

IPIC 2024



Artificial Intelligence in the Physical Internet

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Outline



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*AI in PI
framework*
RQ1
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Summary



**Key
References**

Introduction & Objectives

The primary objective of this study is to investigate the influence of Artificial Intelligence (AI) on the evolution of the Physical Internet (PI), a transformative vision for logistics systems, through a thorough analysis of pertinent literature.

Specifically, the study focuses on three aspects:

- ***RQ1: What are the most prevalent AI methods?***
- ***RQ2: What are some PI-Theme-specific AI enhancements?***
- ***RQ3: What are the potential AI methods for PI?***

Review Methodology

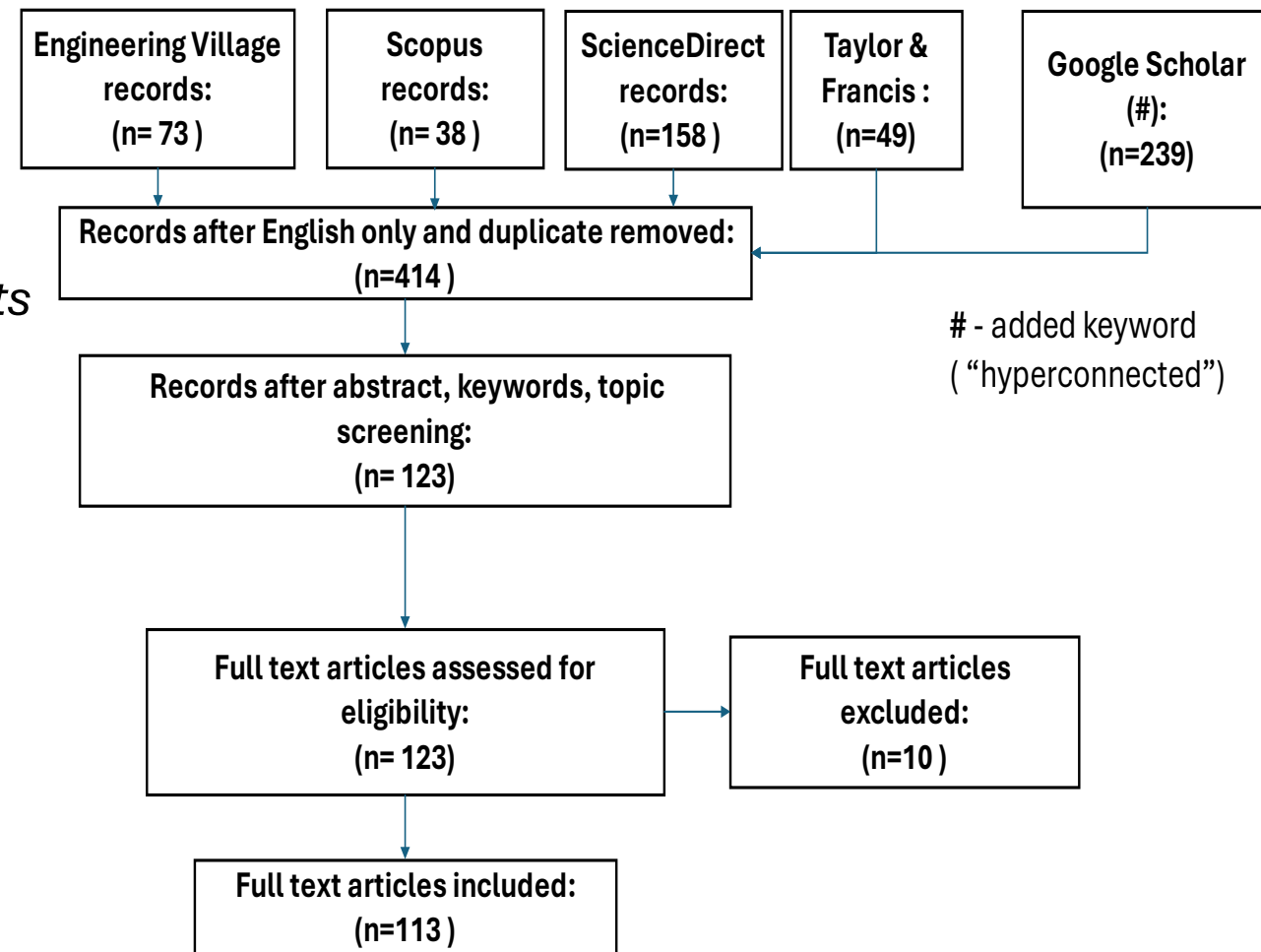
The RQs are addressed using the Systematic Literature Review (SLR) technique. This review adapts Thomé et al. (2016) guidelines, including five steps:

- (i) planning and formulating the problem;
- (ii) searching the literature;
- (iii) data gathering and quality evaluation;
- (iv) data analysis, synthesis and interpretation;
- (v) presenting results and updating the review.

