Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

Leveraging Digital Twins for Enhanced Sustainable Warehouse Management

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Contexte and Introduction

New sustainability challenges

The government has signed voluntary sustainability commitment charters with major e-commerce and warehousing actors

5.5 to 10% of global GHG emissions are attributed to transport and logistics activities

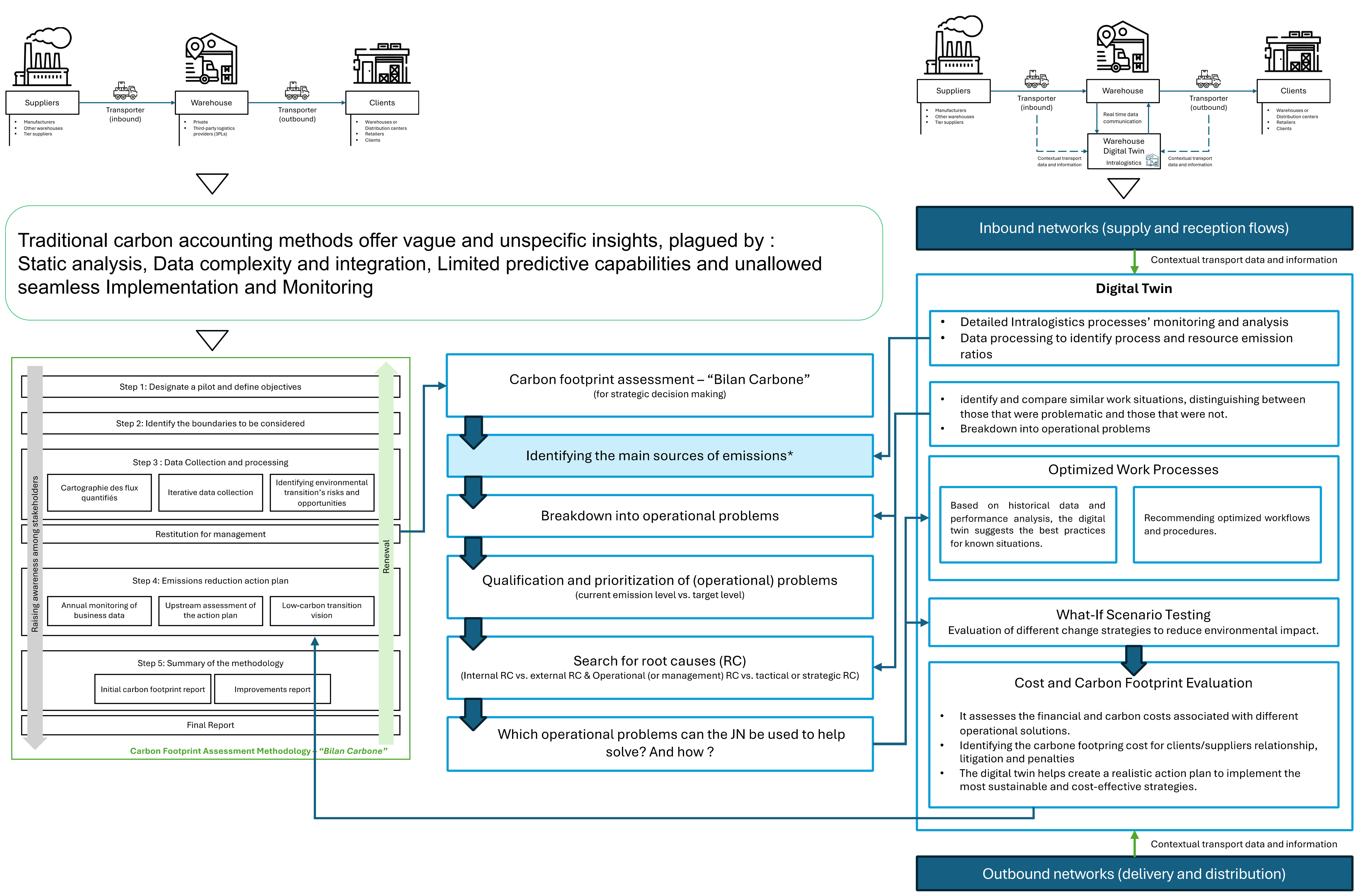
of which 11% are due to warehousing activities

Research Gaps

Challenges in sustainability supervision due to inadequate instrumentation and information systems overlooking environmental and social considerations.

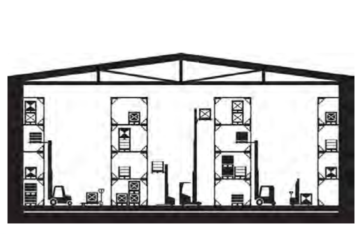
Scarcity of literature combining digital twins and sustainable warehousing.

Problem Description and Methodology



Next Steps and Research perspectives

Next steps : *Establishing the experiment using a 3PL's data*



Quantitative and iterative Top-Down and Bottom-Up evaluation of the results obtained from both methodologies (classic vs digital twin enabled carbon accounting)

Next steps

Digital twin assisted calculation of the environmental impact of warehousing/intralogistics (lifecycle analysis).

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Leveraging Artificial Intelligence for Advancing Circular Economy: Challenges, Opportunities, and Real-World Applications

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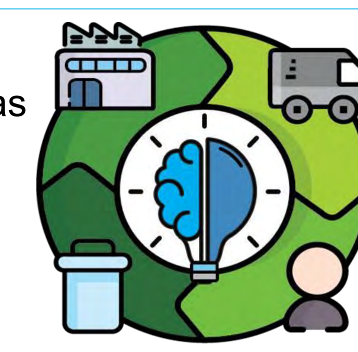
Introduction

Transforming Waste into Value: The Circular Economy

- The circular economy (CE) aims to decouple economic growth from resource consumption by keeping products and materials in use as long as possible. This involves reducing waste, reusing materials, and recycling efficiently.
- The CE is a fundamental shift from the traditional linear model of "take, make, waste" to a closed-loop system that minimizes environmental impact and maximizes resource efficiency.

The Power of AI in the CE

- Artificial intelligence (AI) is a powerful tool for enabling and accelerating the transition to a circular economy.
- AI can analyze vast amounts of data, optimize processes, and predict outcomes, making it a valuable asset for driving sustainability and resource efficiency.

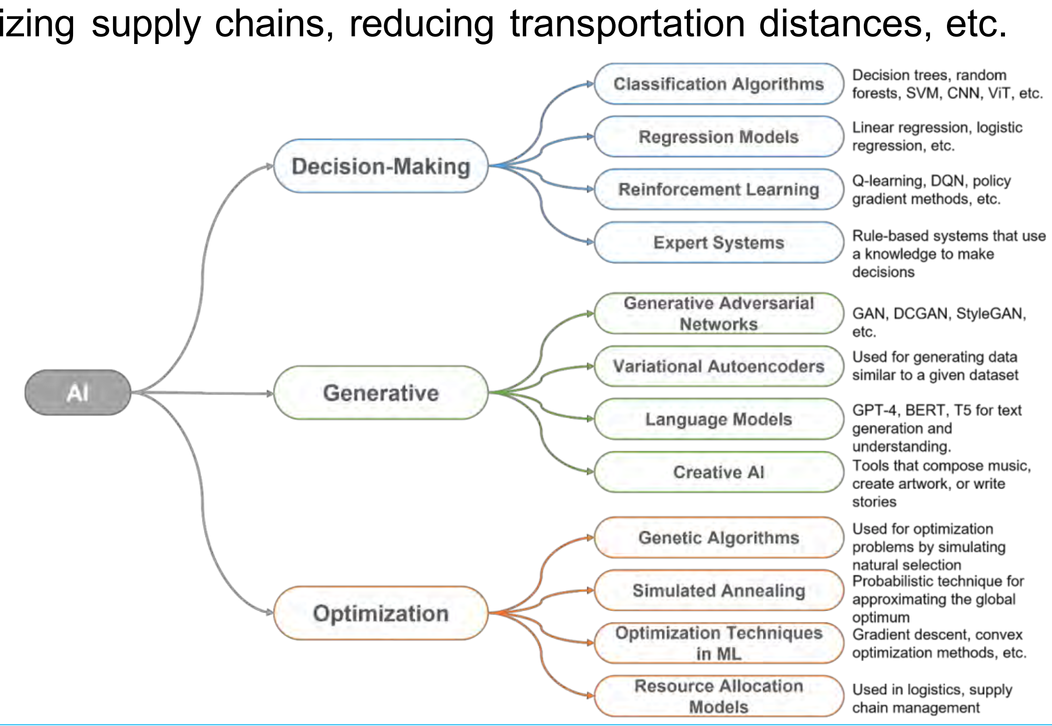


AI4CE

AI Categorization and Capabilities

AI : Application-oriented AI categorization

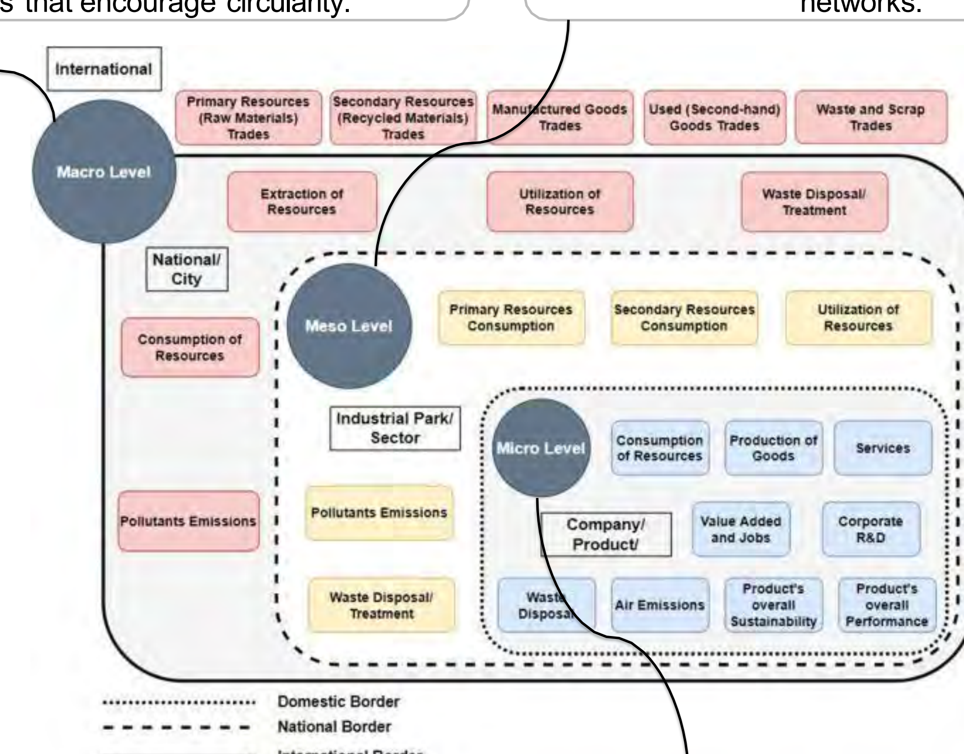
- **Decision-Making AI:** Uses algorithms to analyze data and make informed decisions, for example, identifying the most efficient way to sort waste, optimizing resource allocation, or predicting potential product failures.
- **Generative AI:** Creates new solutions and products, such as designing sustainable materials, developing new recycling techniques, or generating innovative business models for circularity.
- **Optimization AI:** Finds the best solutions to achieve specific goals, including optimizing supply chains, reducing transportation distances, etc.



AI's Potential in CE

AI can support national-level initiatives by forecasting resource needs, promoting sustainable business models, and developing policies that encourage circularity.

AI can be integrated into industrial parks and smart cities to optimize resource flows, manage waste effectively, and enhance transportation networks.



AI can be used within individual businesses to optimize waste sorting, improve product design, and track product lifecycles.

AI-Powered Approaches to Boost the CE

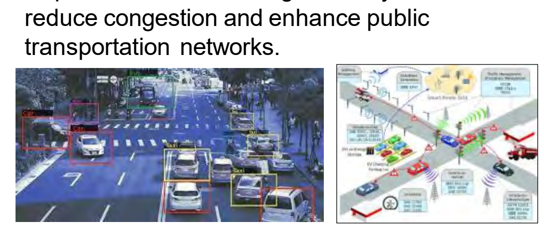
AI for CE

Waste Management

- AI-powered systems can automatically sort and classify waste, improving recycling efficiency and reducing contamination.
- AI can also optimize waste collection routes, reducing transportation costs and emissions.

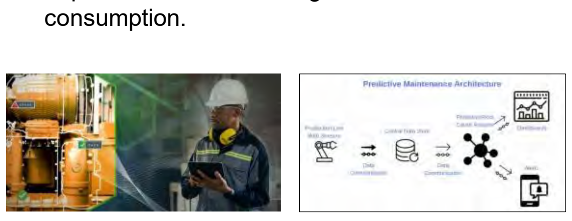
Sustainable Transportation

- AI can optimize vehicle performance and energy efficiency, reducing fuel consumption and promoting cleaner transportation.
- AI-powered traffic management systems can reduce congestion and enhance public transportation networks.



Predictive Maintenance

- AI can predict equipment failures, enabling timely maintenance and extending the lifespan of products, thus reducing waste and resource consumption.



Supply Chain

- AI can optimize supply chain processes, ensuring that materials are used efficiently and waste is minimized.
- AI-driven systems can also track products throughout their lifecycle, enabling efficient reuse and recycling.

Challenges and Future Directions

Overcoming the Barriers

- ***Data Availability and Interoperability:*** The lack of readily available and standardized data can hinder AI applications in the circular economy.
- ***Ethical Considerations:*** It's essential to address potential biases, privacy concerns, and societal impacts of AI applications in circular economy initiatives.
- ***Implementation Costs:*** Adopting AI technologies can require significant investment, potentially posing a challenge for some businesses.

A Sustainable Future

- To fully realize the potential of AI in the circular economy, ongoing research, development, and collaboration are crucial.
- Policymakers need to create an environment that encourages the adoption of AI and supports circular economy initiatives.
- AI has the potential to revolutionize how we manage resources and address environmental challenges, paving the way for a more sustainable future.

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Spatial-Temporal Graph Neural Networks for On-Street Parking Space Prediction

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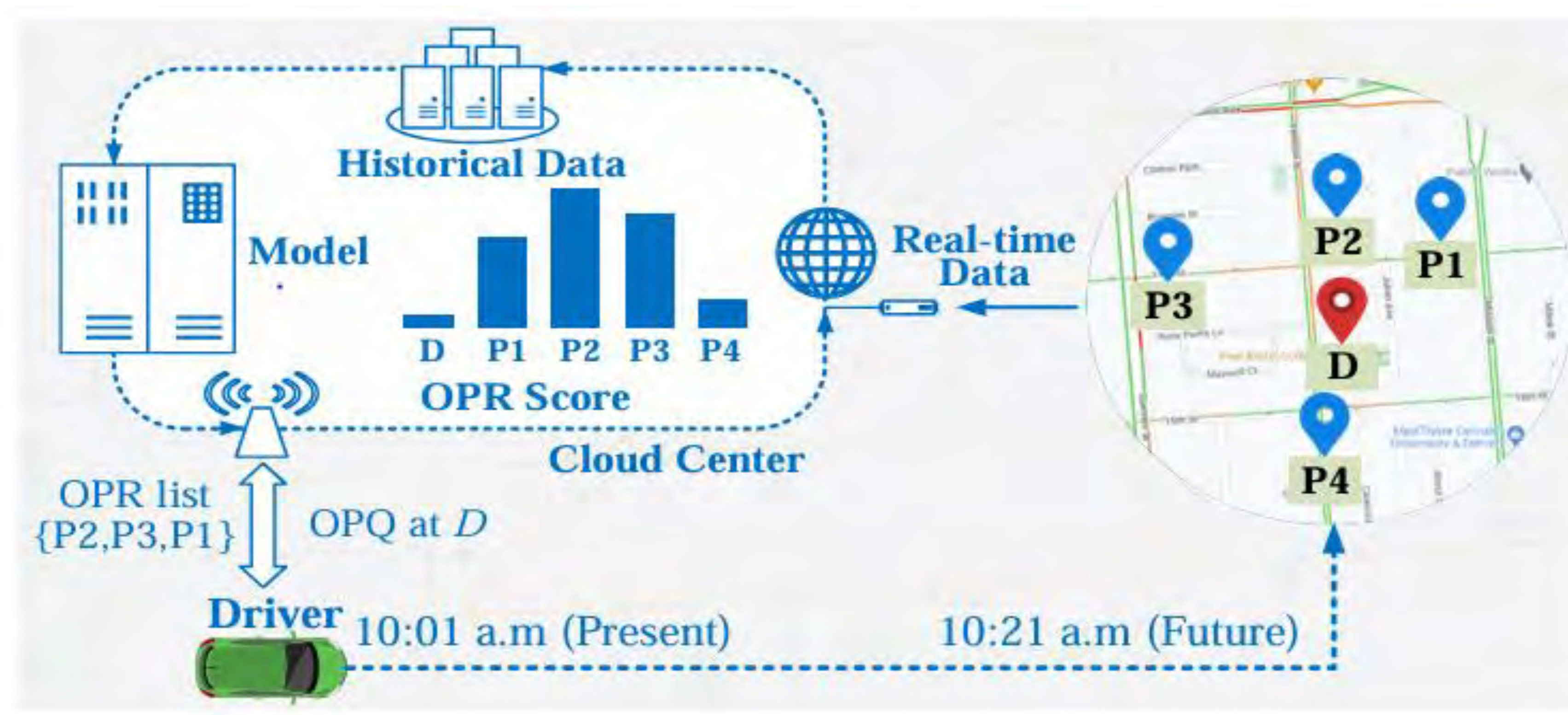
Introduction

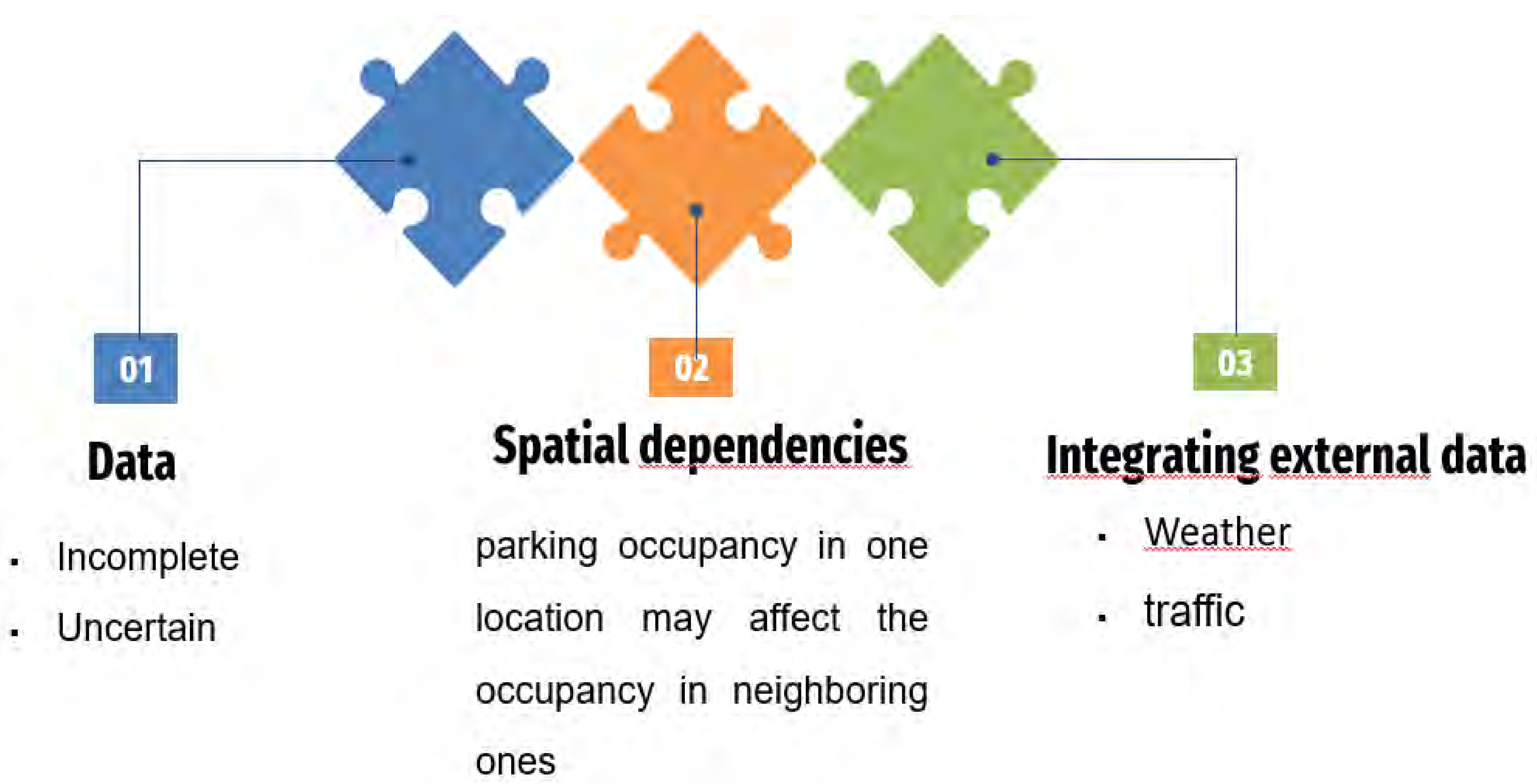
Parking management play a significant role in supporting sustainable urban development :



