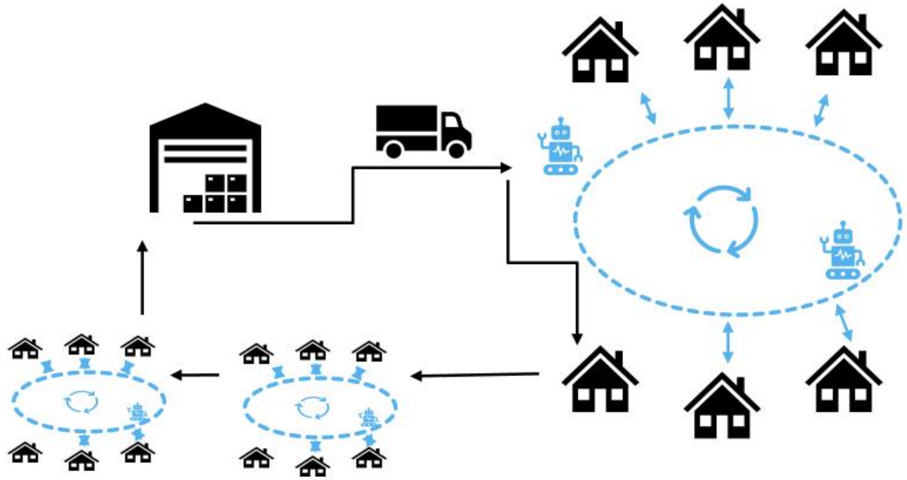
Koordinator: VTI

DRIVE SWEDEN

Current situation for package deliveries the last (kilo)meter: the “Milk run”



Robots for package deliveries the last (kilo)meter tomorrow: Community Robots



Examples of robots in descending order:
Hugo, LMAD, Starship

Problem formulation

$$\text{Minimize} \quad Z: \sum_{p\in P}\left(c^T\cdot x_p^T+\sum_{z\in Z}\sum_{r\in R_z} c_r\cdot x_{p,z,r}^R\right)+fc^T\cdot y^T+\sum_{z\in Z}\sum_{r\in R_z}(fc^R\cdot z_{z,r}^R+c^T\cdot z_{z,r}^R) \tag{1}$$

$$\sum_{r\in R_{z_p}} x_{p,z,r}^R + x_p^T = 1, \quad \forall p\in P \tag{2}$$

$$x_p^T = 1, \quad \forall p\in P \text{ where } w_p > m^W \text{ or } m_p > m^M \tag{3}$$

$$\sum_{p\in P:z_p=z} x_{p,z,r}^R \le mc^R\cdot z_{z,r}^R, \quad \forall z\in Z, \forall r\in R_z \tag{4}$$

$$\sum_{p\in P} x_p^T + \sum_{z\in Z}\sum_{r\in R_z} z_{z,r}^R \le y^T\cdot mc^T \tag{5}$$

$$x_{p_1,z,r}^R + x_{p_2,z,r}^R \le 1, \quad \forall z\in Z, \forall r\in R_z, \forall (p_1,p_2)\in P\times P, \text{ if } d_{p_1,p_2} > m^D \tag{6}$$

$$x_p^T \in \{0,1\}, \quad \forall p\in P \tag{7}$$

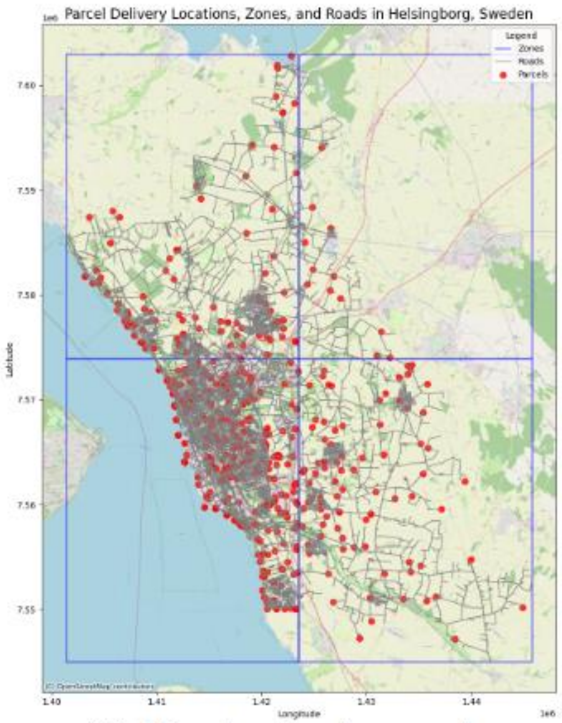
$$x_{p,z,r}^R \in \{0,1\}, \quad \forall p\in P, \forall z\in Z, \forall r\in R_z \tag{8}$$

