

Artificial Intelligence for Improved Manufacturing & Logistics Process Performance

Prof Jacomine Grobler

26 May 2023



Photo by Stefan Els

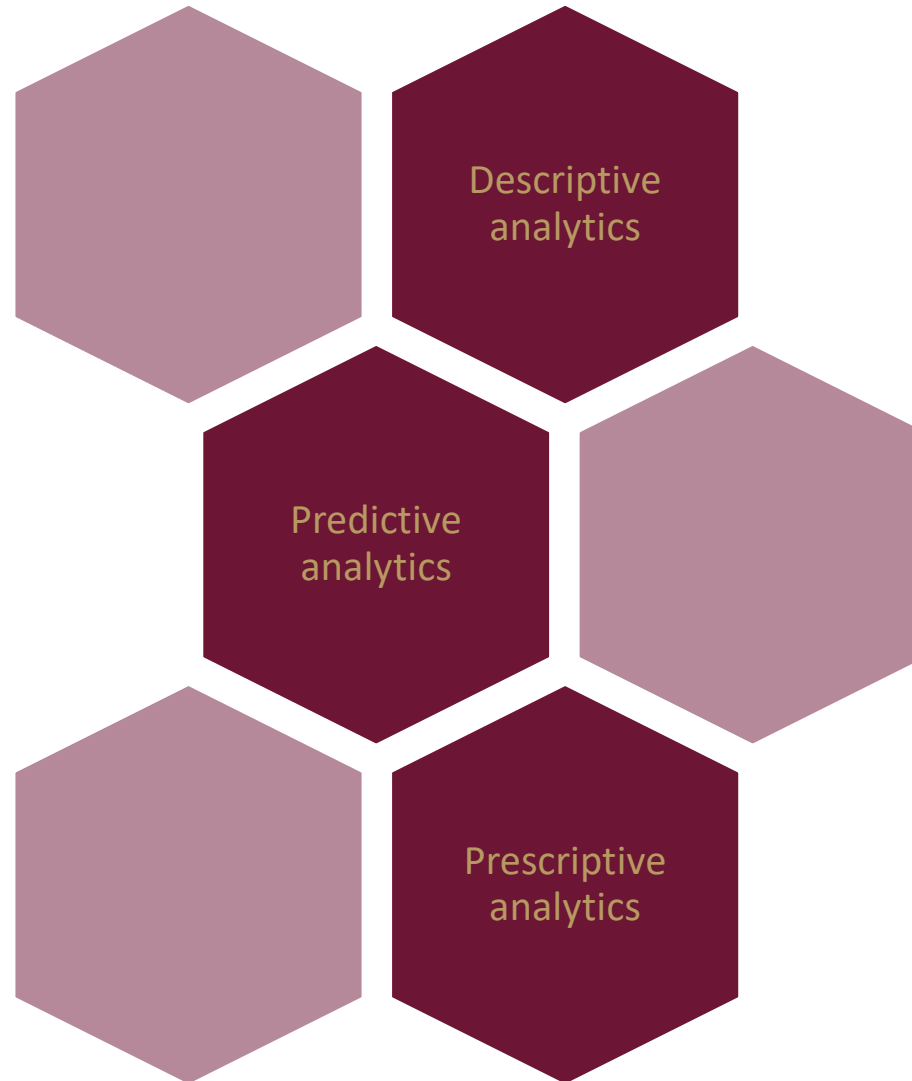


Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

forward together
sonke siya phambili
saam vorentoe

DATA

Making sense of the data...





Mozambican Cassava Suppliers



Cassava stiff porridge



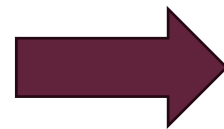
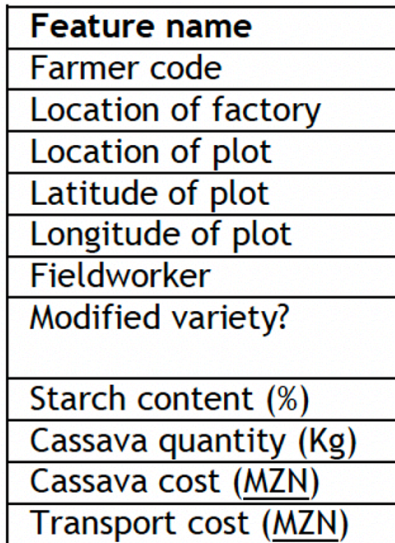
Boiled cassava roots