Challenges and Methods

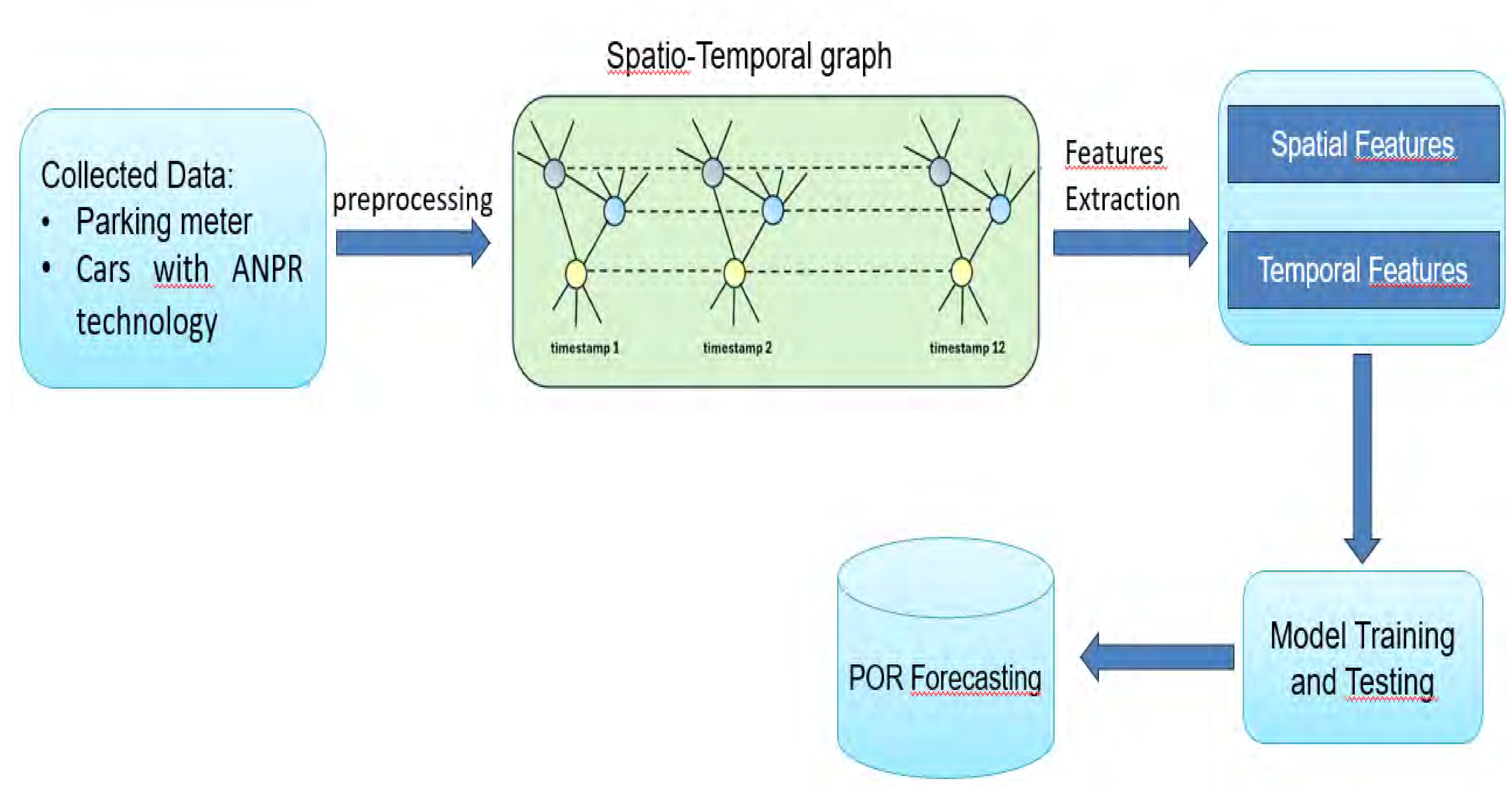
Challenges

Challenges associated with on-street parking demand prediction :



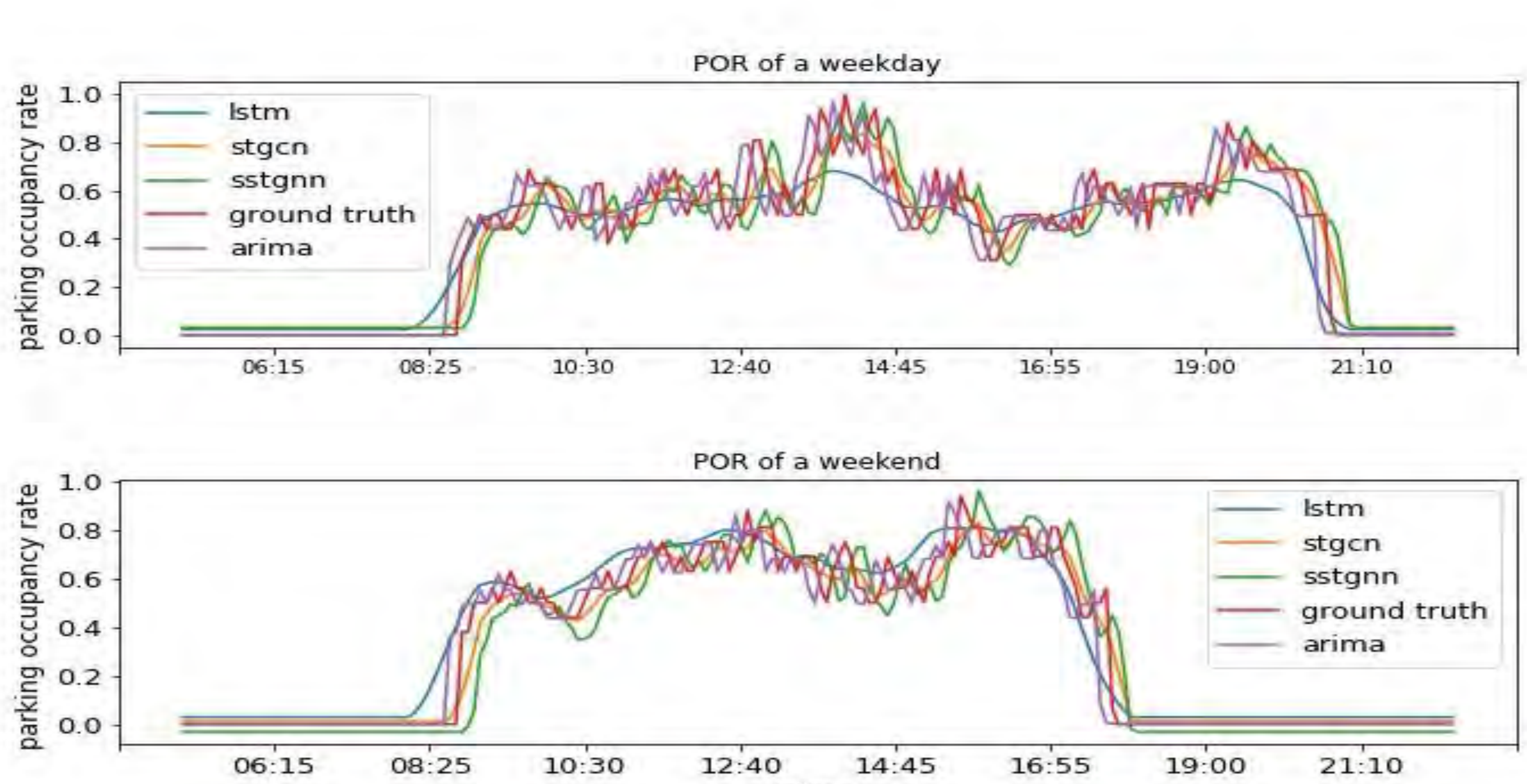
Methods

Spatial-Temporal Graph Neural Networks for POR prediction

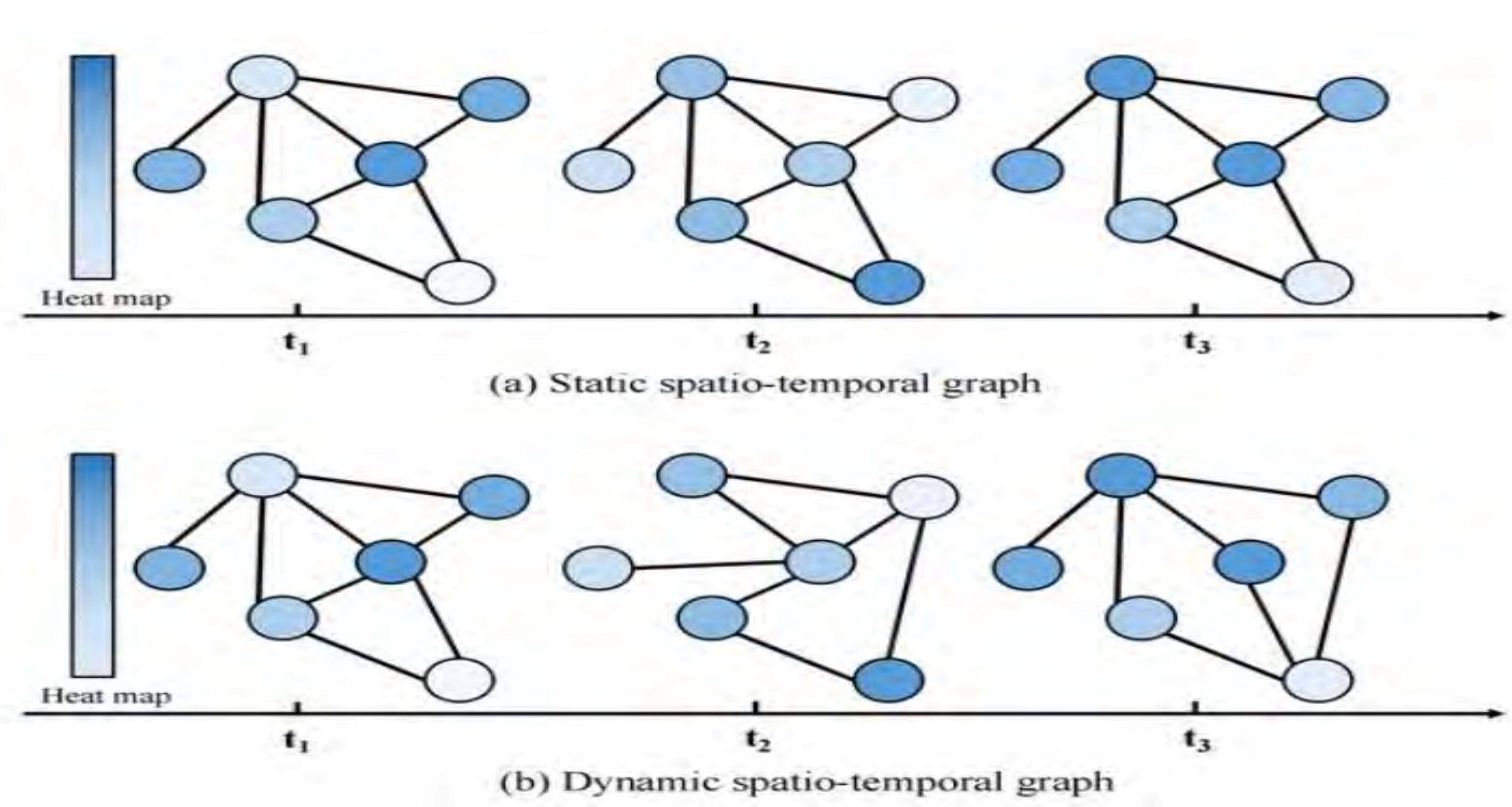


Results and future work

POR prediction of a randomly selected parking block with a 15-min time horizon on a weekday and a weekend



In the future, we plan to design a novel matrix to describe the interactions between different parking locations.



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Adaptive Learning for Dyslexic Students in the Metaverse Using Generative AI

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Context

- Dyslexia affects about **10% of the population**, leading to difficulties in reading, writing, and spelling.
- Traditional educational methods often fall short in addressing the unique needs of dyslexic students.
- The **Metaverse** and **Generative AI** offer new possibilities for creating adaptive learning environments.

Dyslexia

Dyslexia is a learning disorder characterized by difficulties with accurate and/or fluent word recognition and by poor spelling abilities.

Different Types of Dyslexia :

- Phonological dyslexia
- Surface dyslexia
- Mixed dyslexia

Signs Of Dyslexia

State of the Art

Current educational technologies mainly focus on web and mobile platforms, often employing gamification. However, they lack integration **with immersive environments** like the metaverse. Existing research **primarily targets children**, neglecting the needs of adult dyslexic learners.

This gap highlights the necessity for innovative solutions tailored to dyslexic students **within the metaverse.**

EasyLexia: Main page layout

Adaptive Learning Technologies for Dyslexic Students

Research questions

Q1/ How can Generative AI be utilized to create personalized learning content for dyslexic adults in the Metaverse?

Q2/ What features of VR/AR environments are most effective in enhancing the learning experience for dyslexic adults?

Q3/ What methodologies can be implemented to evaluate the effectiveness of adaptive learning systems in improving educational outcomes for dyslexic adults?

Conclusion

Our preliminary research indicates that generative AI in the metaverse has the potential to transform the educational experiences of dyslexic students.

By creating a dynamic and adaptive learning environment, we can address their unique challenges and unlock their full potential .

Future Work

Refining AI Models: Enhancing algorithms to better address dyslexic learners' needs.

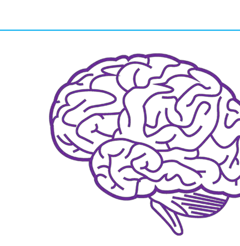
Longitudinal Studies: Assessing long-term impacts on academic outcomes and well-being.

Experiments in the Metaverse: Implementing and evaluating educational interventions.

Data Collection and Analysis: Using analytics to improve adaptive systems.

Publishing Results: Sharing findings through academic papers and presentations.

Approach



We will use Generative AI to create adaptive learning experiences for dyslexic students in the Metaverse.
By collecting user data, we will personalize educational content to meet individual needs. This content will be delivered through immersive VR/AR environments, ensuring interactive and engaging learning.

Références

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Rello, L., Otal, Y., Pielot, M., 2014. A Computer-Based Method to Improve the Spelling of Children with Dyslexia. ASSETS'14. The 16th international ACM SIGACCESS conference on Computers & accessibility,

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Location routing problem in a Physical Internet context

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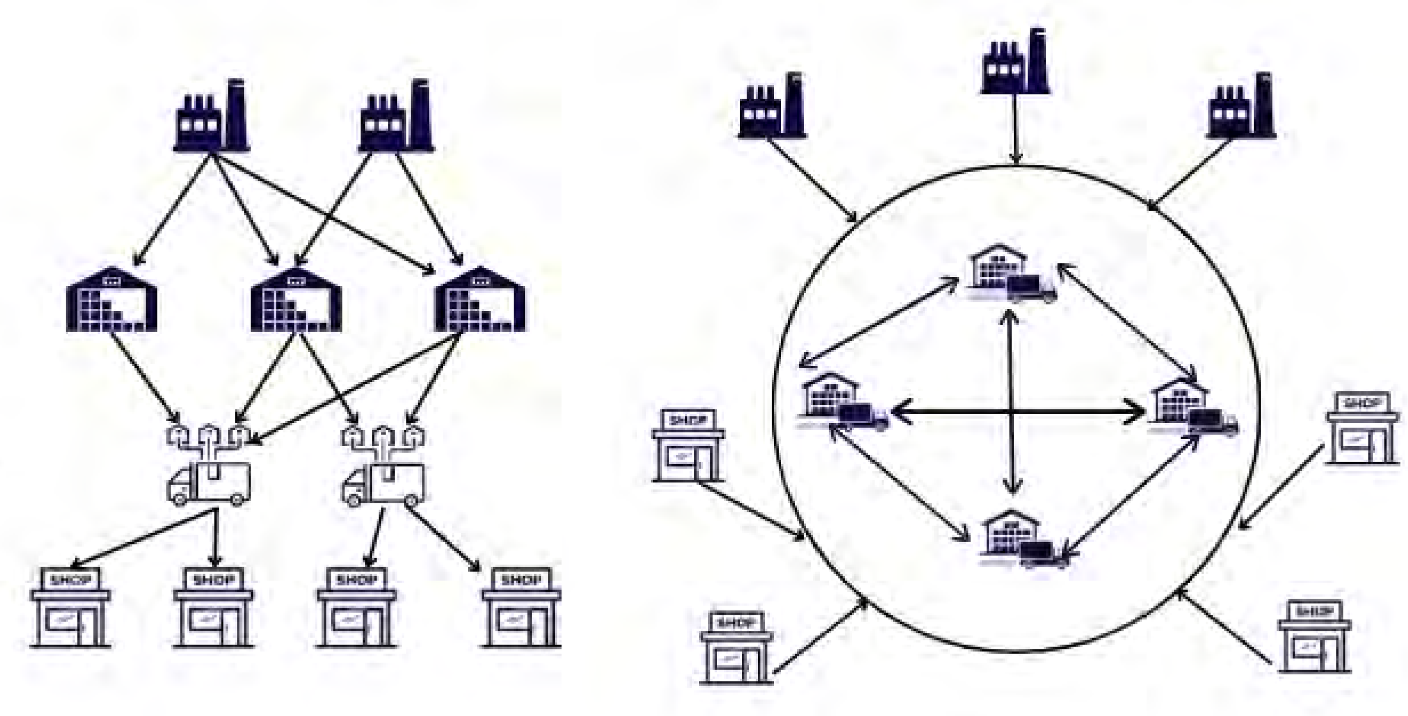
Introduction

Context

- A new concept to ensure the global mobility of physical goods.
- Inspired from the way computers are interconnected through the (digital) Internet.
- Encapsulating products in standardized modular containers.