$$z_{z,r}^R \in \{0,1\}, \quad \forall z\in Z, \forall r\in R_z \tag{9}$$

$$y^T \in \mathbb{Z}^+, \quad \text{(non-negative integer)} \tag{10}$$

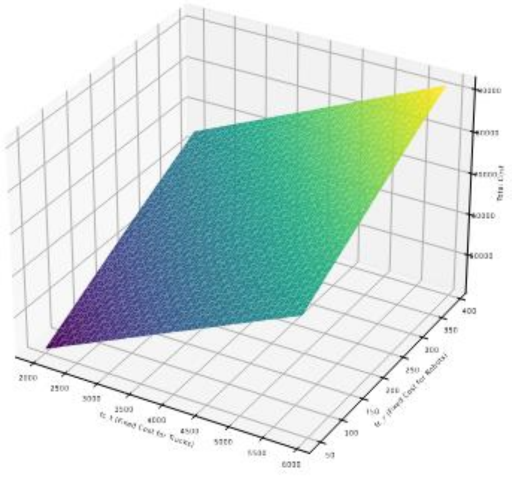
	Notation	Explanation
Parameters	P	Set of parcels.
	Z	Set of zones.
	R_z	Set of robots in zone z.
	mc^T	Maximum capacity of a truck (in parcels).
	mc^R	Maximum capacity of a robot (in parcels).
	c^T	Cost of delivering a parcel using a truck.
	c^R	Cost of delivering a parcel using a robot.
	fc^T	Fixed cost of using a truck.
	fc^R	Fixed cost of using a robot.
	d_{p_1,p_2}	Distance between parcels p_1 and p_2.
	m^D	Maximum distance between two parcels a robot can cover.
	m^W	Maximum weight a robot can carry.
	m^M	Maximum size of a parcel suitable for robot delivery.
	w_p	Weight of parcel p.
	m_p	Size (measurement) of parcel p.
	z_p	Zone of parcel p.
Indices	p	Parcel index, $p \in P$
	z	Zone index, $z \in Z$
	r	Robot index, $r \in R_z$
Variables	x_p^T	$\begin{cases} 1, & \text{if parcel } p \text{ is delivered by truck} \\ 0, & \text{otherwise} \end{cases}$
	$x_{p,z,r}^R$	$\begin{cases} 1, & \text{if parcel } p \text{ is delivered by robot } r \text{ in zone } z \\ 0, & \text{otherwise} \end{cases}$
	$z_{z,r}^R$	$\begin{cases} 1, & \text{if robot } r \text{ in zone } z \text{ is used} \\ 0, & \text{otherwise} \end{cases}$
	y^T	Number of trucks used

(a) Notation list.

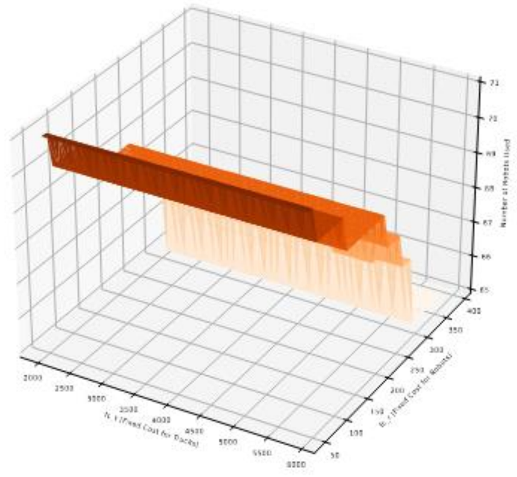


(b) Map showing the parcels.

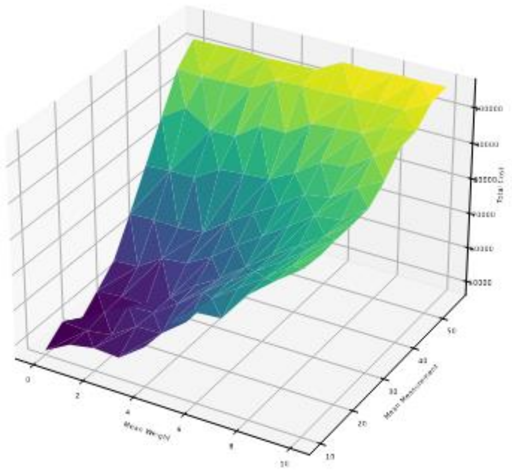
Figure 2. Overview of the notation list and of the study area showing a potential partial distribution to be optimized.



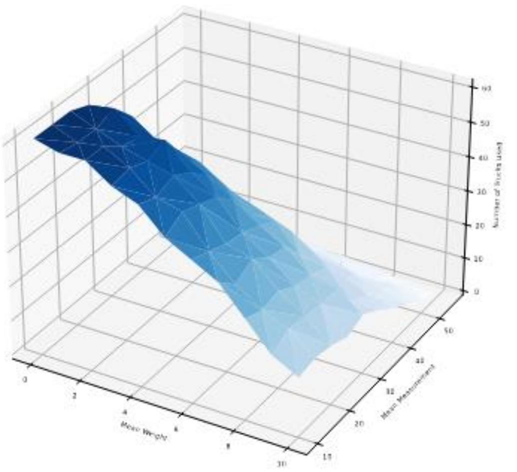
(a) Objective function as a function of fc_t and fc_r



(b) Number of robots as a function of fc_t and fc_r



(c) Impact of parcel characteristics on total costs



(d) Parcel characteristics and robots applied

Figure 3. Initial results of our sensitivity analysis.