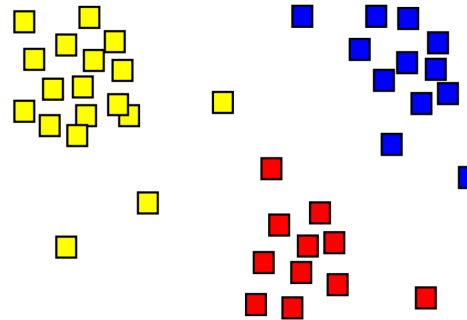
Cassava leaves

Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

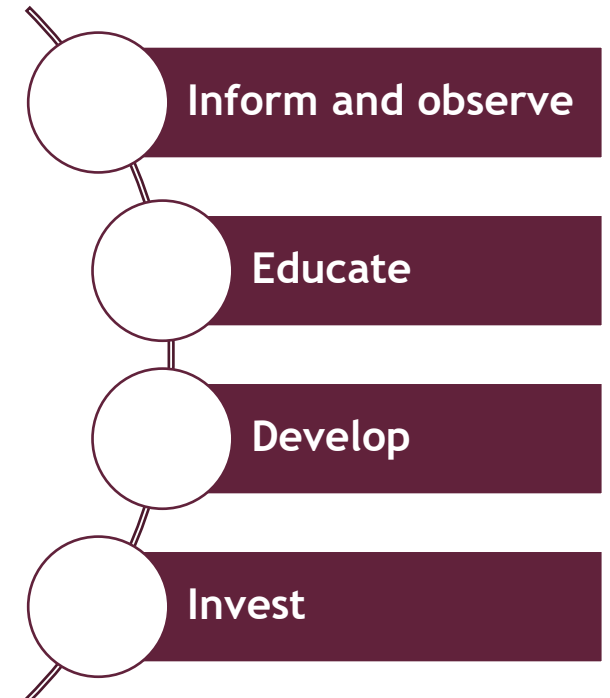
forward together
sonke siya phambili
saam vorentoe



- K-means
- AHC
- SOM



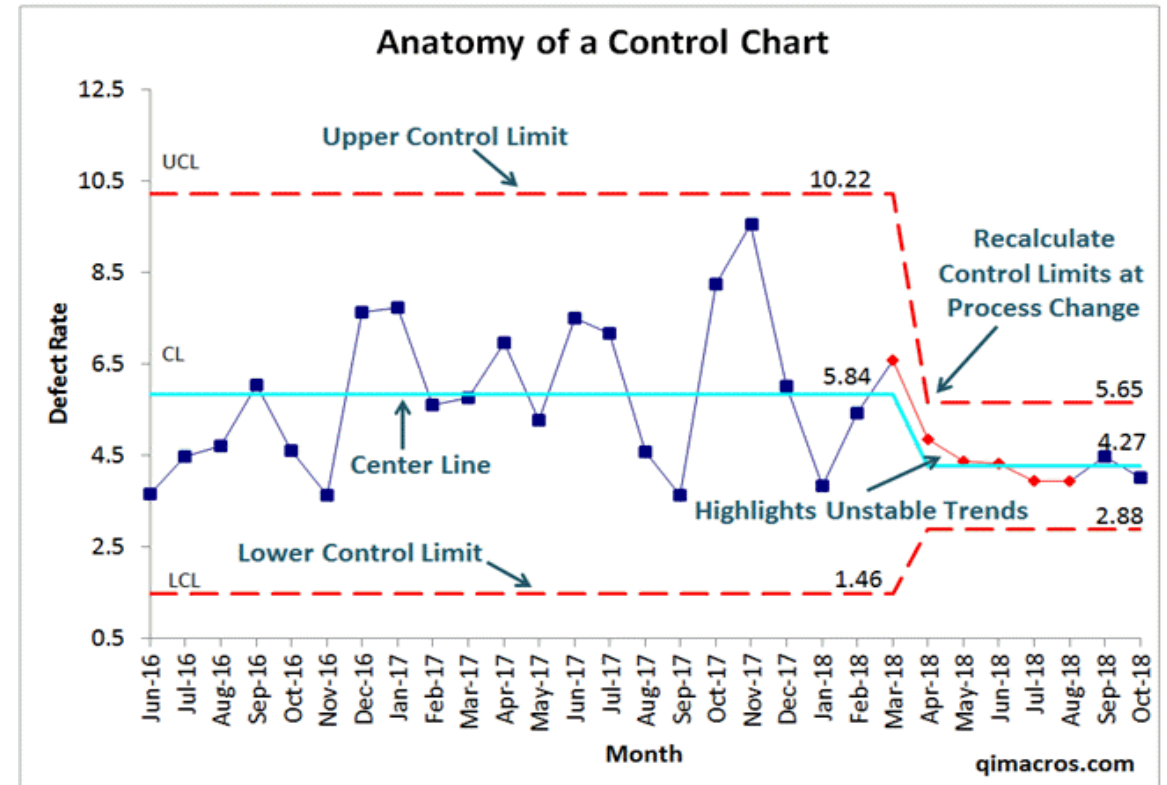
- Supply risk
- Effectiveness of operations
- Performance improvements



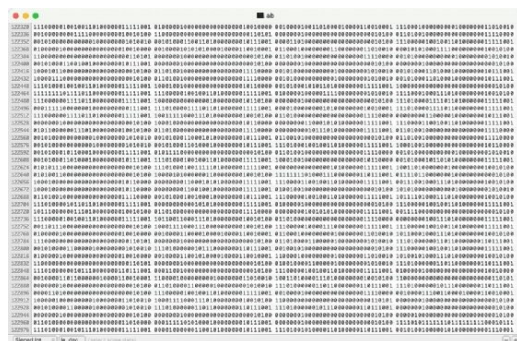
Engineering | EyobuNjineli | Ingenieurswese

Acknowledgements: Ntebaleng Matshabaphala

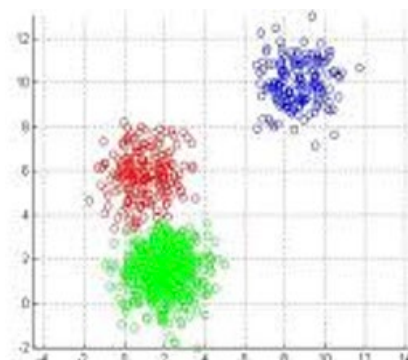
Using AI for manufacturing quality prediction



Clustering and classification



K-means



Pass	☒	Fail	☐
Pass	☒	Fail	☐
Pass	☒	Fail	☐
Pass	☒	Fail	☐
Pass	☒	Fail	☐
Pass	☐	Fail	☒
Pass	☒	Fail	☐
Pass	☐	Fail	☐