Classical network — PI network

Physical Internet network

- Designed to be more adaptable to supply chain disruptions.
- Shared network infrastructure among multiple companies.
- Centralized hubs facilitate efficient distribution.
- Promotes collaboration and resource sharing

Research

Problem description

Location routing problem in the context of Physical internet

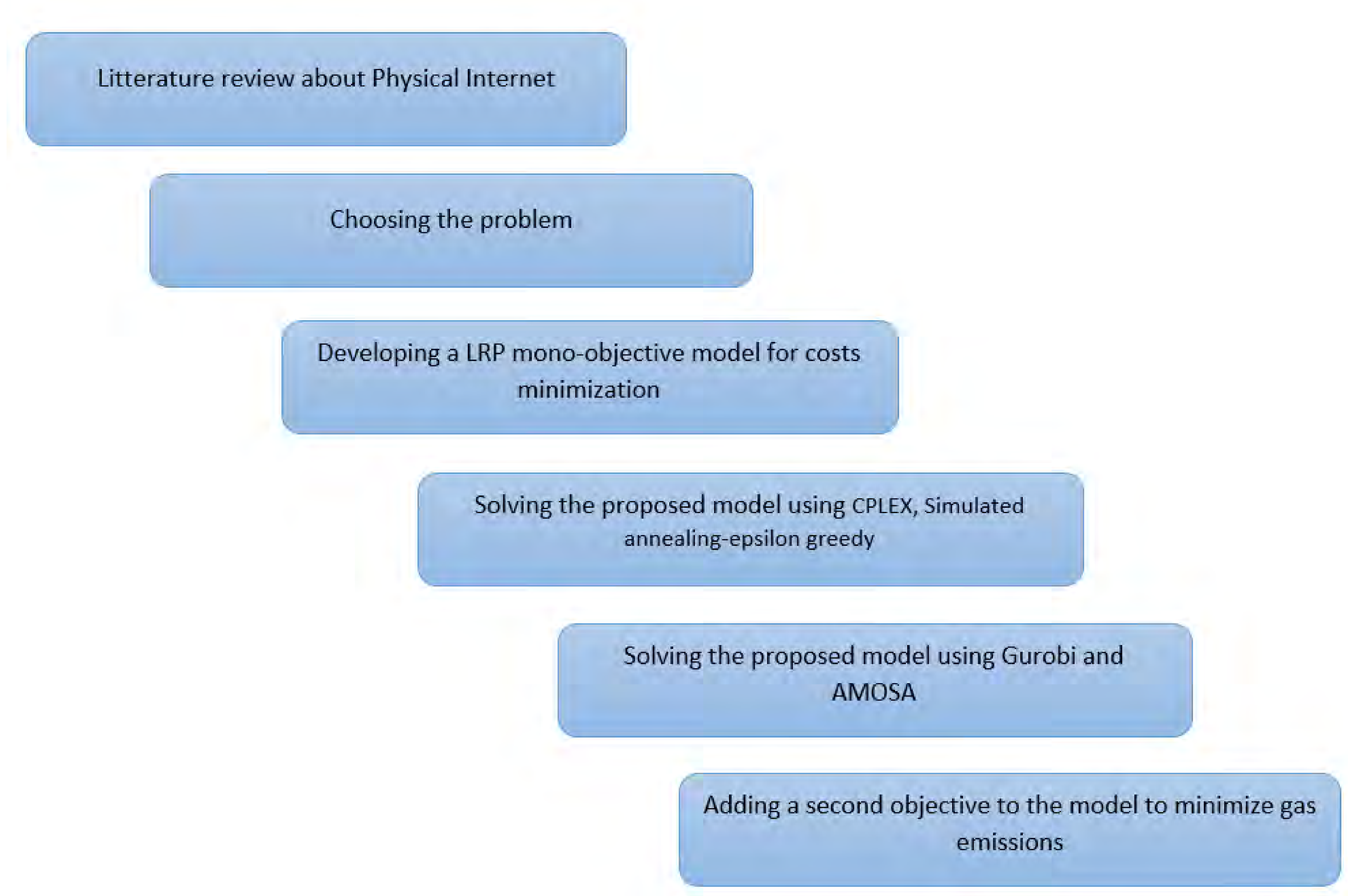
Economic aspect :
Minimization of total costs

$$Z1 = \min TC \left(\sum_h \sum_i \sum_k D_{hi} \cdot Y_{hik} + \sum_h \sum_i \sum_j \sum_k \text{Dist}_{ij} \cdot X_{ijhk} + \sum_i \sum_h \sum_k D_{hi} \cdot Z_{ihk} \right) + \sum_h O_{Ch} \cdot Q_h$$

Environnemental aspect :
Minimization of total gas emissions

$$Z2 = \min FE \cdot FC \left(\sum_h \sum_i \sum_k D_{hi} \cdot Y_{hik} + \sum_h \sum_i \sum_j \sum_k \text{Dist}_{ij} \cdot X_{ijhk} + \sum_i \sum_h \sum_k D_{hi} \cdot Z_{ihk} \right) + \sum_h (1/O_{Ch}) \cdot Q_h$$

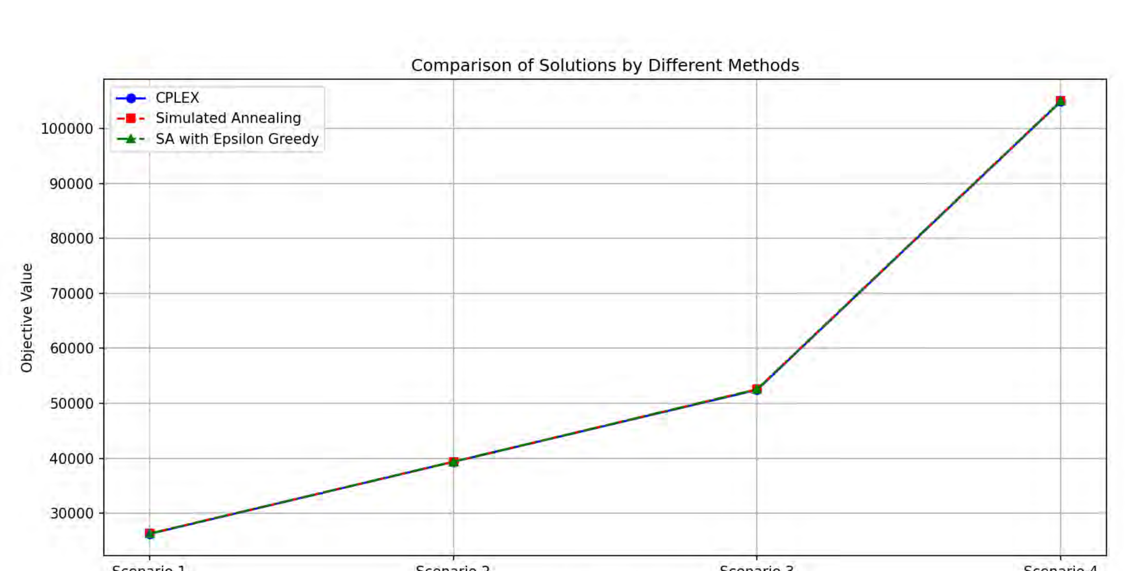
Research methodology



Results

Comparing Results of CPLEX, SA and SA-Epsilon greedy

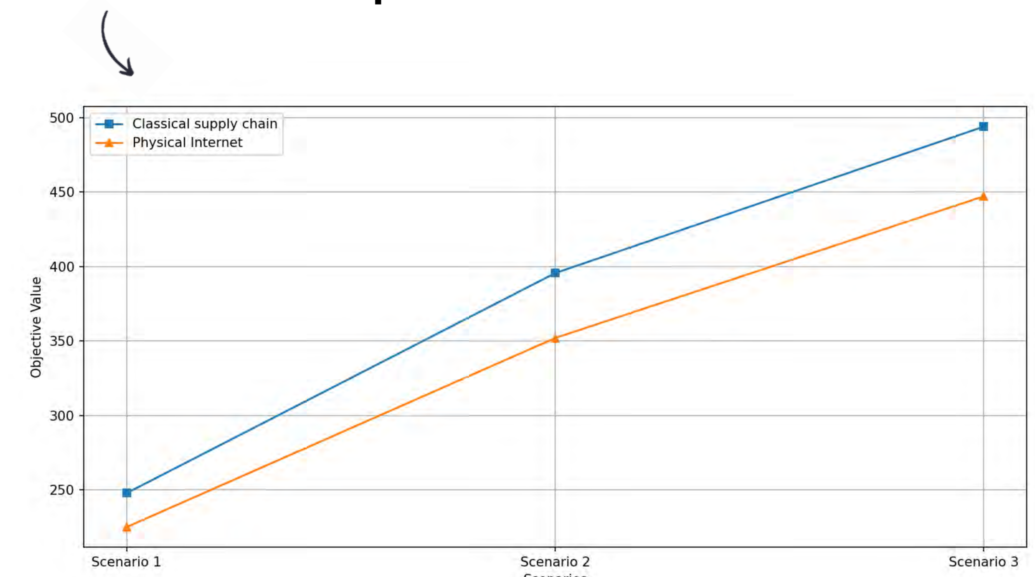
Scenario	CPLEX	SA-Epsilon greed	GAP%	SA	GAP%
Scenario 01	26225	26255,8	$< 1\%$	26282,4	$< 1\%$
Scenario 02	39352	39362,3	$< 1\%$	39370,5	$< 1\%$
Scenario 03	52447,2	52554,56	$< 1\%$	52545,9	$< 1\%$
Scenario 04	104948	105021,6	$< 1\%$	105026,7	$< 1\%$



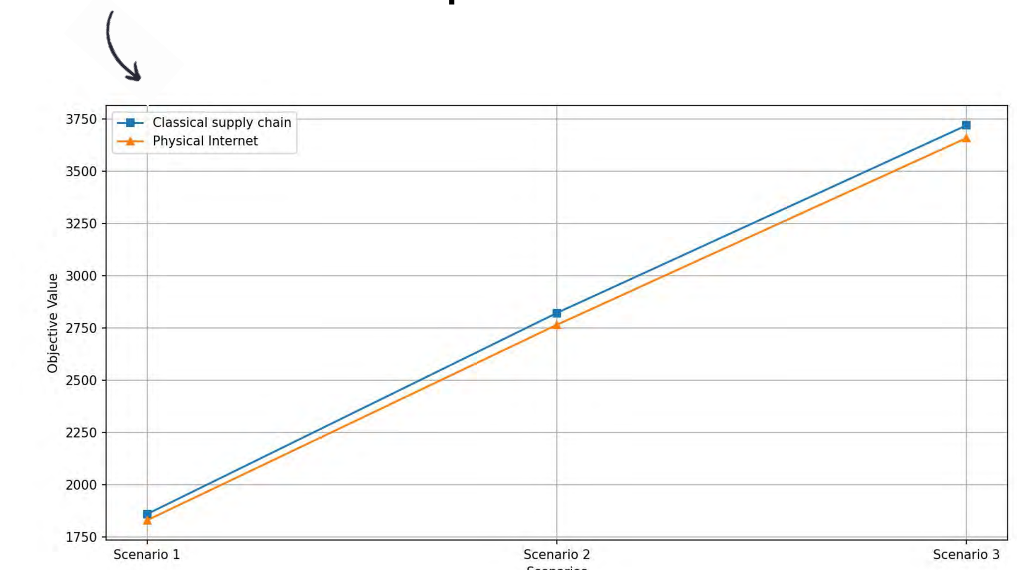
Comparing Physical Internet and classical supply chain

Scenario	Physical internet		Classical	
	F1	**F2**	**F1**	**F2**
Scenario 01	26225	1830.96	26247.8	1860.60
Scenario 02	39352	2765.3	39395.6	2821.97
Scenario 03	52447.72	3658.28	52494	3719.12

Economic aspect : F1



Environmental aspect : F2



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Visual memory, biometrics and applications to cybersecurity

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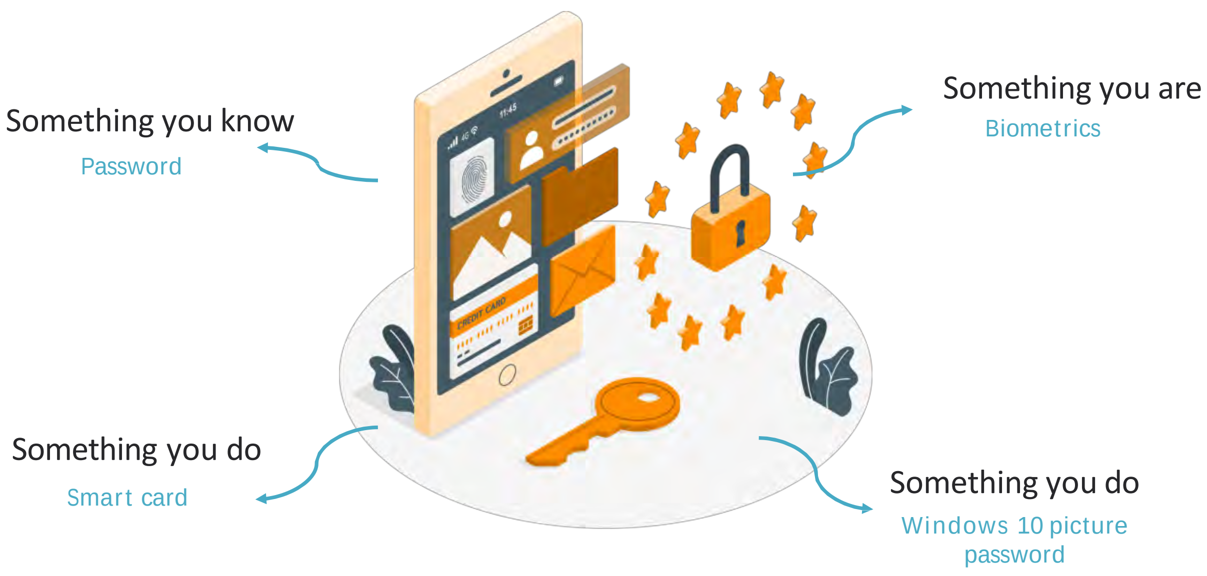
Background and issues :



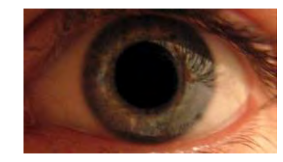
Limits : Vulnerability to attacks (e.g. brute force, sim swapping), reproduction of biometric characteristics.

Pupil size can be considered a physical and behavioral biometric. [1]

Principle: When we present an image (a stimulus), the pupil contraction reflex indicates how new the stimulus is to the user.

Critical challenges: Data collection and processing, Variability of pupillary reflexes.

Biometrics **+** Visual memory

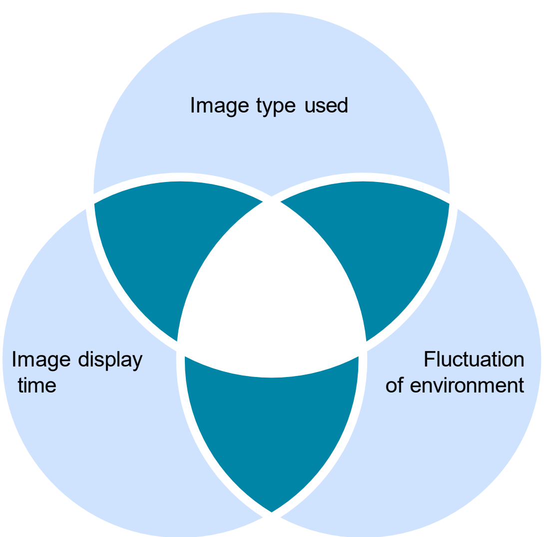


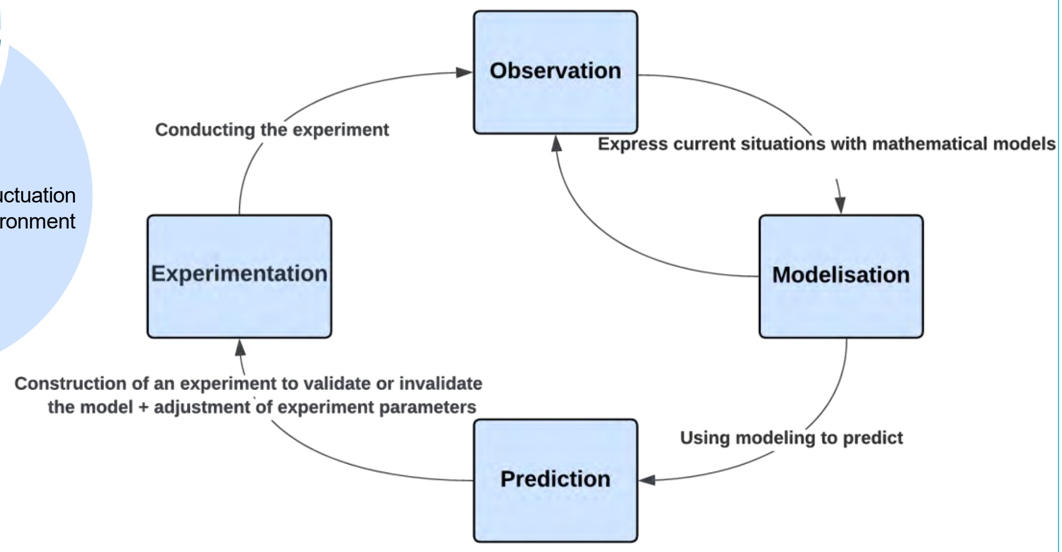
Research question:
How can we optimize automatic image recognition detection using the pupillary reflex, while taking into account the limits of human image recognition capacity?

[1] Cantoni, Virginio, et al. "Demographic classification through pupil analysis." *Image and Vision Computing* 102 (2020): 103980.

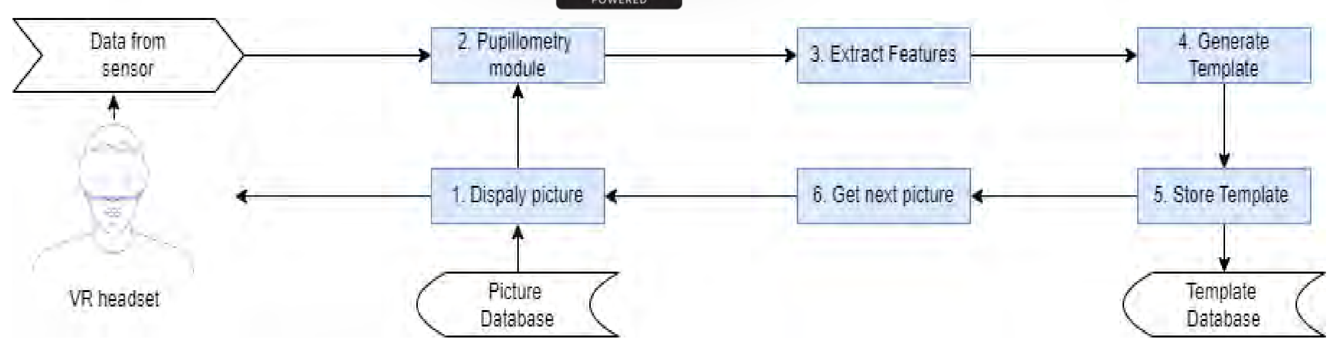
Aimed solution :

Overall design

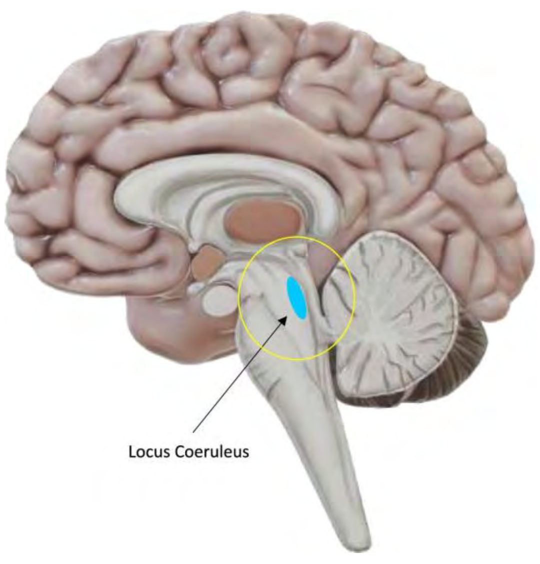


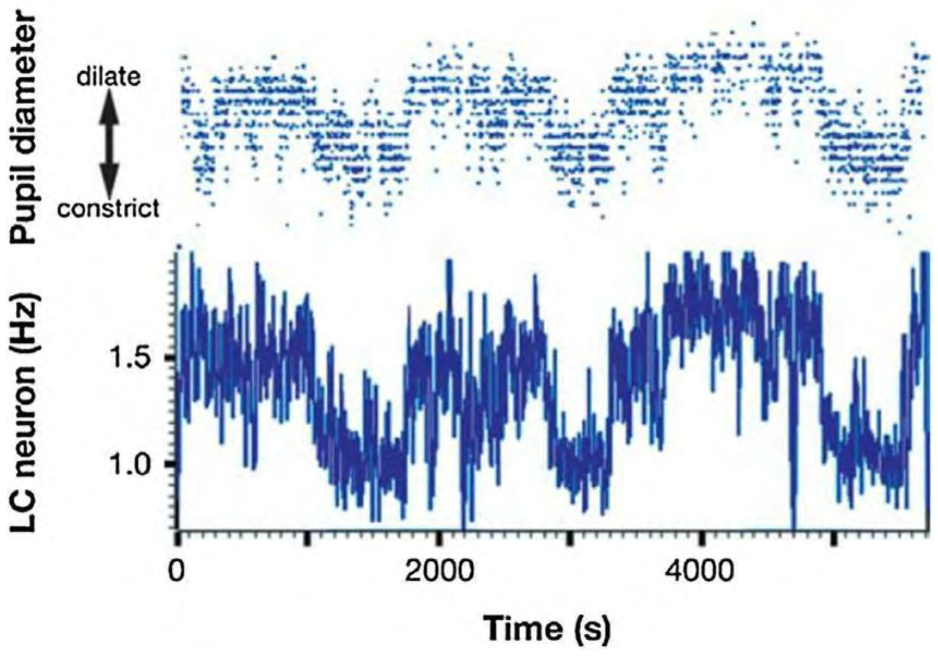


Experiments



State of the art :





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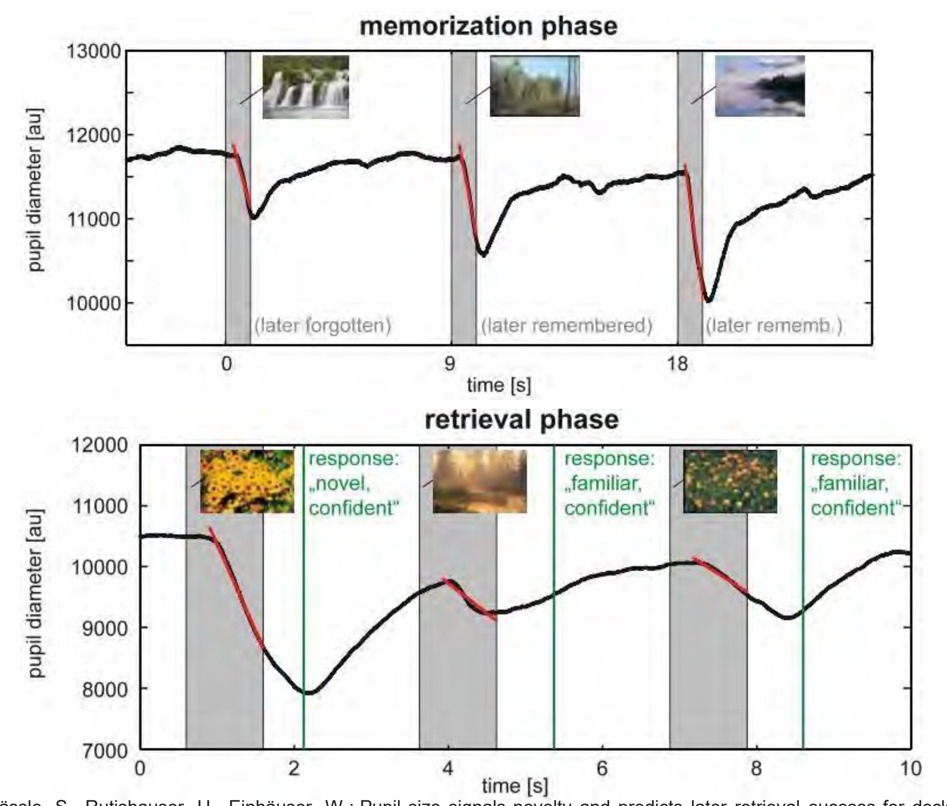

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INSA Institut National des Sciences Appliquées Hauts-de-France | Institut Carnot ARTS

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Shedding light on dark data: Circular economy perspectives

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Dark Data: The Problem

Environmental

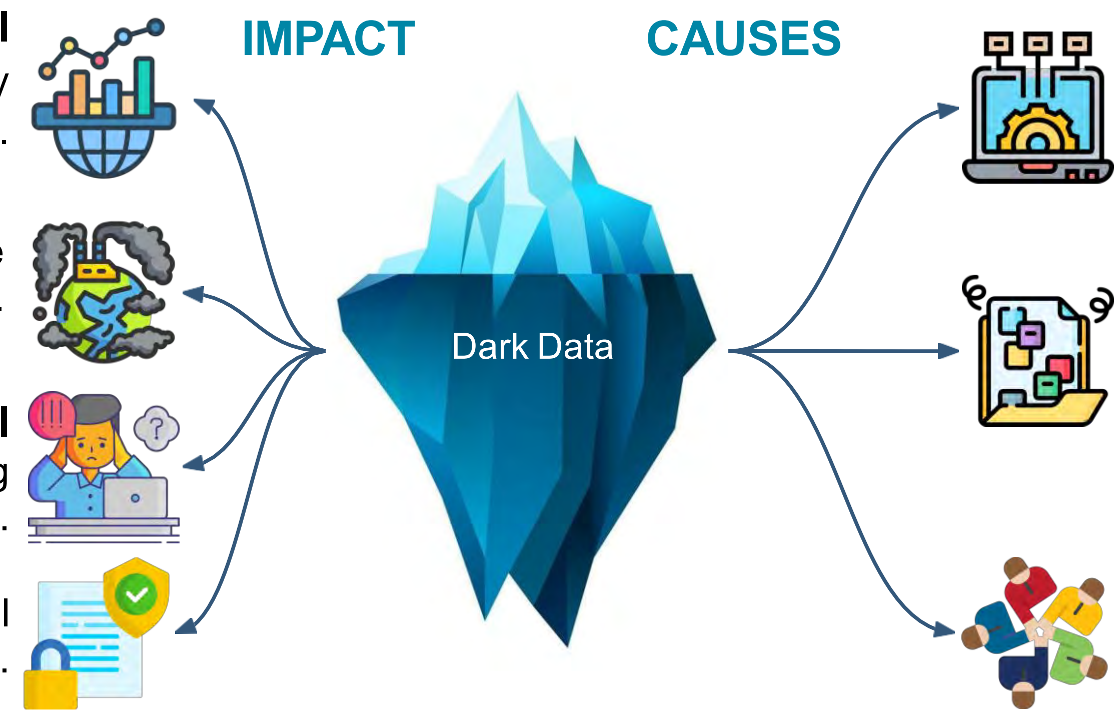
Massive data generation leads to increased energy consumption and carbon emissions from data centers.

The production, storage, and disposal of data storage devices contribute to pollution and resource depletion.

Societal

Inefficient data management hinders decision-making and research progress.

Data waste can lead to privacy concerns and ethical challenges.



Technological

Data obsolescence, insufficient metadata, and rapid technological evolution.

Procedural

Lack of data governance, curation, and integration.

Human

Inefficient data handling practices, data duplication, and outdated data.

Addressing Data Waste: Circular Economy Principles

Data Management: A Key to Reducing Waste

The Importance of Data Management

- Effective data management practices, including governance, quality assurance, and sharing protocols, are crucial for reducing data waste.
  - *Data Governance:* Establish clear data management policies and protocols.
  - *Data Curation:* Implement effective data storage, organization, and metadata management.
  - *Data Sharing:* Promote open data initiatives and foster collaborative data management practices.
- These practices help ensure that data is collected, processed, stored, and utilized efficiently, minimizing unnecessary accumulation.

The Circular Economy Framework for Data Management

- The CE framework, particularly the 5R concept (rethink, reduce, reuse, recycle, repair), offers a comprehensive approach to sustainable data management.

The 5R Concepts in Data Waste Management

Challenges and Future Directions

Overcoming Barriers to Circular Data Management

- **Data Silos & Interoperability** - Organizations struggle to share and reuse data due to isolated systems and inconsistent data formats.
  - *Solution:* Develop common data standards, metadata frameworks, and open data initiatives.
- **Data Privacy & Security** - Sharing data raises concerns about privacy, security, and intellectual property.
  - *Solution:* Implement data anonymization, secure sharing platforms, and robust data governance frameworks.
- **Resistance to Data Sharing** - Some organizations are hesitant to share data due to concerns about competitive advantage or misuse.
  - *Solution:* Promote a culture of data sharing and collaboration, highlighting the benefits of open data.

Towards a Sustainable Digital Future

- **Develop Data Governance for Circularity** - Establish guidelines for responsible data collection, storage, use, and sharing.
- **Invest in Circular Data Technologies** - Fund research and development of data anonymization tools, data cleaning algorithms, and sustainable data storage systems.
- **Foster Collaboration & Partnerships** - Encourage collaboration among businesses, researchers, and policymakers to develop and implement circular data management solutions.

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The Role of Industry 4.0 Technologies in Enhancing Reverse Logistics and Transportation in the Context of Circular Economy

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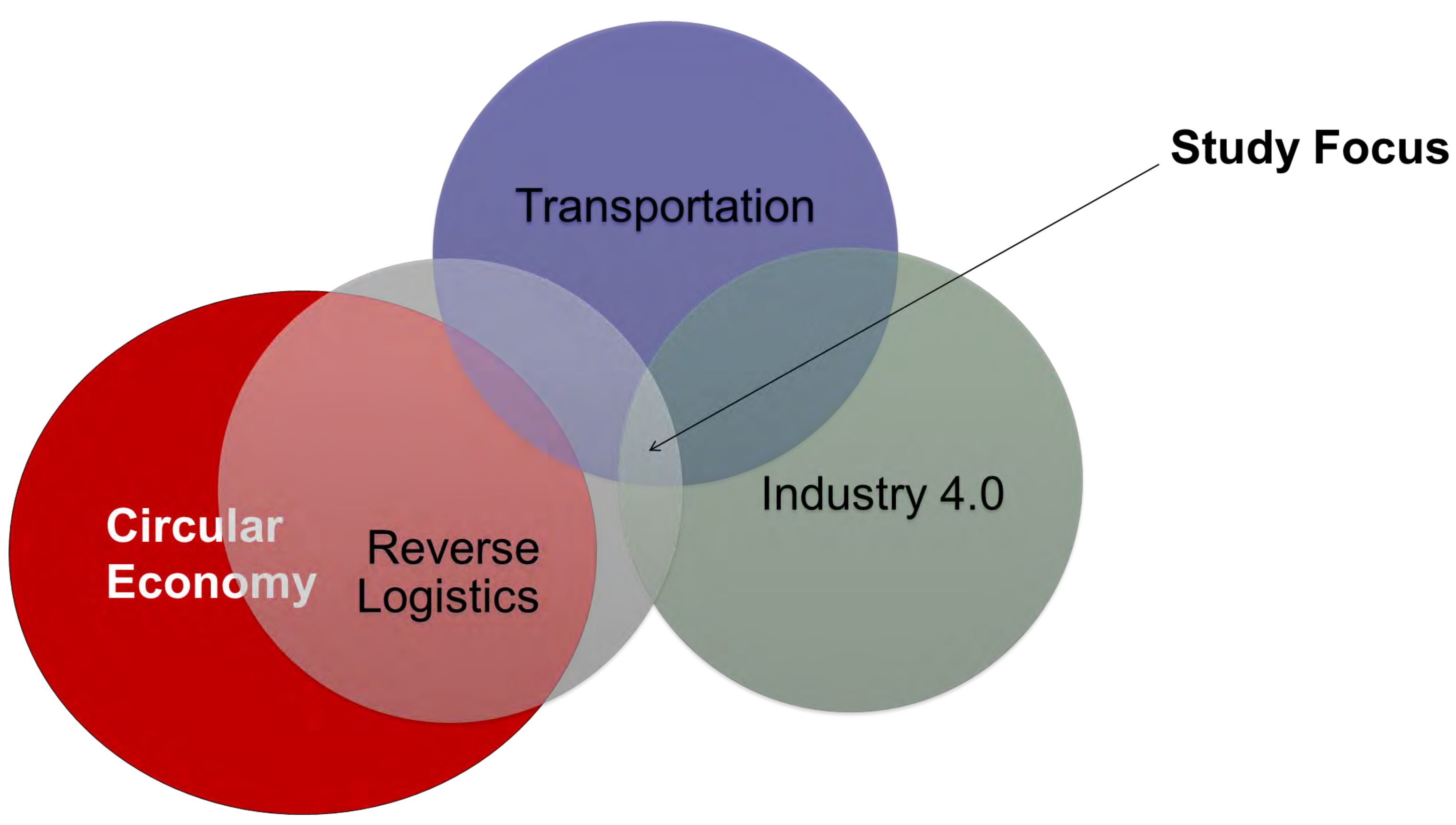
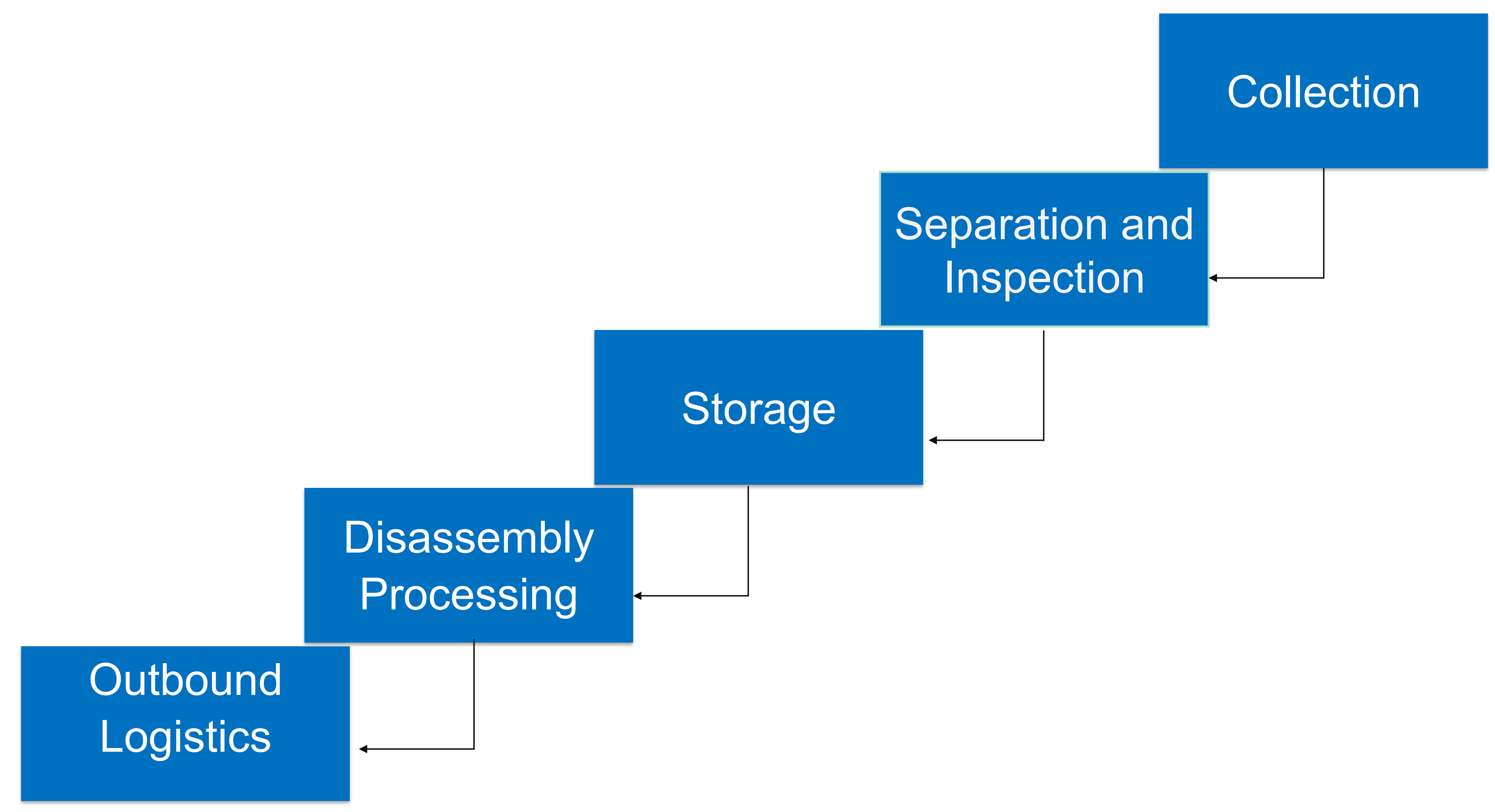
Background





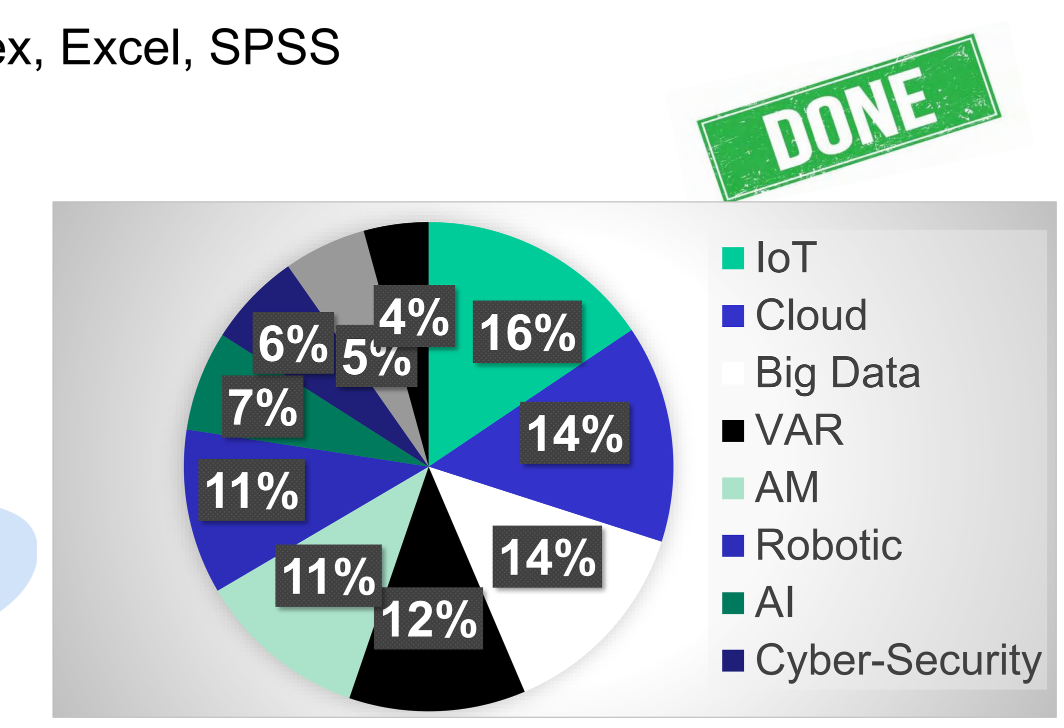
Objective/ Methodology

Objective:

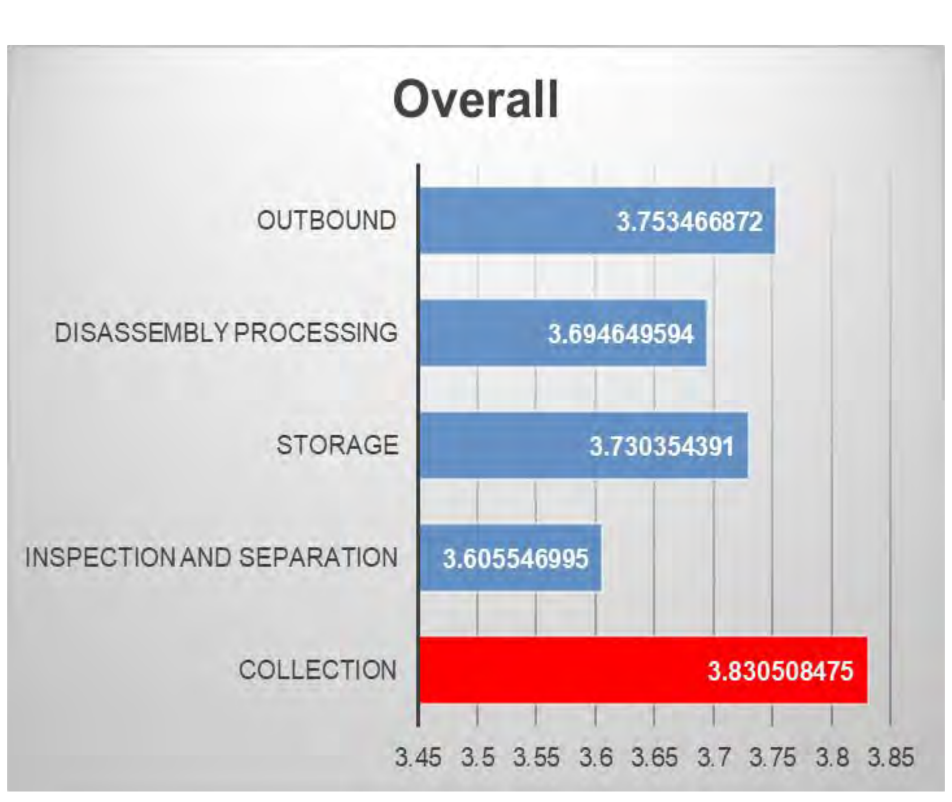
- Investigates the fundamentals of **digitalizing transportation** within the context of a **circular economy**.
- Develop new optimization algorithms and evaluation frameworks for quantifying and analyzing tradeoffs between ecological and economic objectives.