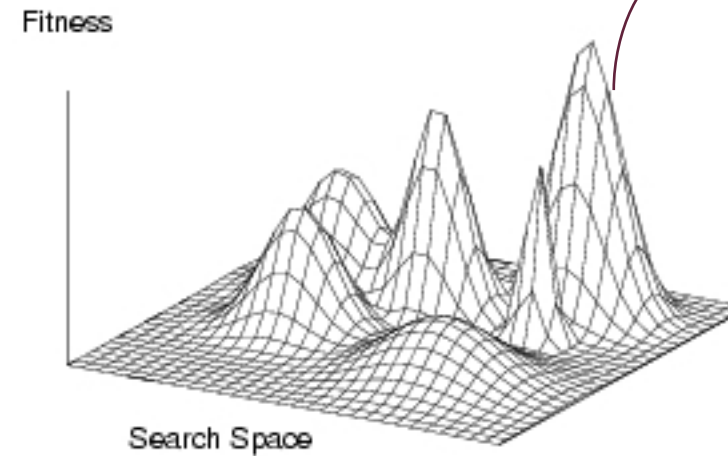
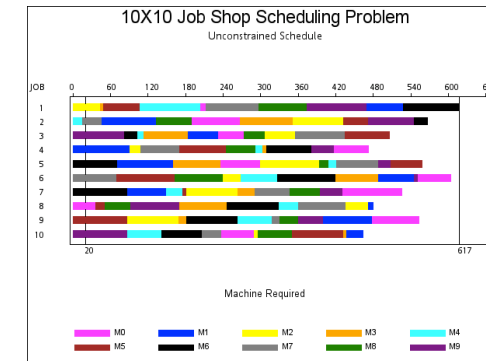
- 968 production line features
- 20 001 observations
- 0.56% failed products

- Naïve Bayes
- Support Vector Machines
- Random Forests

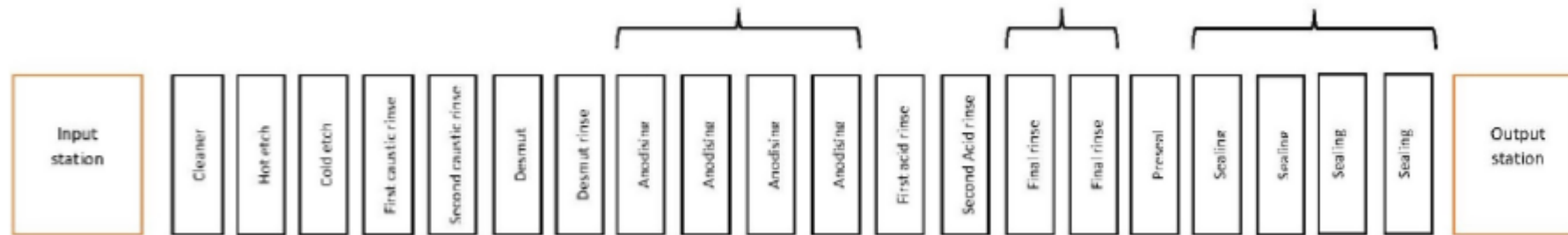
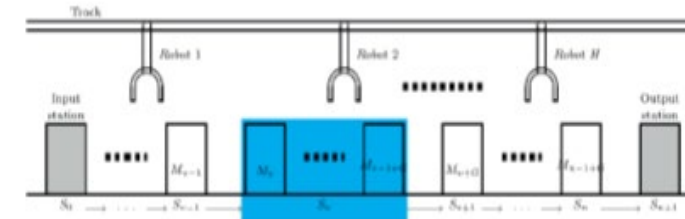
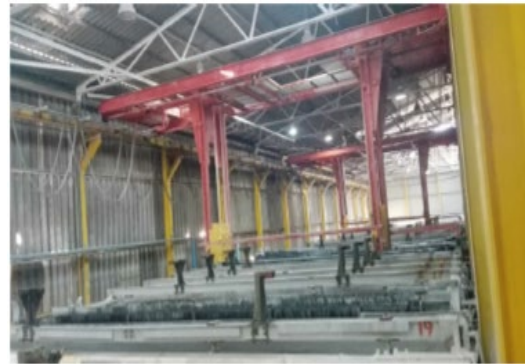
From 49.6% to 99.8%

Prescriptive analytics for scheduling

- Objective function
- Decision variables
- Constraints

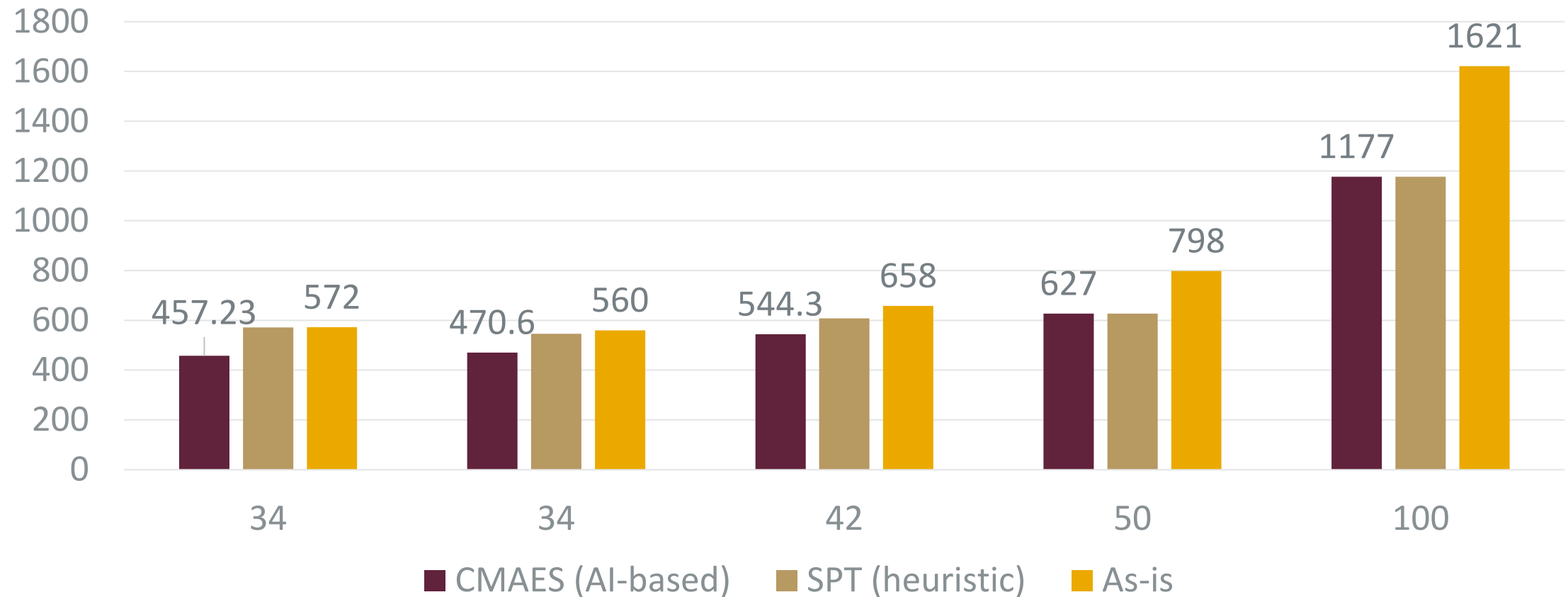


Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

[illegible][illegible]

Aluminium anodising scheduling

Completion time vs # customer nodes







Mathematical model



Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

forward together
sonke siya phambili
saam vorentoe

Interception time

$$TI^j = \frac{-2(\mathbf{c}^j - \mathbf{p}^j) \cdot (\mathbf{v}_t^{ik}) \pm \sqrt{2((\mathbf{c}^j - \mathbf{p}^j) \cdot \mathbf{v}_t^{ik})^2 - (4(v_d^2 - v_t^2)(-d(\mathbf{c}^j, \mathbf{p}^j)^2))}}{2(v_d^2 - v_t^2)}$$

Interception point

$$\mathbf{pI}^j = \mathbf{c}^i + (\mathbf{v}_t^{ik}) \cdot (TI^j + \delta^j + (\tau^j - s_i))$$

Truck and drone Mathematical model

$$x_{ijk} = \begin{cases} 1 & \text{if the truck services Node } i \text{ before } k \text{ while the drone services } j \text{ in between} \\ 0 & \text{Otherwise} \end{cases}$$

$$b_j = \begin{cases} 1 & \text{if the customer } j \text{ is serviced by the drone} \\ 0 & \text{if customer } j \text{ is serviced by the truck} \end{cases}$$

$$z_{ik} = \begin{cases} 1 & \text{if the truck travels between Nodes } i \text{ and } k \\ 0 & \text{Otherwise} \end{cases}$$

$$\min \sum_{i=1}^n \sum_{k=1}^n \sum_{j=1}^n x_{ijk} T_{ijk} \quad (4.3)$$

Subject to:

$$T_{1jk} - s_k \leq M(1 - x_{1jk}) \quad \forall j, k \in \{1, \dots, n\} \quad (4.4)$$

$$s_i + T_{ijk} - s_k \leq M(1 - x_{ijk}) \quad \forall i, j, k \in \{1, \dots, n\} \quad (4.5)$$

$$z_{ii} = 0 \quad \forall i \in \{1, \dots, n\} \quad (4.6)$$

Subject to:

$$z_{ii} = 0 \quad \forall i \in \{1, \dots, n\} \quad (4.4)$$

$$x_{iii} = 0 \quad \forall i \in \{1, \dots, n\} \quad (4.5)$$

$$z_{ik} = \sum_{j=1}^n x_{ijk} \quad \forall i, k \in \{1, \dots, n\} \quad (4.6)$$

$$b_j = \sum_{i=1}^n \sum_{k=1}^n x_{ijk} \quad \forall j \in \{1, \dots, n\} \quad (4.7)$$

$$\sum_{i=1}^n z_{iq} - \sum_{k=1}^n z_{qk} = 0 \quad \forall q \in \{1, \dots, n\} \quad (4.8)$$

$$\sum_{k=1}^n z_{ik} = 1 - b_i \quad \forall i \in \{1, \dots, n\} \quad (4.9)$$

$$\sum_{i=1}^n z_{ik} = 1 - b_k \quad \forall k \in \{1, \dots, n\} \quad (4.10)$$