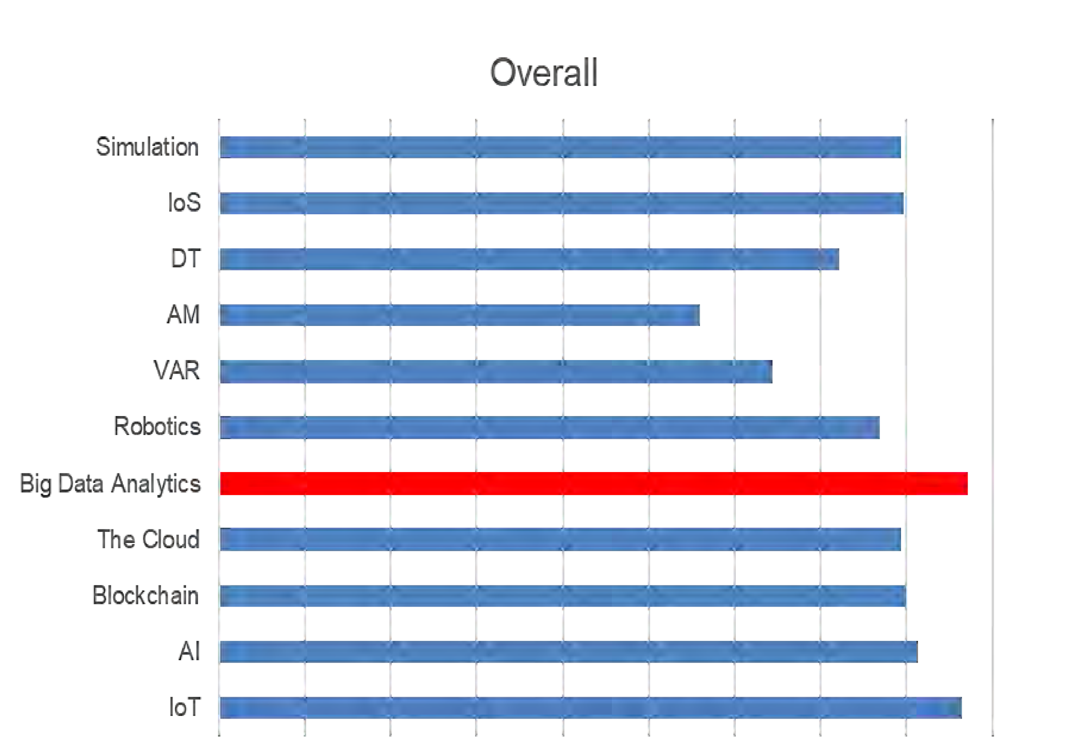
Methodology:

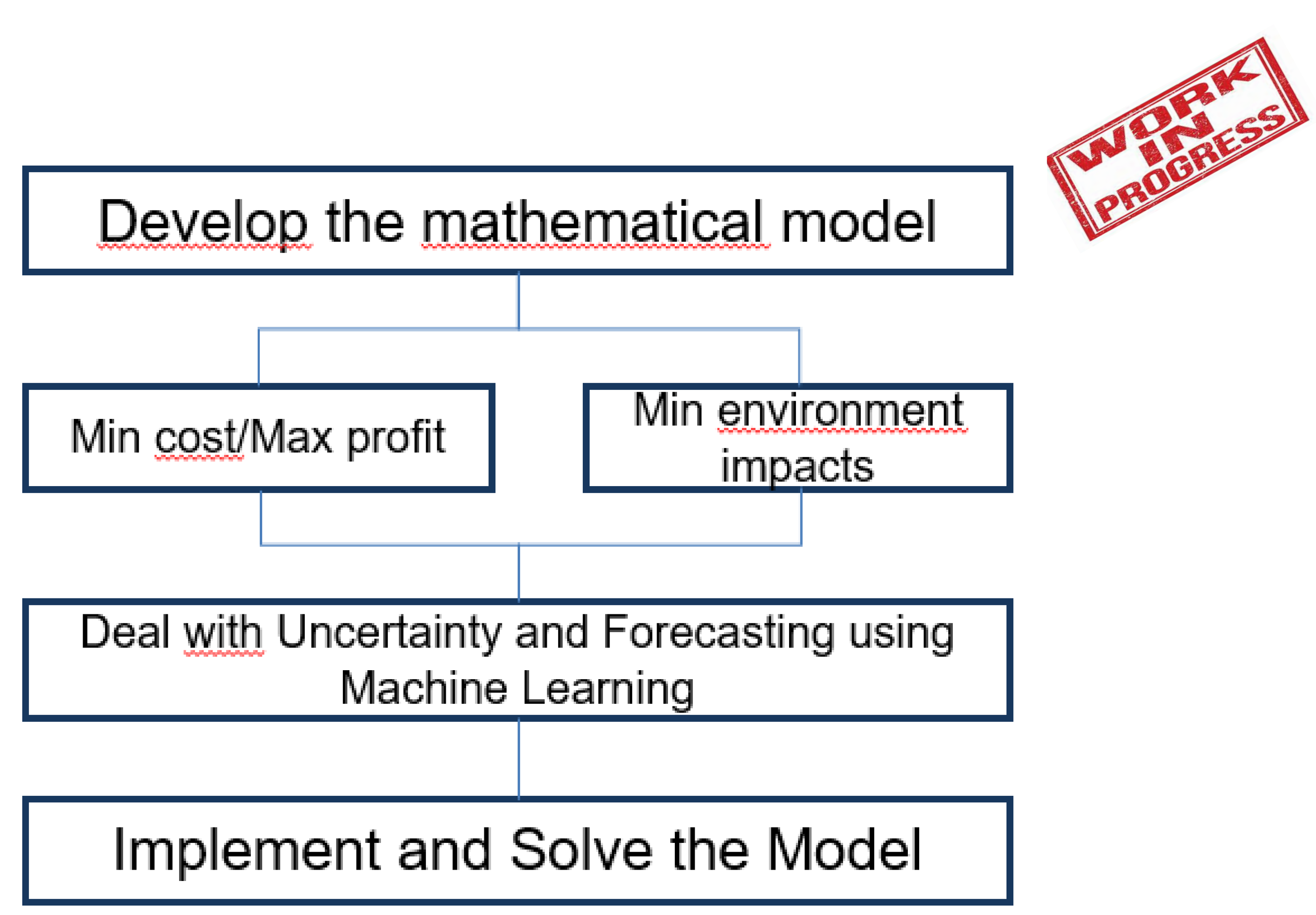
- Empirical Analysis
- Matehmatical Programming
- Optimization
- Analytical tools: Python, Cplex, Excel, SPSS



Results/ Future Plans







TEC-LOG[d]

Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

Metaheuristic Optimization of Waste Management in Circular Economy Using Smart Bins

Niama YAHIAOUI, Abdelghani BEKRAR[1], Mehdi SOUIER [2]

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High School of applied sciences ESSA- Tlemcen, Algeria [2]

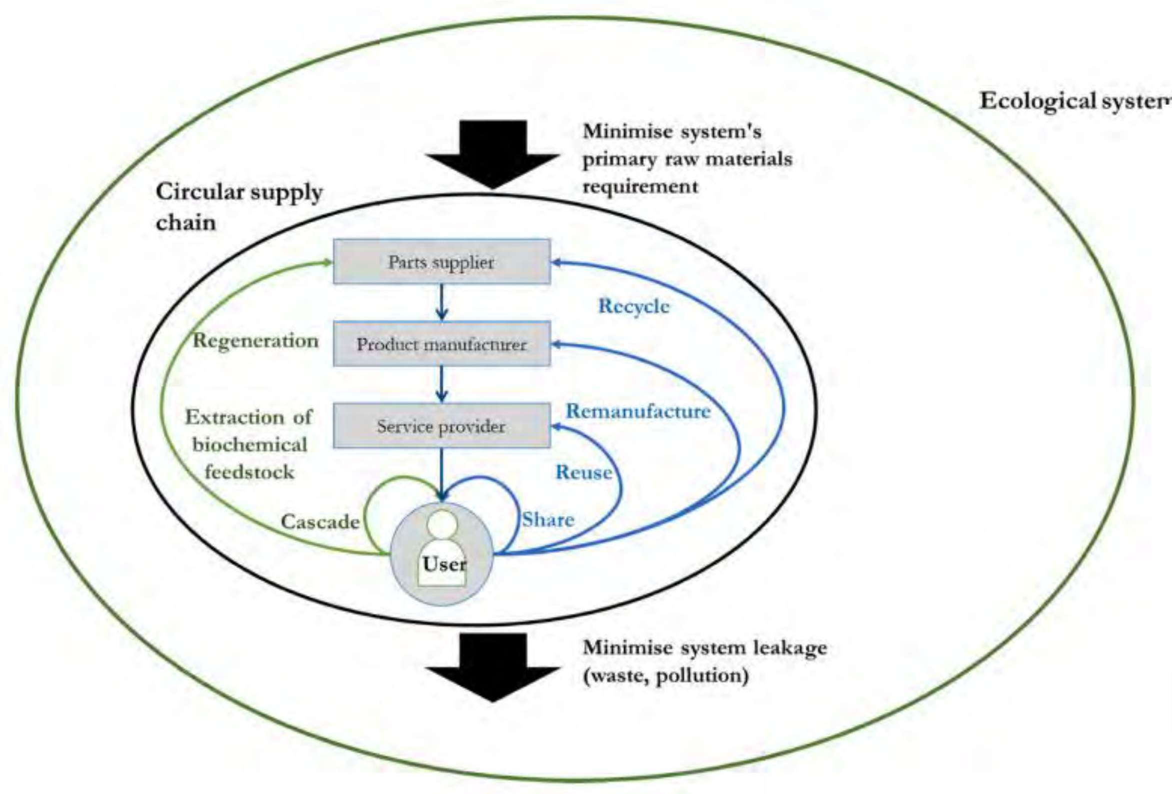
CIRCULAR ECONOMY

CONTEXT

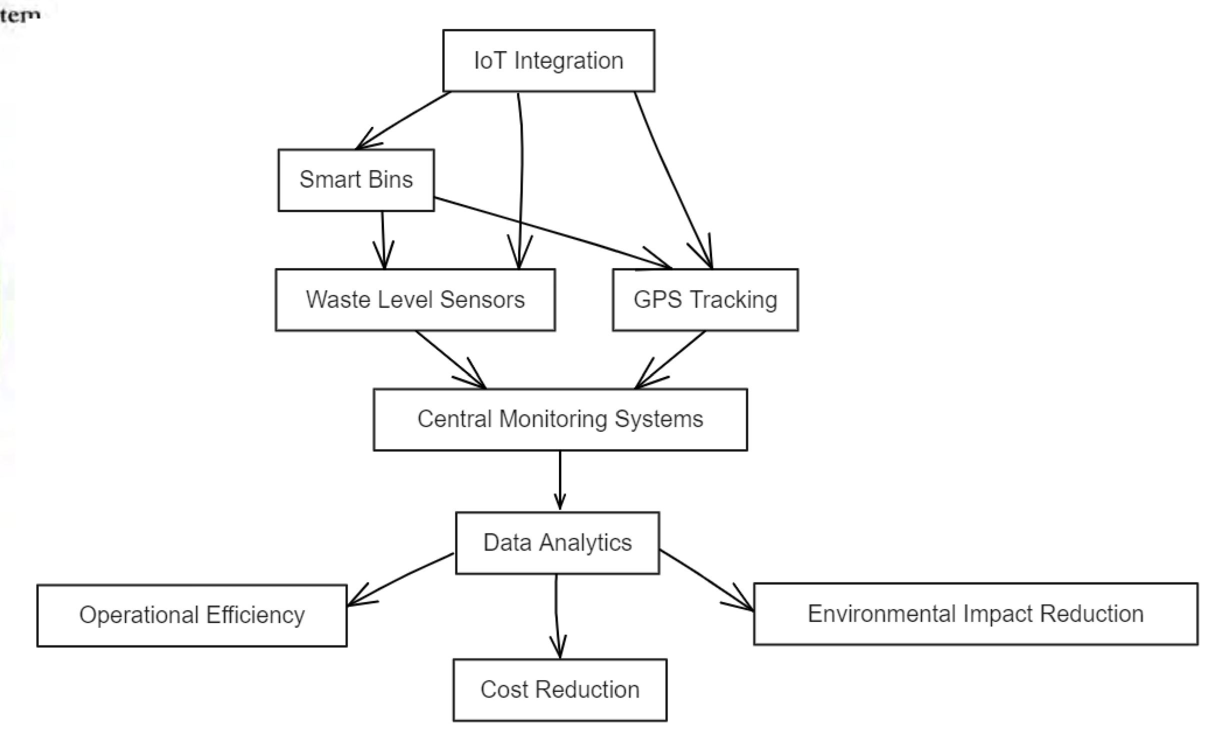
CIRCULAR ECONOMY (CE) : concept was developed to reverse unsustainable patterns of development and create long-term prosperity [1]

INDUSTRY 4.0 : Integrate mechanical and virtual systems into comprehensive cyber-physical systems (AI, machine to-machine connectivity, and real time data management) [2]

SMART Waste MANAGEMENT : Supply of Information about collection, organization, transmission, storage, and retrieval



Jacqueline Maria Bloemhof-Ruwaard. Sustainable Logistics Management:from castle on the cloud to cathedral. Wageningen University, Wageningen UR, 2015.



RESEARCH

PROBLEM DESCRIPTION

Vehicle Routing Problem:

- Optimizing the collection and transportation routes
- Considering vehicle capacity and time windows constraints
- Enabling dynamic route planning
- Enhance efficiency and reduce cost

Objective Function:

$$Z1 = \min \left(\sum_i \sum_j \sum_v C_{ij} \cdot X_{ijv} \cdot D_{ij} + \sum_i \sum_j \sum_v \mathrm{FE} \cdot FC \cdot CE \cdot X_{ijv} \cdot D_{ij} \right)$$

Constraints:

$$\sum_v \sum_j X_{vij} = 1 \quad \forall i \neq 1$$

$$\sum_v \sum_i X_{vij} = 1 \quad \forall j \neq 1$$

$$\sum_{j \neq 1} X_{v1j} = UV_v \quad \forall v$$

$$\sum_i \sum_j \sum_v X_{vij} \left(LB_i + LB_j \right) < VC_v \quad \forall b$$

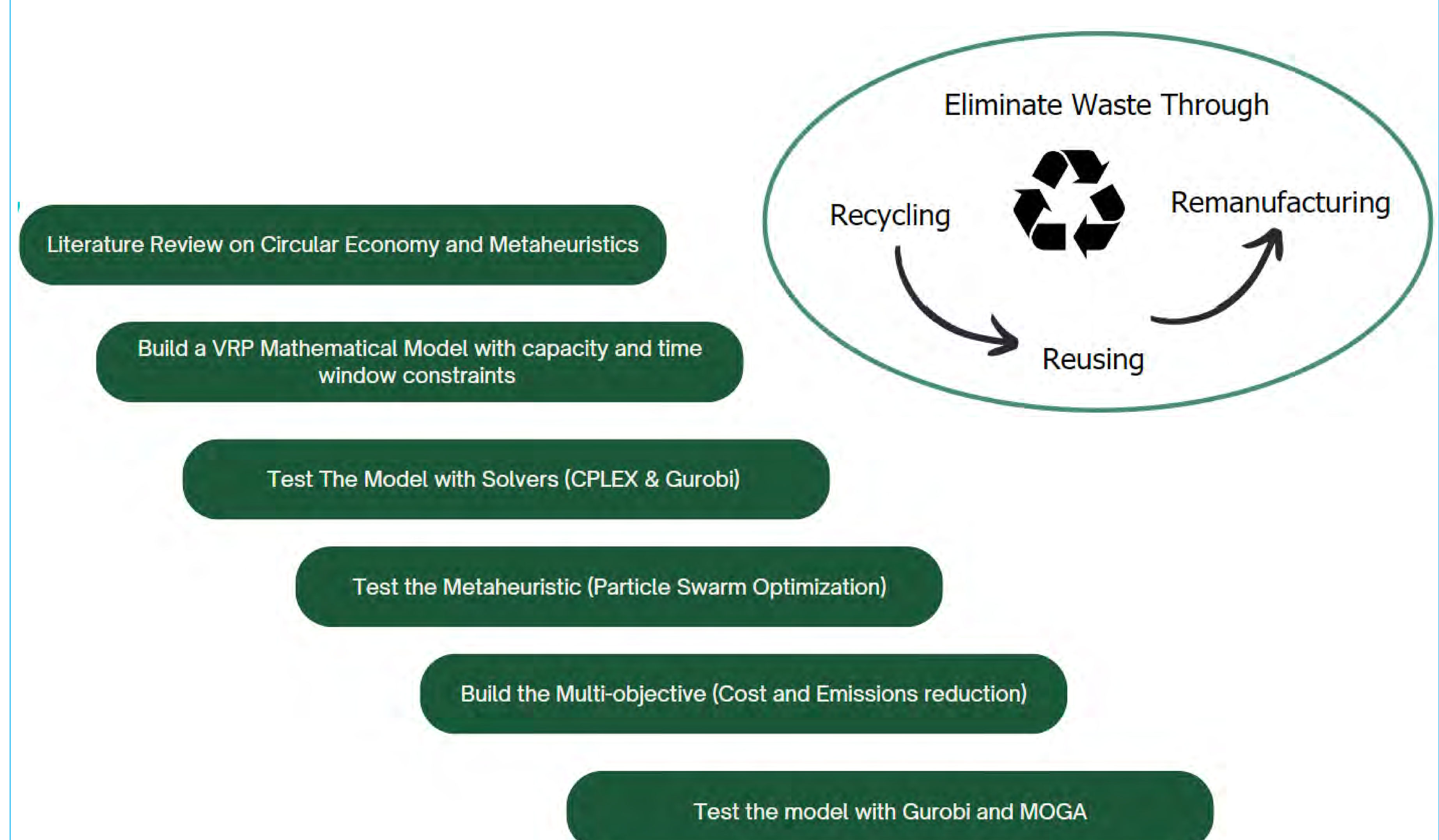
$$\sum_j X_{vij} = \sum_j X_{vji} \quad \forall v \forall i$$

$$X_{ivv} = 0 \quad \forall v \forall i$$

$$T_i + S + K_{ij} - T_i \leq M \cdot (1 - X_{ijv}) \quad \forall i \forall v \forall j \neq 1$$