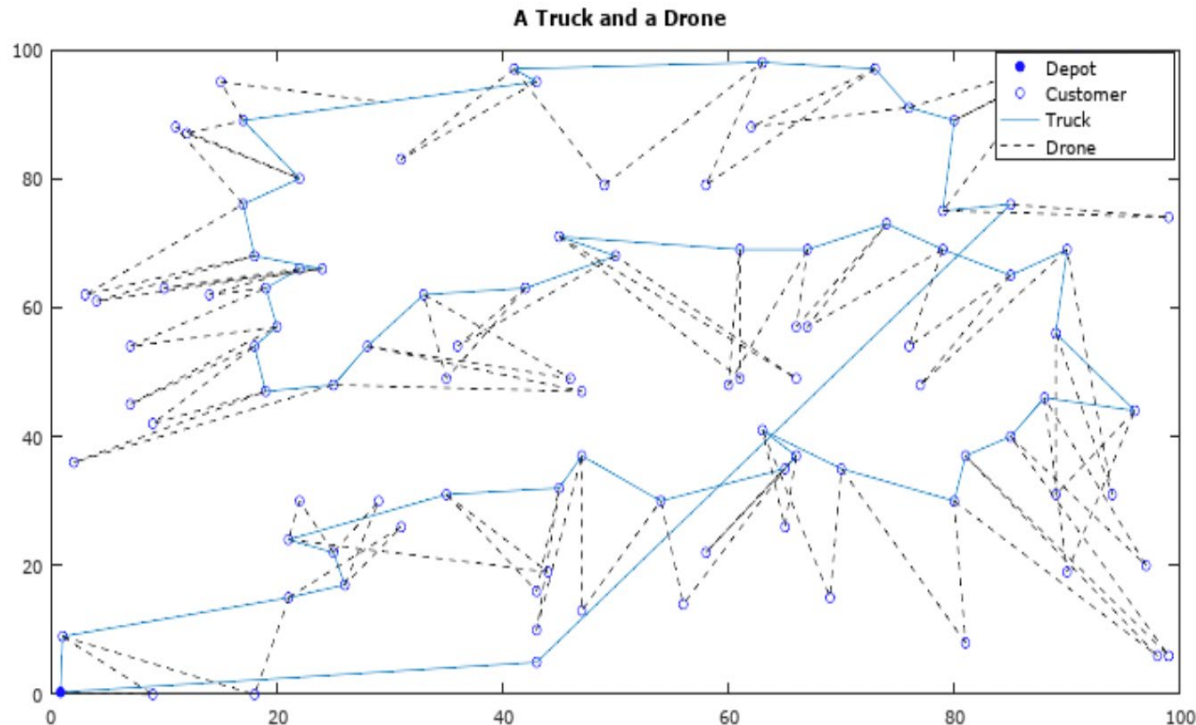
$$\sum_{j=1}^n x_{ijk} \leq 1 \quad \forall i, k \in \{1, \dots, n\} \quad (4.11)$$

$$u_i + z_{ij} \leq u_j + (n - 1)(1 - z_{ij}) \quad \forall i, j, j \neq 1 \in \{1, \dots, n\} \quad (4.12)$$

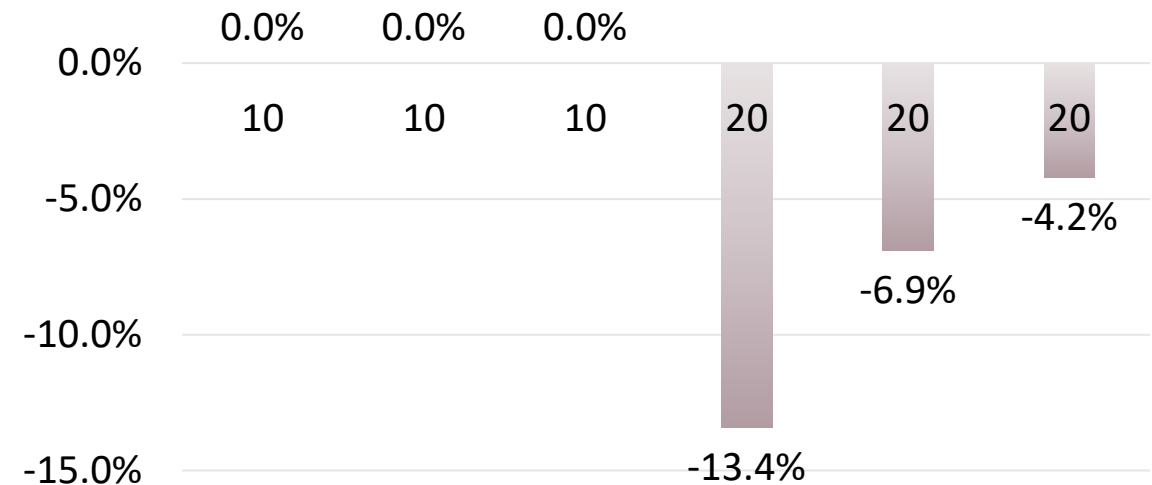
$$u_1 = 0 \quad (4.13)$$

$$x_{ijk}, b_i, z_{ik} \in \{0, 1\} \quad \forall i, j, k \in \{1, \dots, n\} \quad (4.14)$$

Optimal vs AI-based Algorithm Results

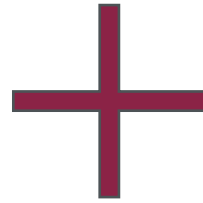
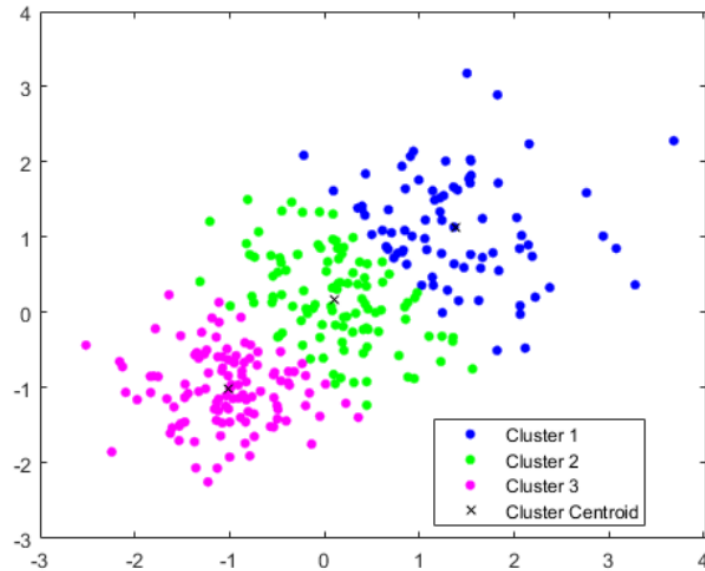


% decrease in performance per customer nodes

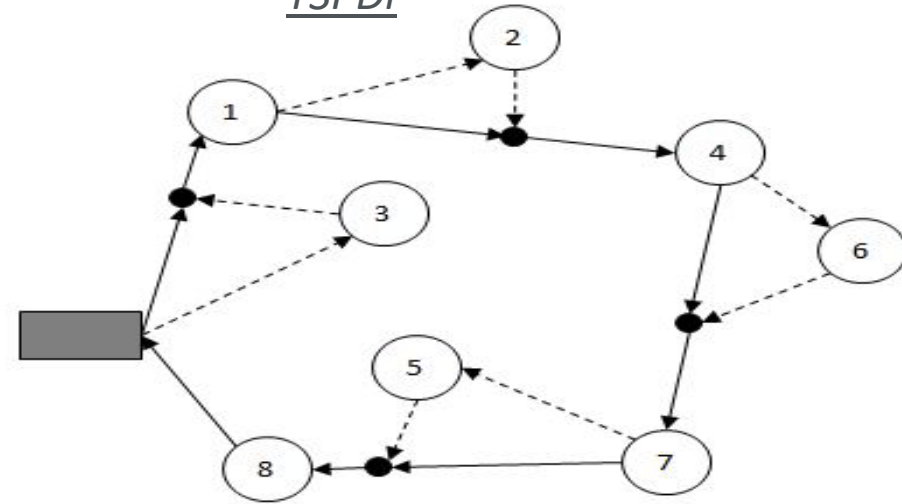


Multiple trucks and drones (VRPDi)