$$E \leq T_i \leq F \quad \forall i$$

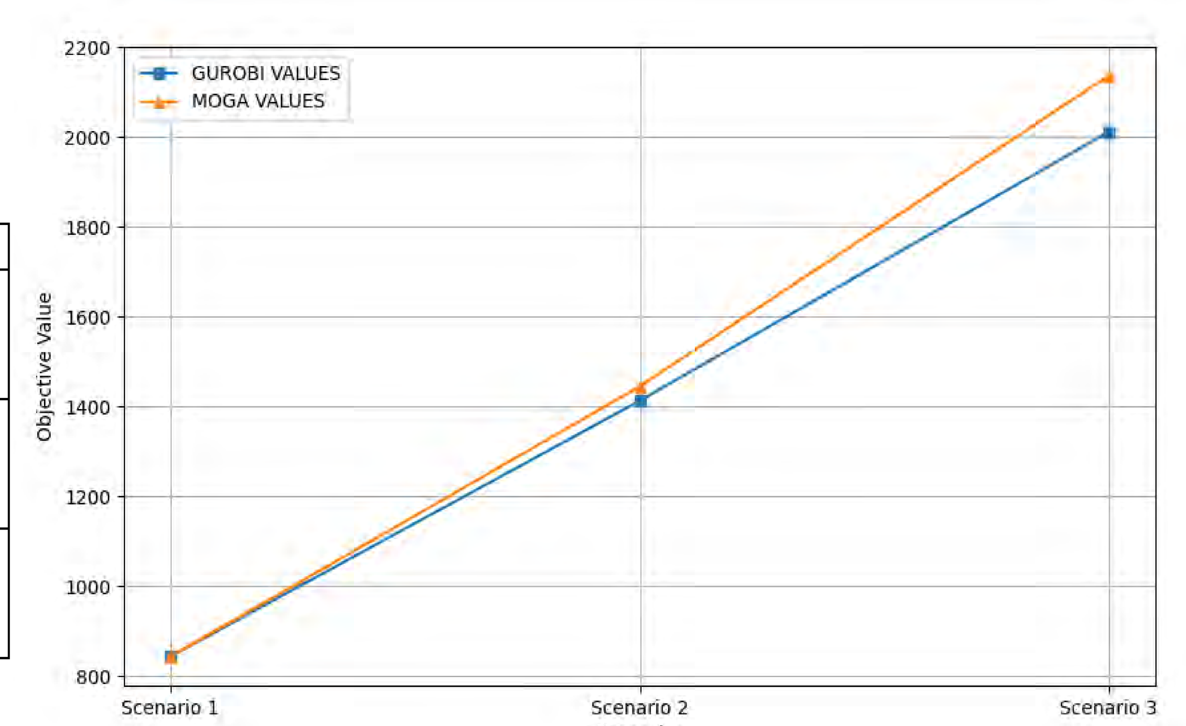
RESOLUTION APPROACH



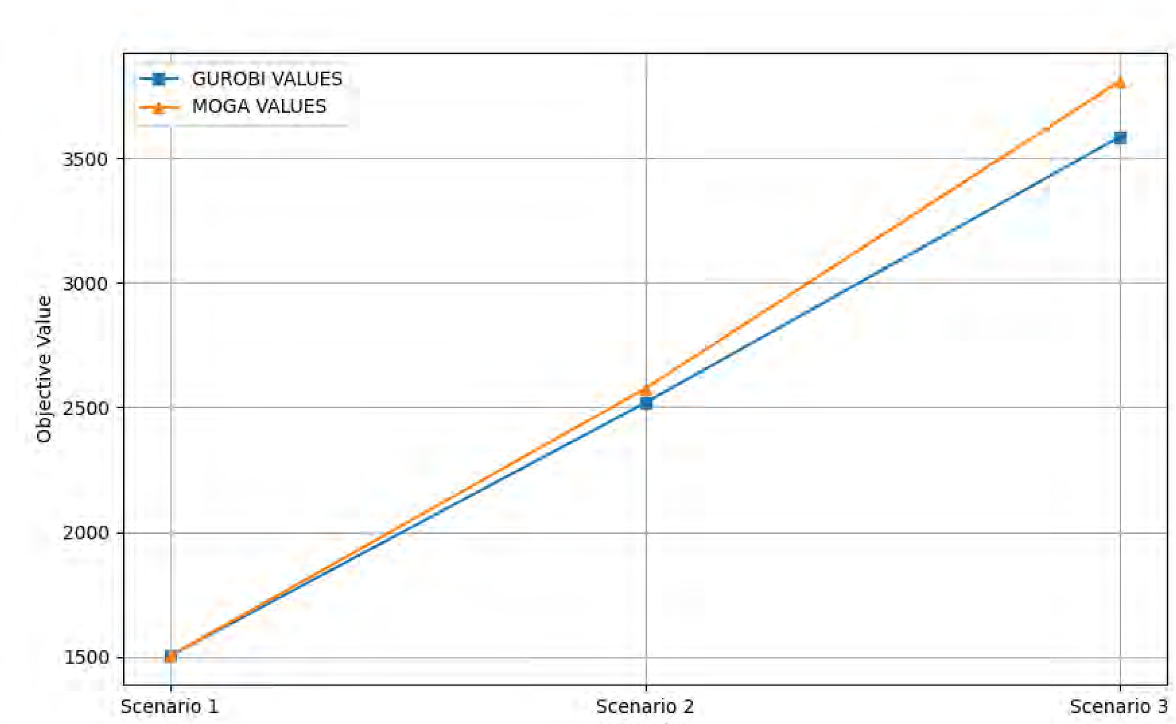
RESULTS

Comparing GUROBI Solver and Metaheuristic

Scenario	Gurobi	MOGA	GAP
Scenario 1	F1 = 844.3 F2 = 1504.2	F1 = 844.3 F2 = 1504.2	F1 = 0% F2 = 0%
Scenario 2	F1 = 1413.25 F2 = 2517.84	F1 = 1445.13 F2 = 2574.64	F1 = 2% F2 = 2%
Scenario 3	F1 = 2011.75 F2 = 3584.13	F1 = 2136.89 F2 = 3807.09	F1 = 5% F2 = 5%



Economic Function



Environmental Function

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1.Abraham Zhang,Barriers to smart waste management for a circular economy in china. Journal of Cleaner Production, 240:118198, 2019.23

2.Amirhossein Salehi-Amiri, Designing an effective two-stage, sustainable, and iot based waste management system. Renewable and Sustainable Energy Reviews, 157:112031, 2022

Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

AI applications in automotive manufacturing industry for predictive maintenance and energy consumption

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LAMIH, IEMN & TMMF

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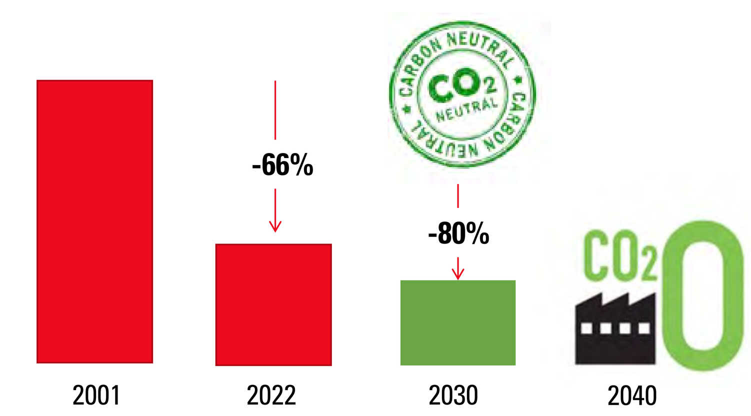
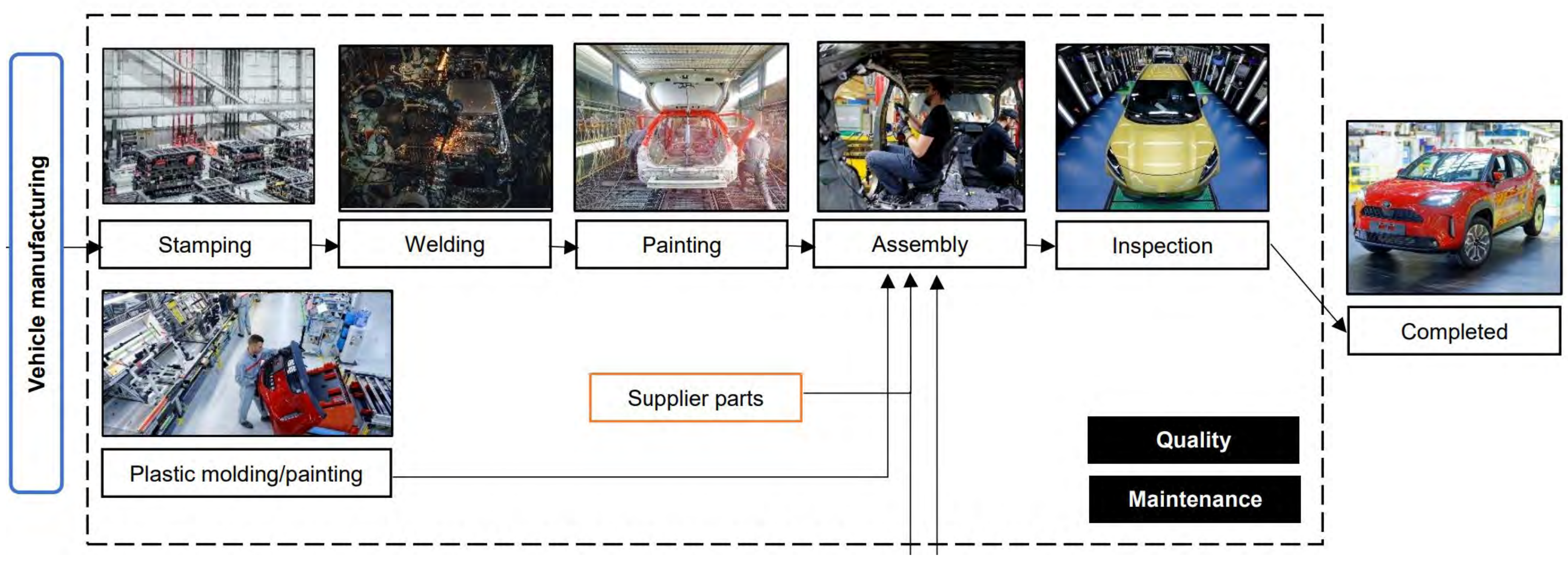
Introduction

Process of manufacturing for Toyota car : Yaris / Yaris Cross

- **Production capacity: 300 000 cars /year**
- **5 000 workers**
- **5 Millions cars produced in TMMF**
- **Robots and humans working in harmony**



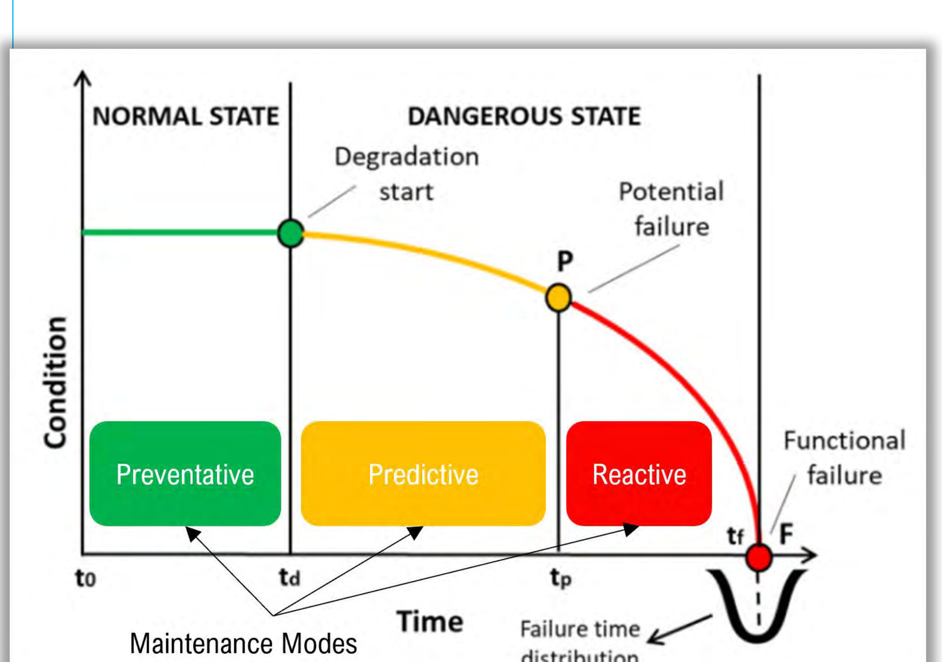
To Zero CO2 emission in 2040



Challenges, applications and methods

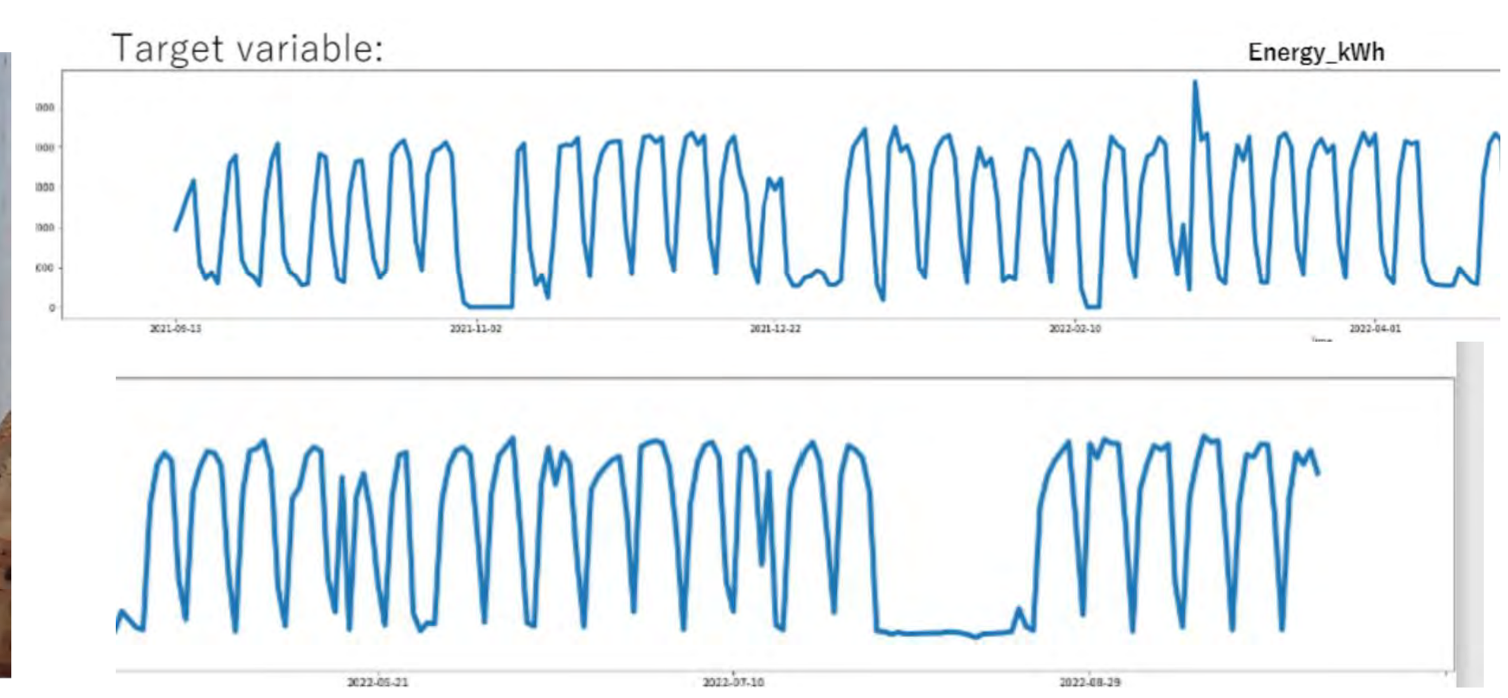
Challenges

- Quality inspection
- Maintenance and fault / anomaly detection
- Energy consumption
- user ergonomics inspection



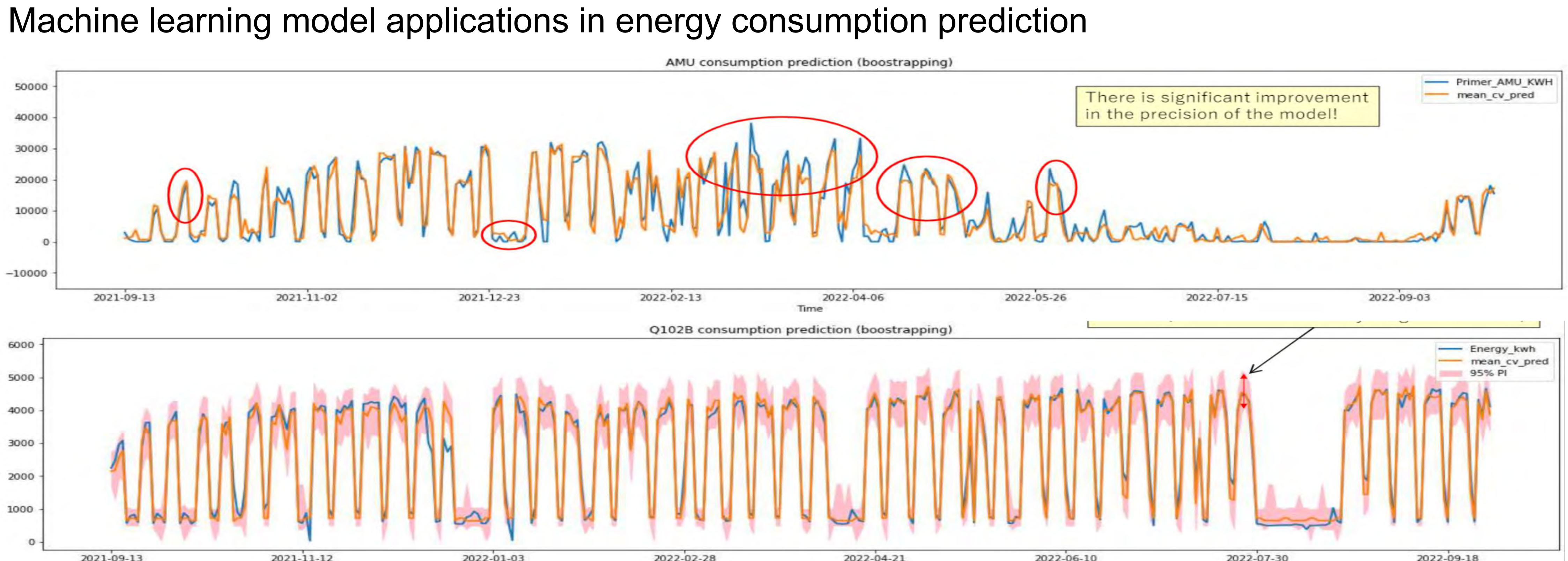
Methods

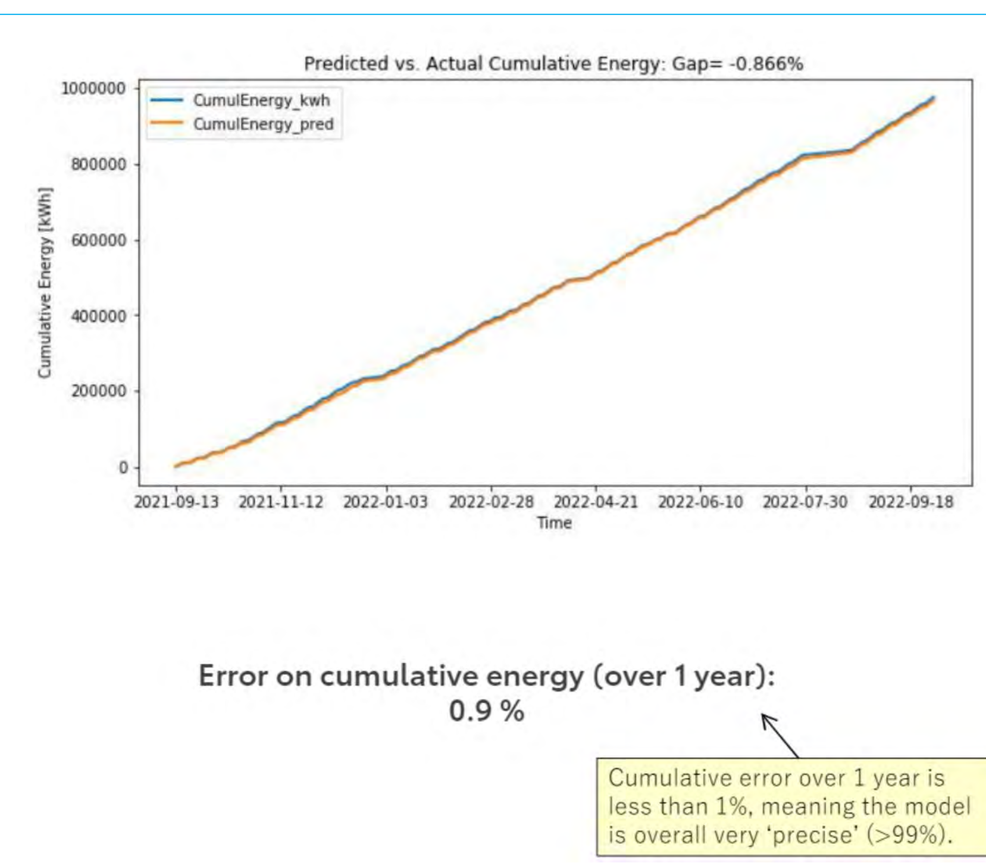
- Statistics analytics
- Machine learning
- Deep learning