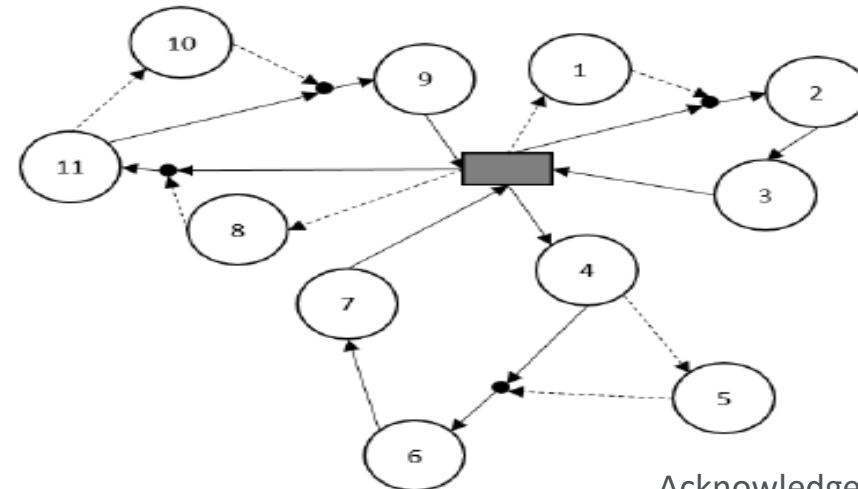
K-means Clustering



TSPDi

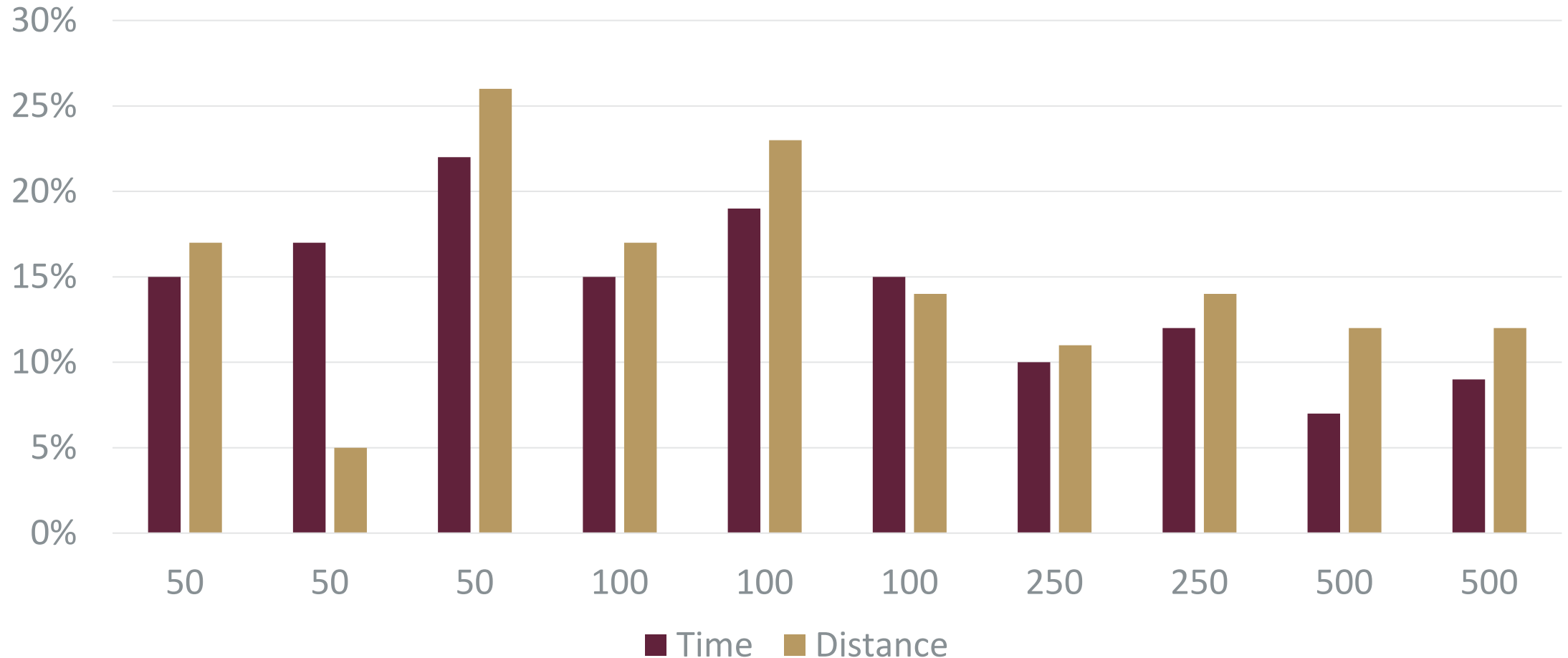


VRPDi



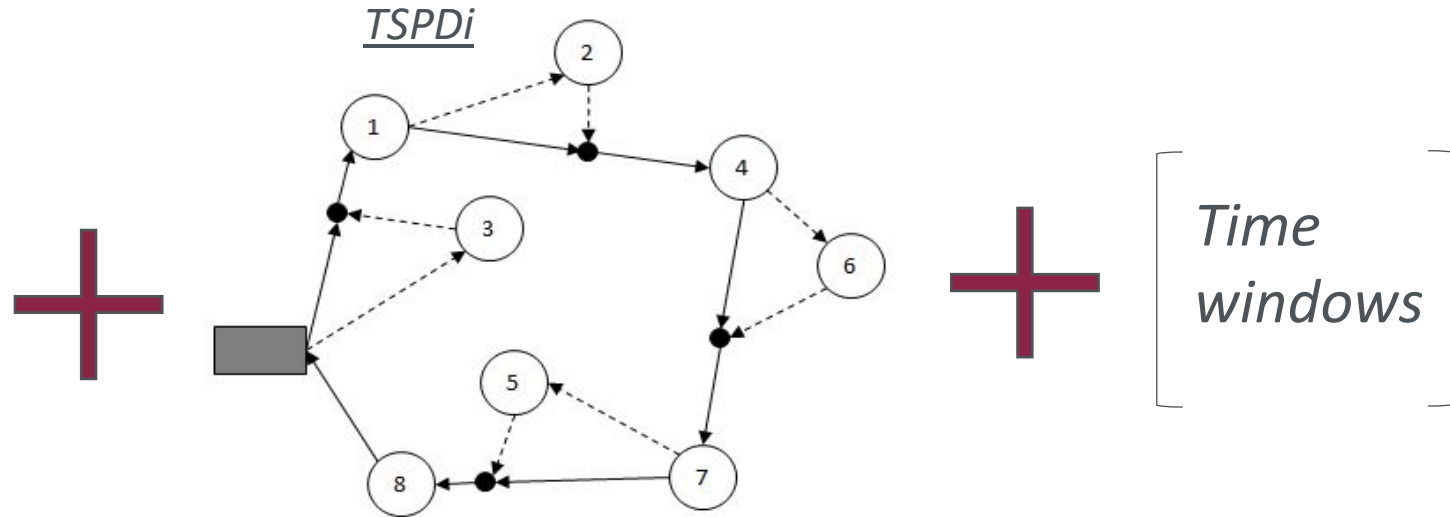
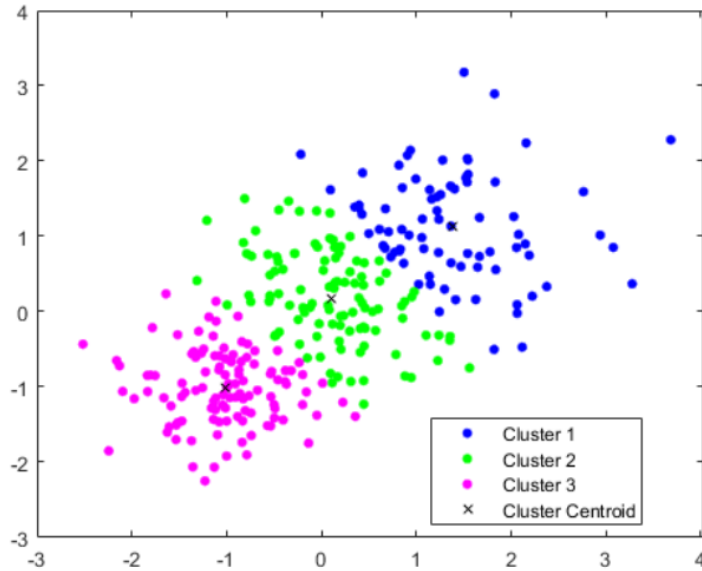
Truck-only vs truck-and-drone system