Results

Machine learning model applications in energy consumption prediction





Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

Application of FML for risk prediction in SC: A case study of Vietnam's textile industry

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INTRODUCTION

Background

- Collaboration
- Disruption (Delay)
- 4IR context
- FML

Literature Review

Search string: ("Federated Machine Learning" OR "Federated Learning") AND ("Supply Chain" OR "Supply Chain Management" OR "Procurement" AND "Risk" OR "Supply Chain Risk" OR "Risk Management" OR "Risk Analysis" OR "Risk Assessment" OR "Risk Identification" OR "Risk Prediction" OR "Risk Mitigation" OR "Risk Monitoring" OR "Uncertainty")

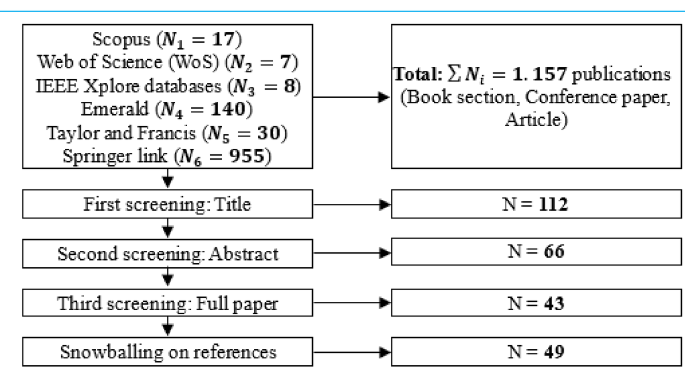


Fig. 1 The PRISMA flow diagram

Fig. 2 Distribution of publications

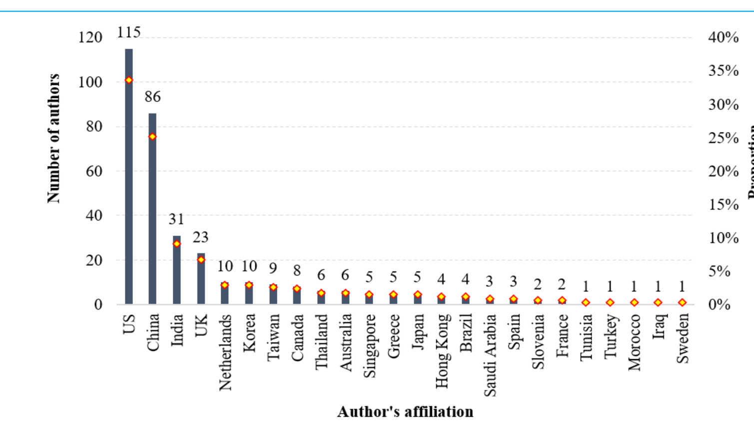


Fig. 3. Analysis on affiliation's authors

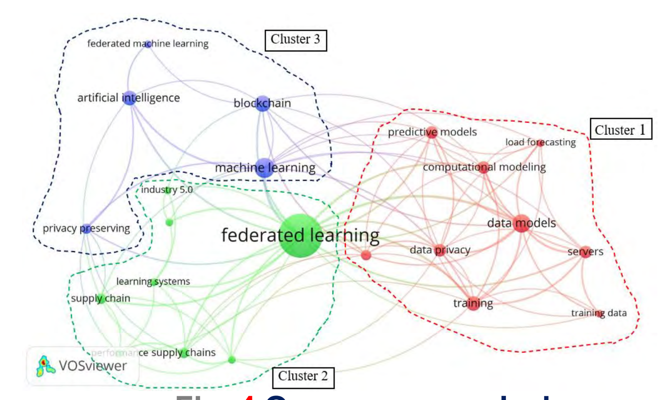


Fig. 4 Occurrence analysis

Learning task	Local learning (ANN 1DCNN)					
Company	CXX		NXX		AXX	
Accuracy	0.9307	0.9932	0.9286	0.9226	0.9199	0.9344
Precision	0.9979	0.9943	0.9369	0.9284	0.9410	0.9376
Recall	0.9320	0.9989	0.9897	0.9929	0.9737	0.9833
F-Score	0.9601	0.9966	0.9625	0.9595	0.9570	0.9650
Learning task	**Federated learning (ANN 1DCNN)**					
Company	**CXX**		**NXX**		**AXX**	
Accuracy	0.9991	0.9999	0.9583	0.9792	0.8958	0.9375
Precision	0.9999	0.9999	0.9999	0.9999	0.9535	0.9362
Recall	0.9999	0.9999	0.9674	0.9787	0.9318	0.9999
F-Score	0.9999	0.9999	0.9579	0.9892	0.9425	0.9416

Table 1. Experimental results comparison
Source: L. Kong, G. Zheng, and A. Brintrup (2024)

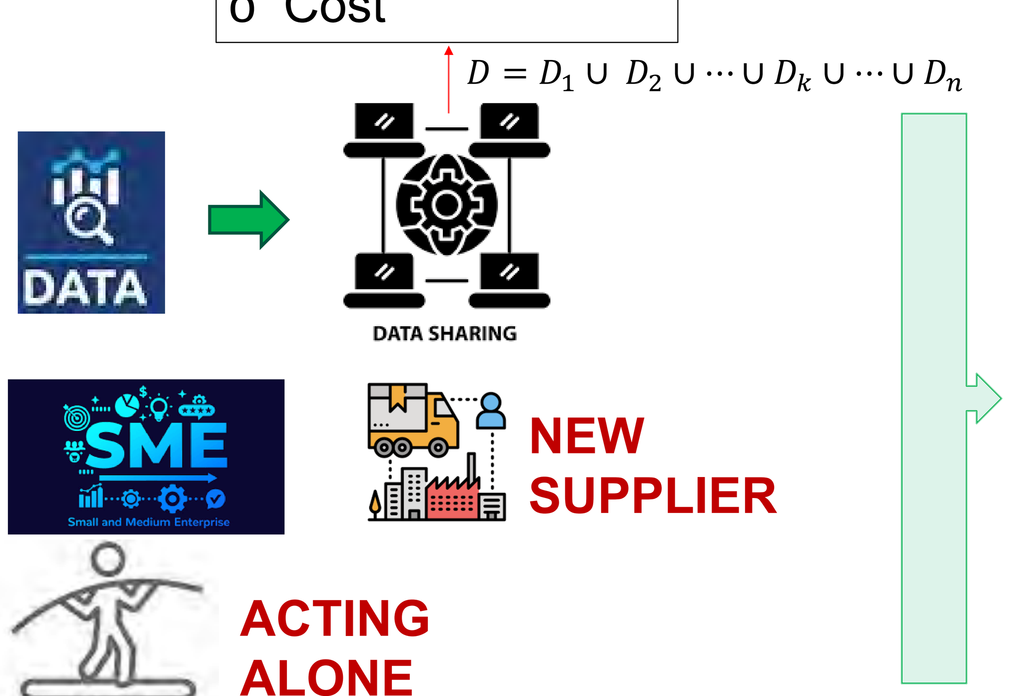
❖ Key points

- o Privacy concerns;
- o Reduces the cost;
- o Risk assessment & mitigation are focused;
- o FL benefits SMEs;
- o Act collective

ISSUES & PROPOSED METHOD

Problem

- o Privacy,
- o Security,
- o Competitiveness,
- o Leakage
- o Oportunisticsm
- o Cost



- **Data Privacy**
- **Cost Efficiency**
- **Improved Collaboration**
- **Better Data Utilization**
- **Scalability**
- **Real-time Updates**
- **Regulatory Compliance**
- **Increased Trust**
- **Enhanced Model Performance**

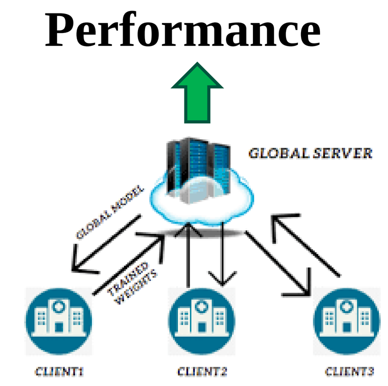


Fig. 5 Traditional and proposed methods

Methodology

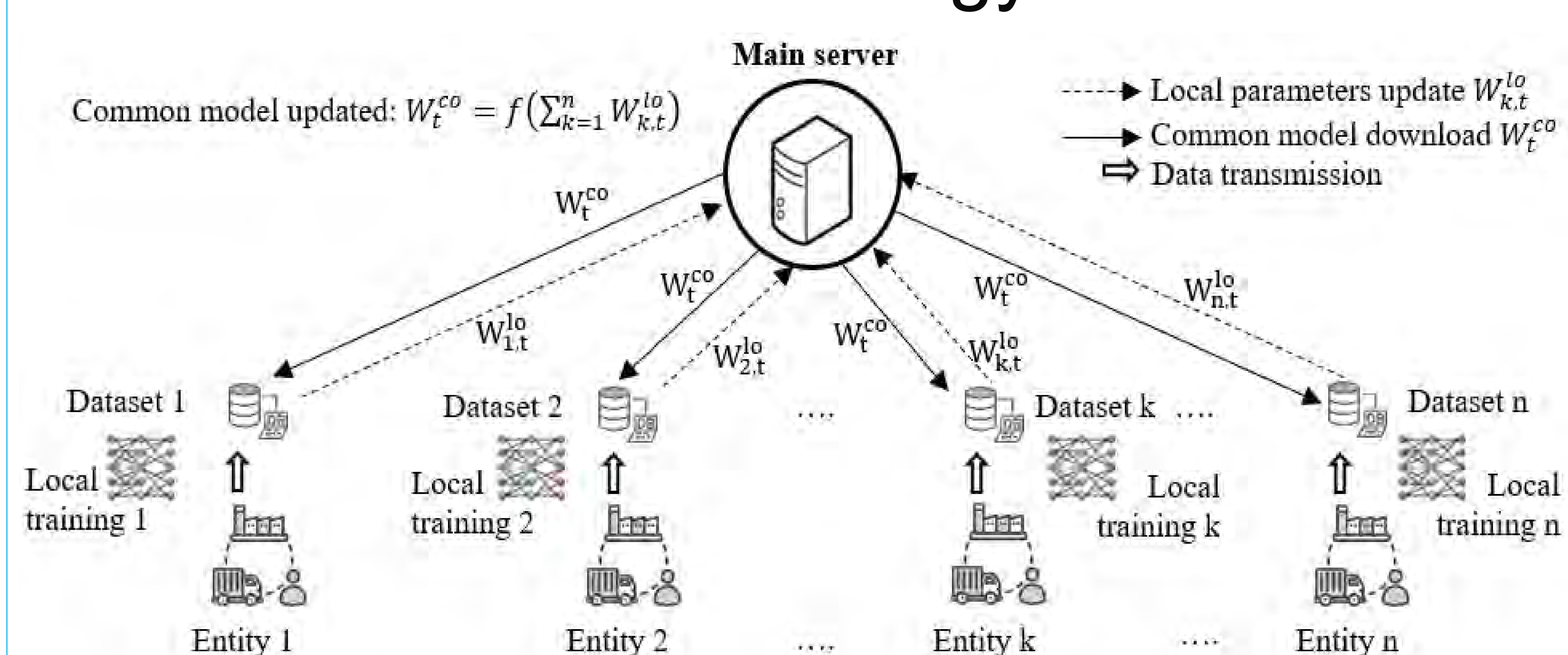


Fig. 6 Framework for applying FML to delivery delay risk prediction in the SC

- Framework: Tensorflow
- Algorithm for aggregating the Common Model: Federated Averaging (FedAvg)
- Algorithms for local training: ANN, CNN, LogReg, MLP, Decision tree, …

FML BASED MODEL FOR SCR PREDICTION

❖ Objective: To predict whether a given order will arrive on time or late

- **Data:** Historical data from 2018 to 2023
- **Data source:** Textile companies (2-5 companies)
- **Performance metrics**: Accuracy, Precision, Recall and F-Score (normalized confusion matrix)
- **Tools**: Python, Google Colab

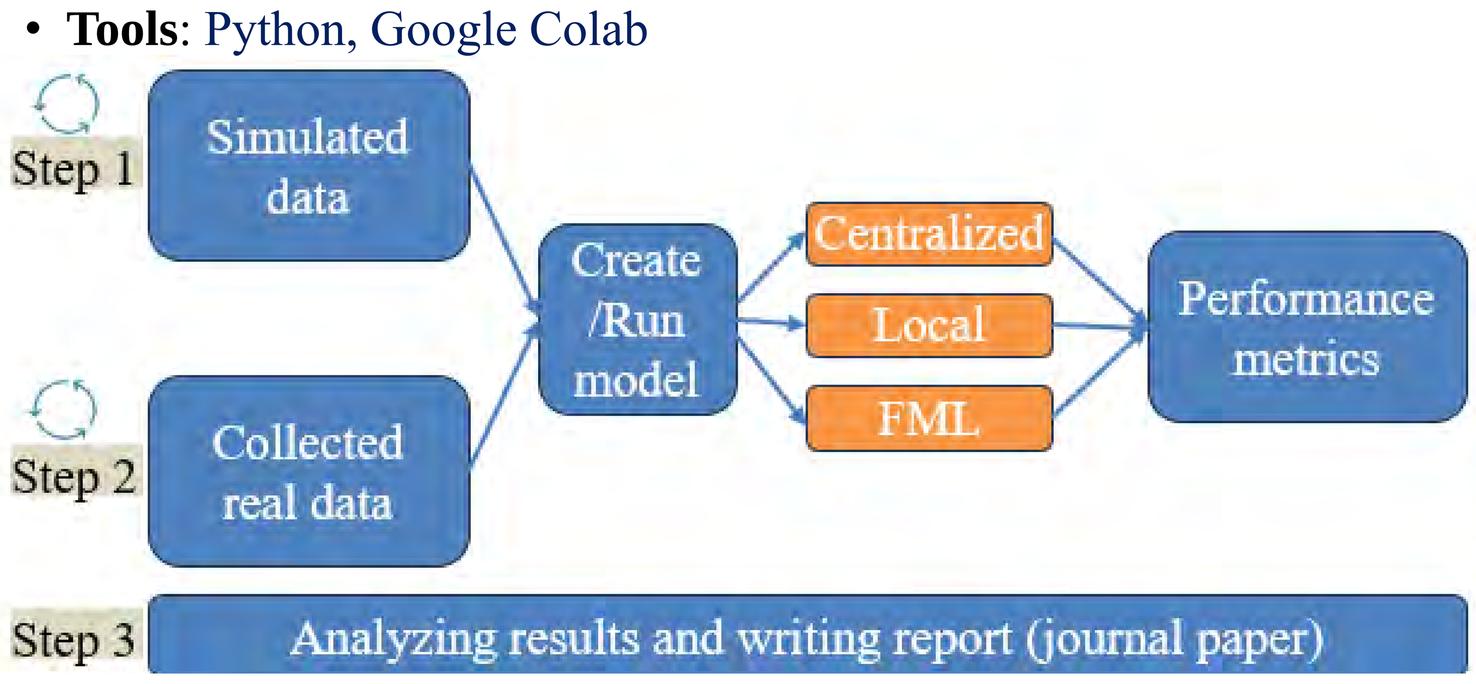


Fig. 7 Process of the study

❖ Input

- Supplier Name (ID)
- Product type
- Quantity ordered
- Contractual delivery time
- Shipping mode
- Days for shipment (scheduled)
- Location
- Order method
- Order created
- Material
- Gross weight
- …

❖ Output

- *Late delivery* $(\Delta L) \equiv$ Delay = Actual time – Contractual time (*if* $\Delta L > 0$: « *Late* »; « On time», otherwise)

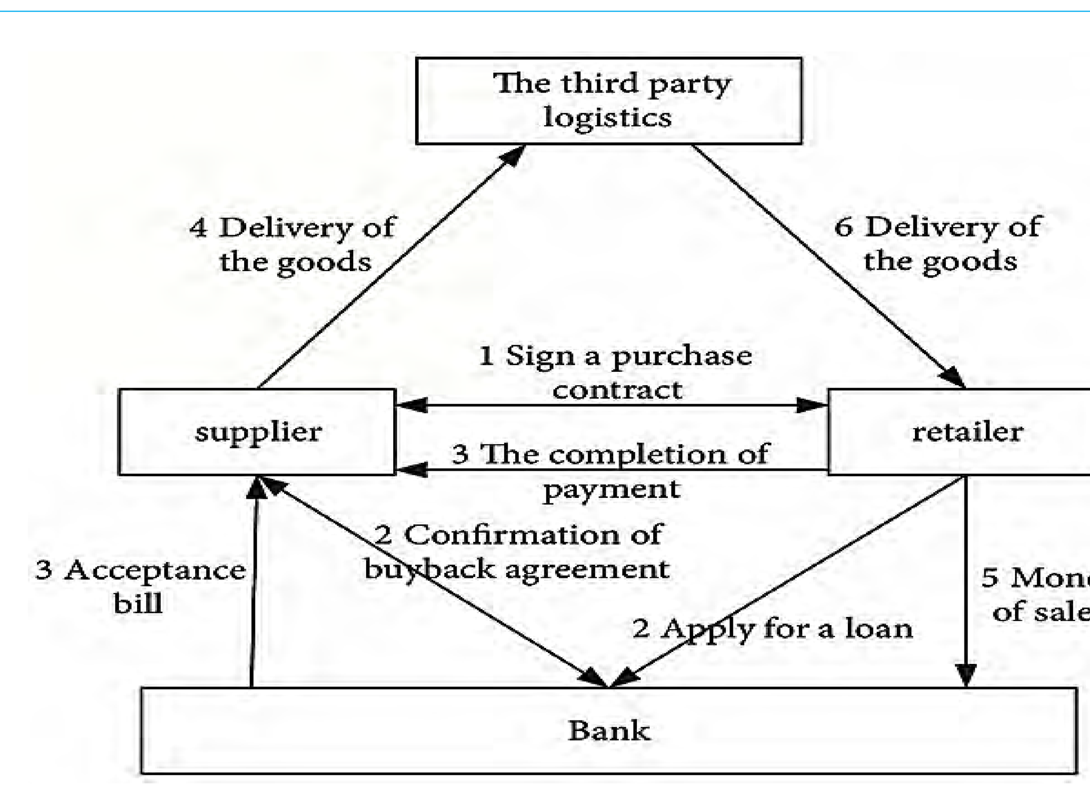


Fig. 8 The process of inventory financing
Source: Jiang & Liu (2018)

Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

CREATION OF A TEACHING AVATAR BY USING THE GENERATIVE AI AND THE METAVERSE

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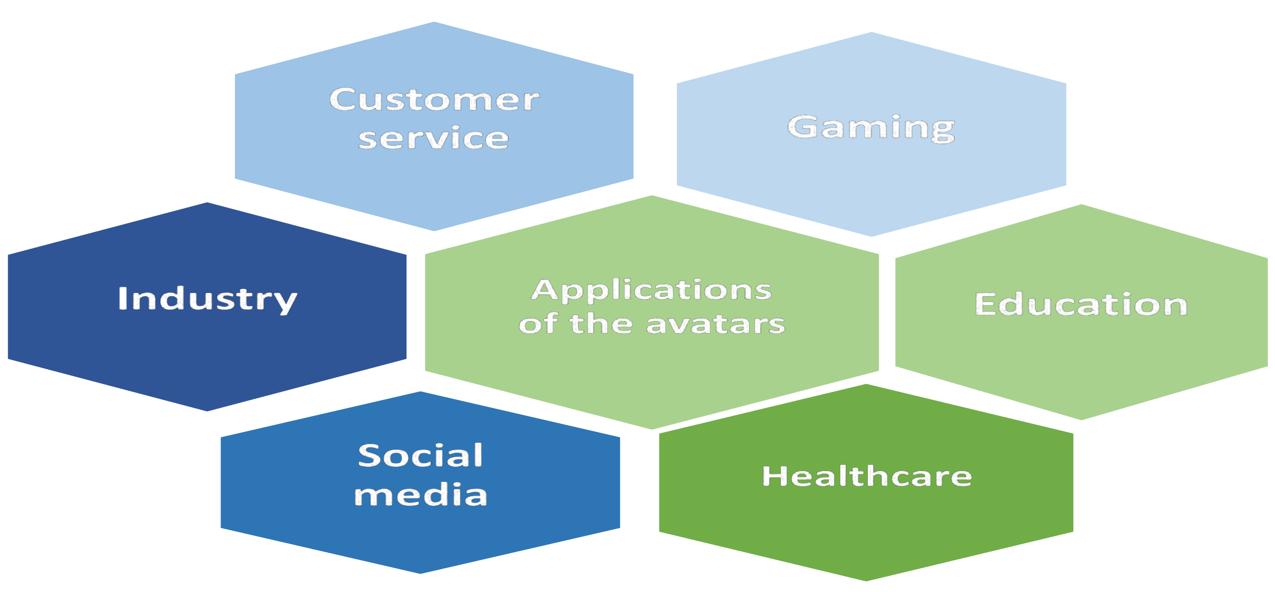
CONTEXT AND RESEARCH QUESTIONS

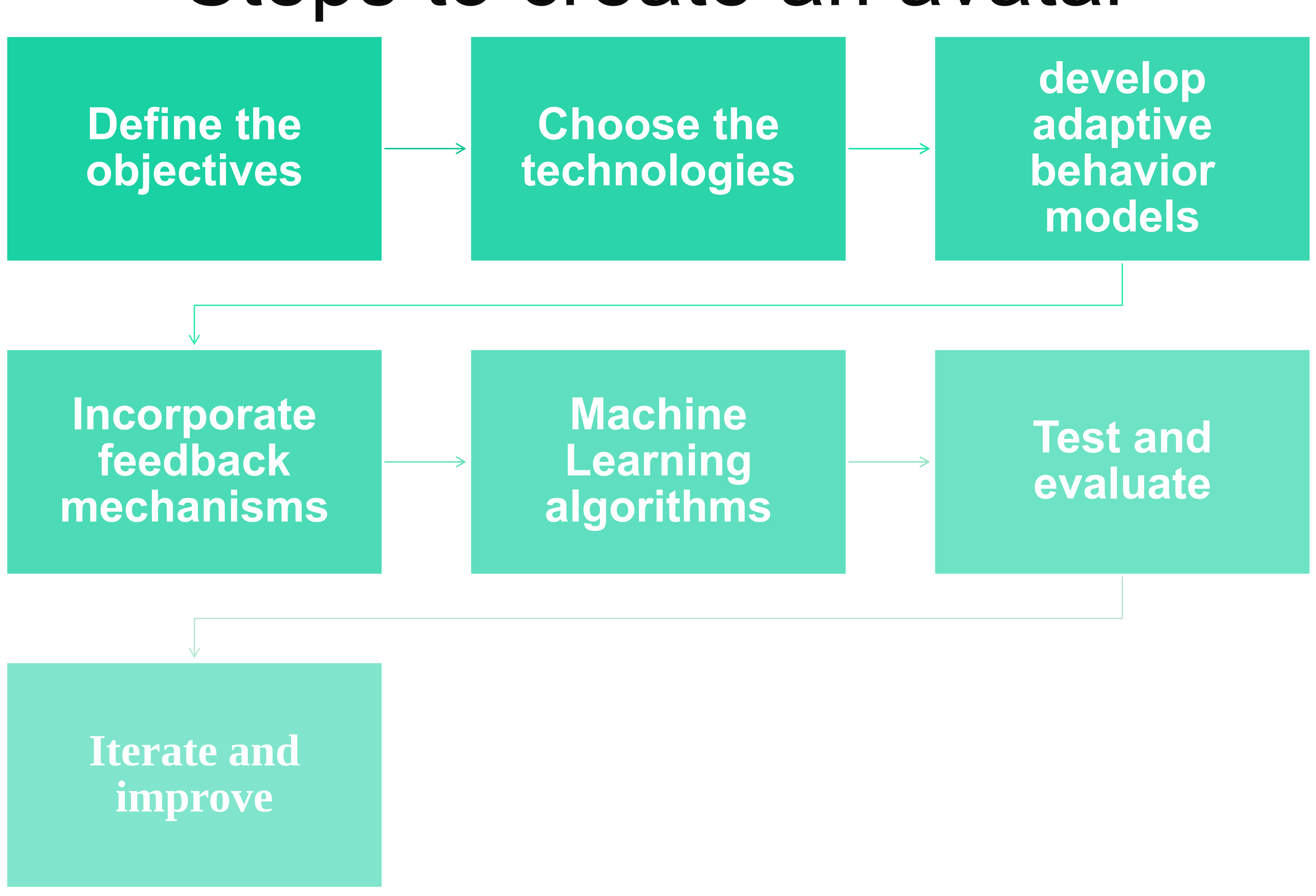


The integration of AI with AR:
☛**More realistic avatars**
☛**Allows users to interact in a more immersive way**.

1. How can avatar creation improve student engagement in virtual learning environments?
2. How avatars can be used to provide personalized support and guidance to students throughout their learning journey?
3. What are the main technologies and methods used to create a teaching avatar with AI and AR?
4. What are the main benefits of using personalized avatars for students in education?

APPROACH

Steps to create an avatar



Technologies used to create an avatar

AI: Create and animate the avatars, including facial recognition, ML, NLP.

AR: Display the avatars in the real world and allow users to interact with them in the real time

Computer vision: Capture and track user movements and gestures, enabling the avatars to mimic and respond to them.

3D Modeling: Create the digital representations of the avatars and their environments.

Motion capture: Capture the movements and expressions of real people to animate the avatars.

Speech recognition: Enable the avatars to understand and respond to spoken commands and conversations.

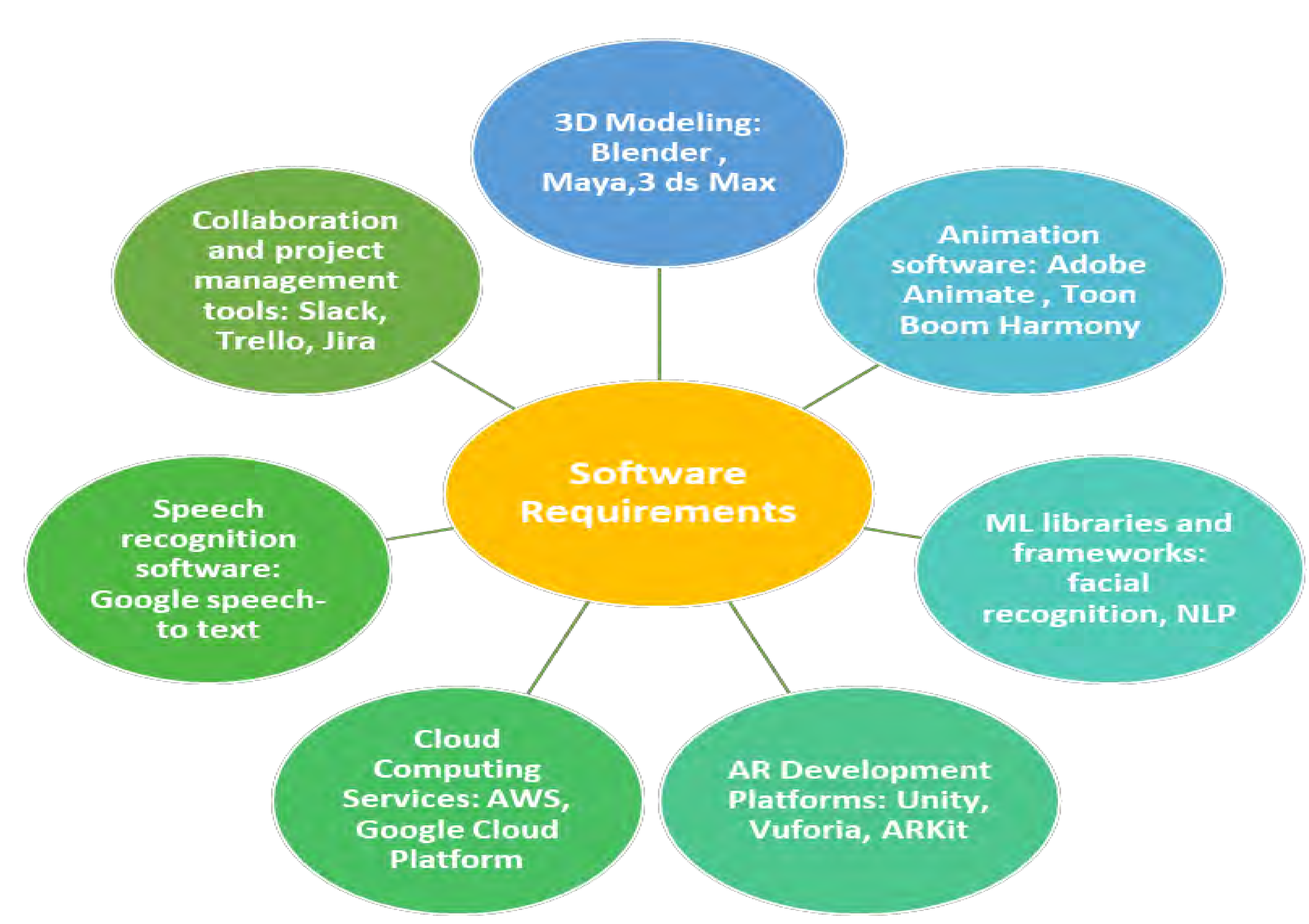
Cloud computing: Store and process the large amount of data required for creating and animating the avatars.

ONGOING AND FUTURE WORK

☛Applying AI,ML,NLP,and facial and emotional recognition to create an adaptive teaching avatar that delivers personalized and effective learning experiences for students.

☛Determine how the avatar will adjust its language, level of difficulty, examples and explanations according to student reactions.

☛Use Machine Learning algorithms to analyze feedback data and adjust avatar behavior according to student preferences and needs.



TEC-LOG[d]

Workshop on Circular Economy, Sustainability, Technology, SCM, Transportation and Logistics for Business and Economic Development

Blockchain Technology To Enhance Transparency And Trust In Supply Chain Networks

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Youcef Imine, Antoine Gallais,Abdessamad Ait El Cadi, Abdelghani Bekrar, Tarik Chargui
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{Youssef.Sellami, Youcef.Imine, Antoine.Gallais, Abdessamad.Aitelcadi}@uphf.fr

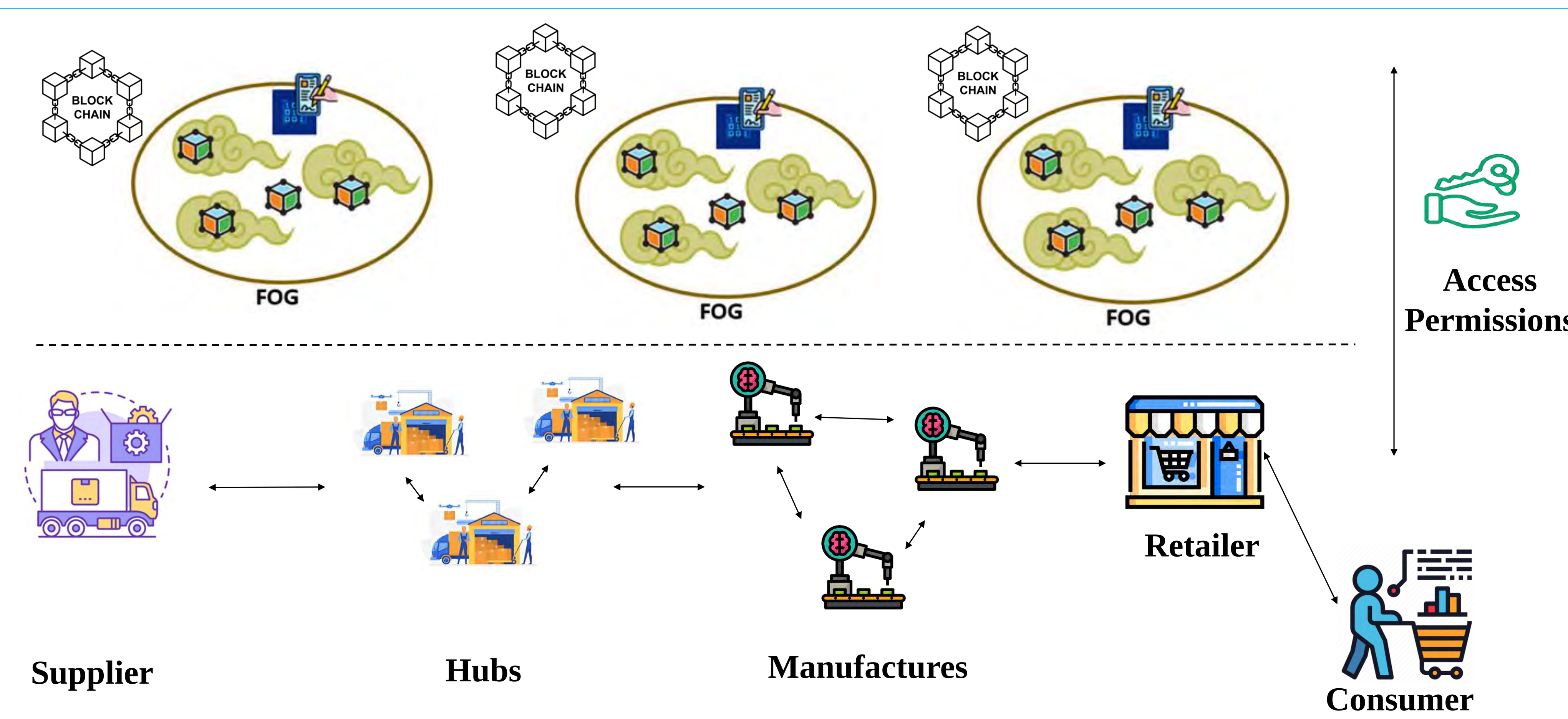
Introduction

- Traceability, transparency, and sustainability are becoming increasingly important in transportation and supply chain networks.

- Blockchain technology has emerged as a potential solution to these problems.

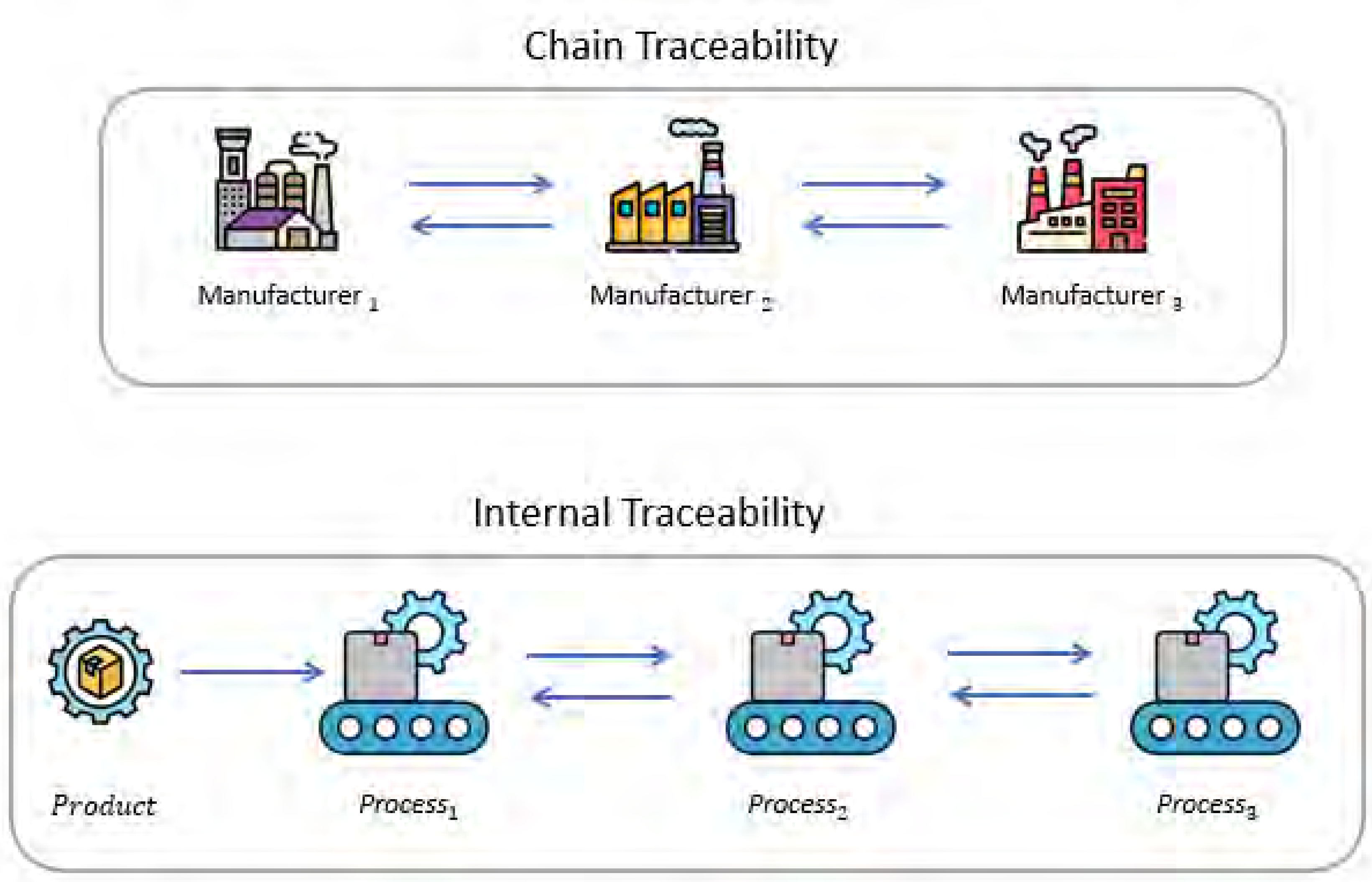
- The selection of a suitable consensus mechanism, on the other hand, is critical in assuring the reliability and efficiency of blockchain-based systems in various sectors

- This study seeks to determine the best consensus mechanism for balancing scalability, security, energy efficiency, and governance requirements in various circumstances



Context

Traceability in the supply chain

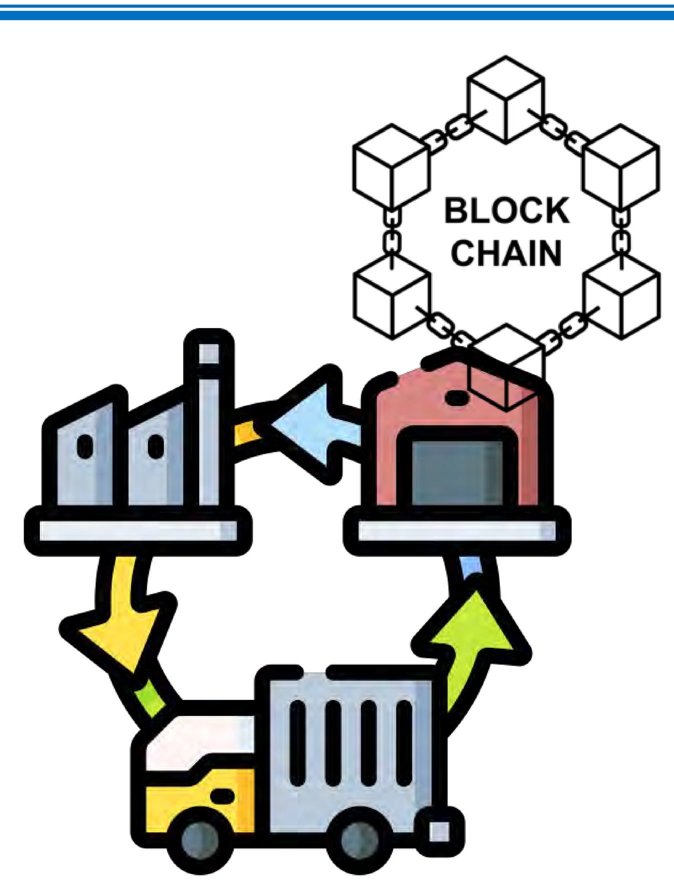


Consensus Methodology

Consensus	Energy Consumption	Scalability	Centralization Risks	Security	Governance Challenges
PoW	High	Limited	Potential	High	Low
PoS	Low	Moderate	Potential	Moderate	Moderate
PBFT	Low	Limited	Low	High	Low
PoS + PoW	Variable	Variable	Variable	Variable	Variable

How to implement new hybrid consensus mechanisms that incorporate supply chain requirements and limit centralization Challenges ?

Benefits and advantages of Blockchain for the Supply chain



Advanced supply chain