% Improvement vs # customer nodes



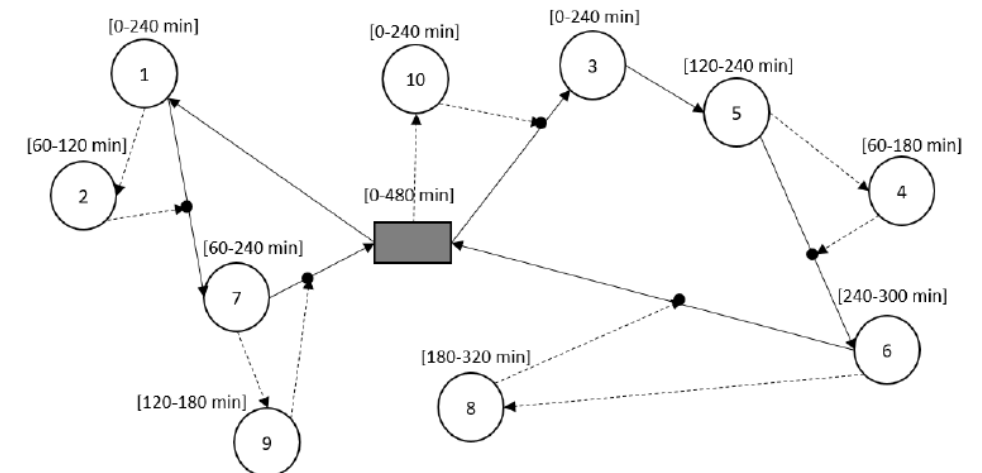
VRPDi with time windows

K-means Clustering



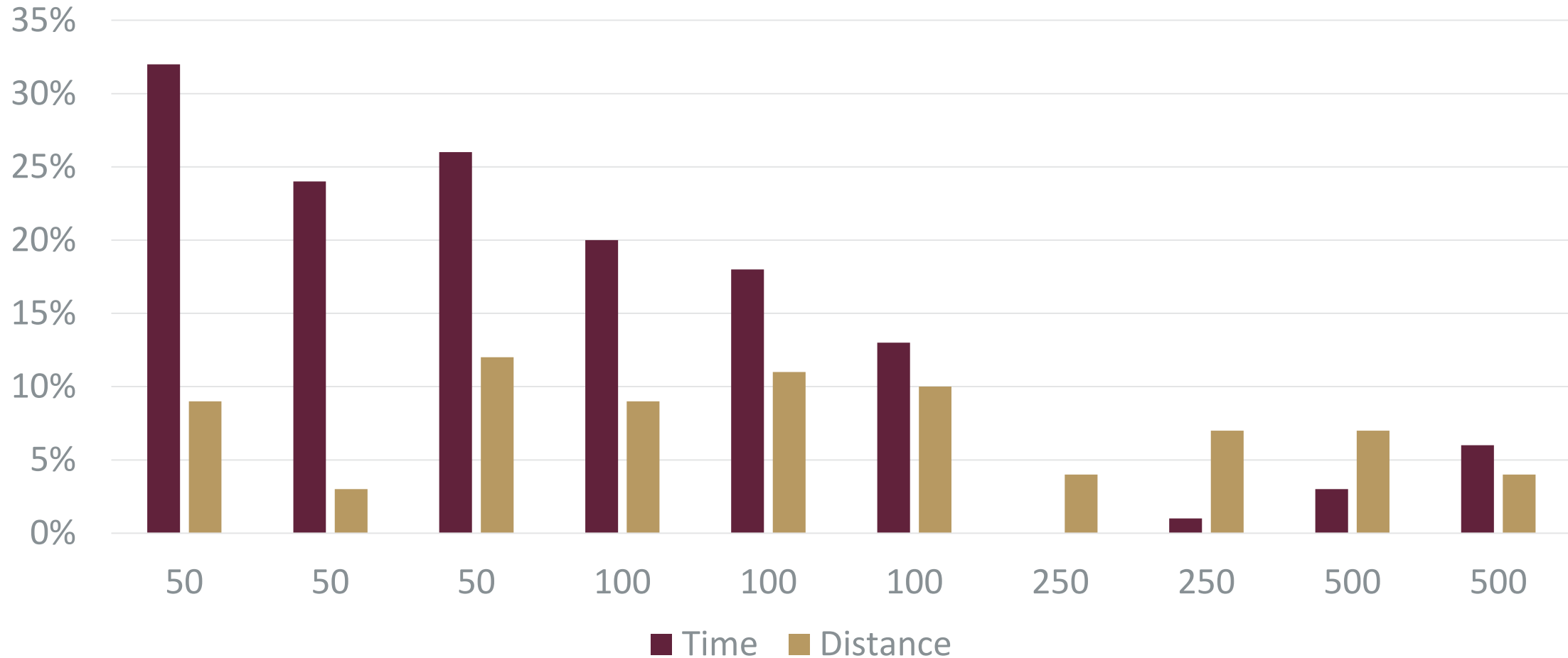
Time windows

VRPDiTW



Truck-only vs truck-and-drone system (with time windows)

% improvement vs # of customer nodes



Artificial Intelligence for Improved Manufacturing & Logistics Process Performance

Thank you
Enkosi
Dankie



Photo by Stefan Els