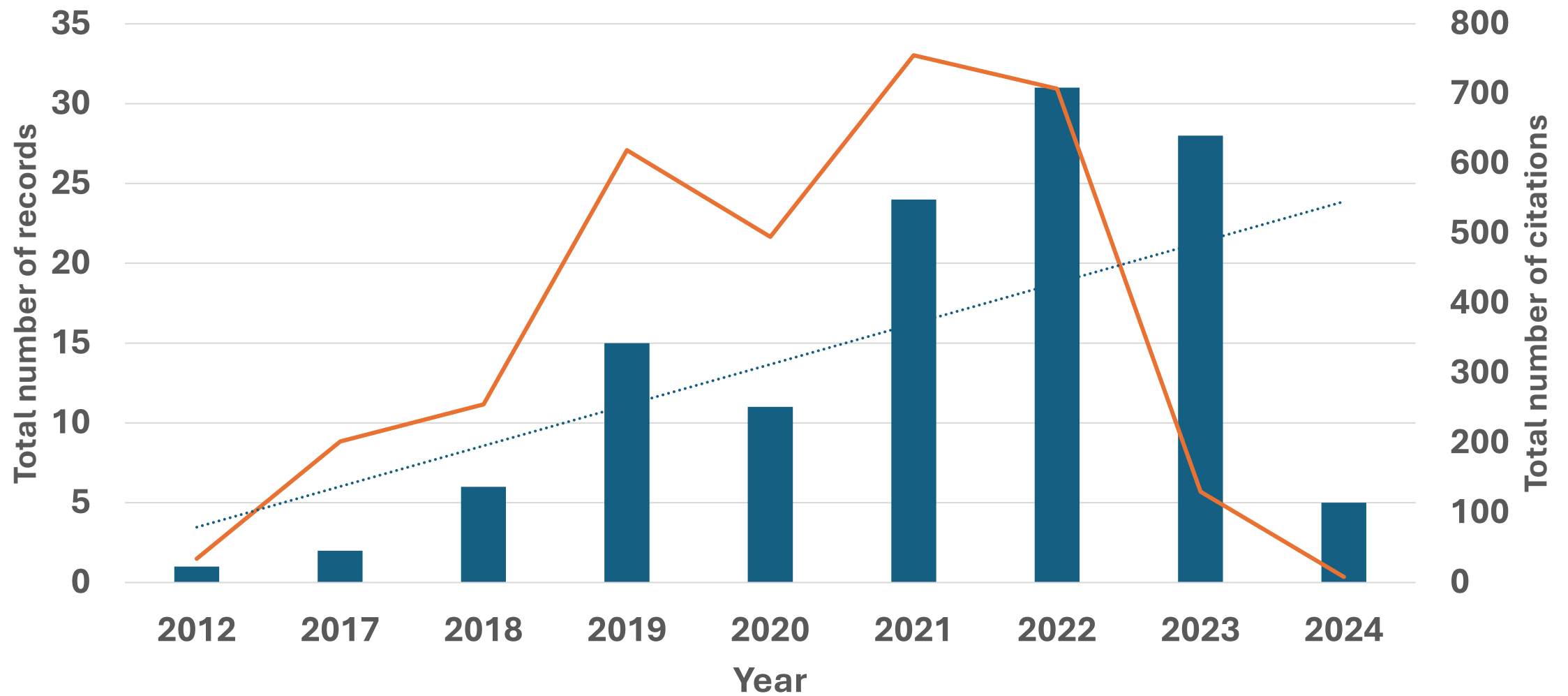
Additionally, the **PRISMA framework** is utilized for both data presentation and review revision.

Following keywords and Boolean operators are employed for extracting the relevant scholarly articles (from 2010 to 2024) for our study:

(“physical internet”) AND (“artificial intelligence” OR “machine learning” OR “deep learning” OR “unsupervised learning” OR “supervised learning” OR “reinforcement learning”) AND (“hyperconnected”)



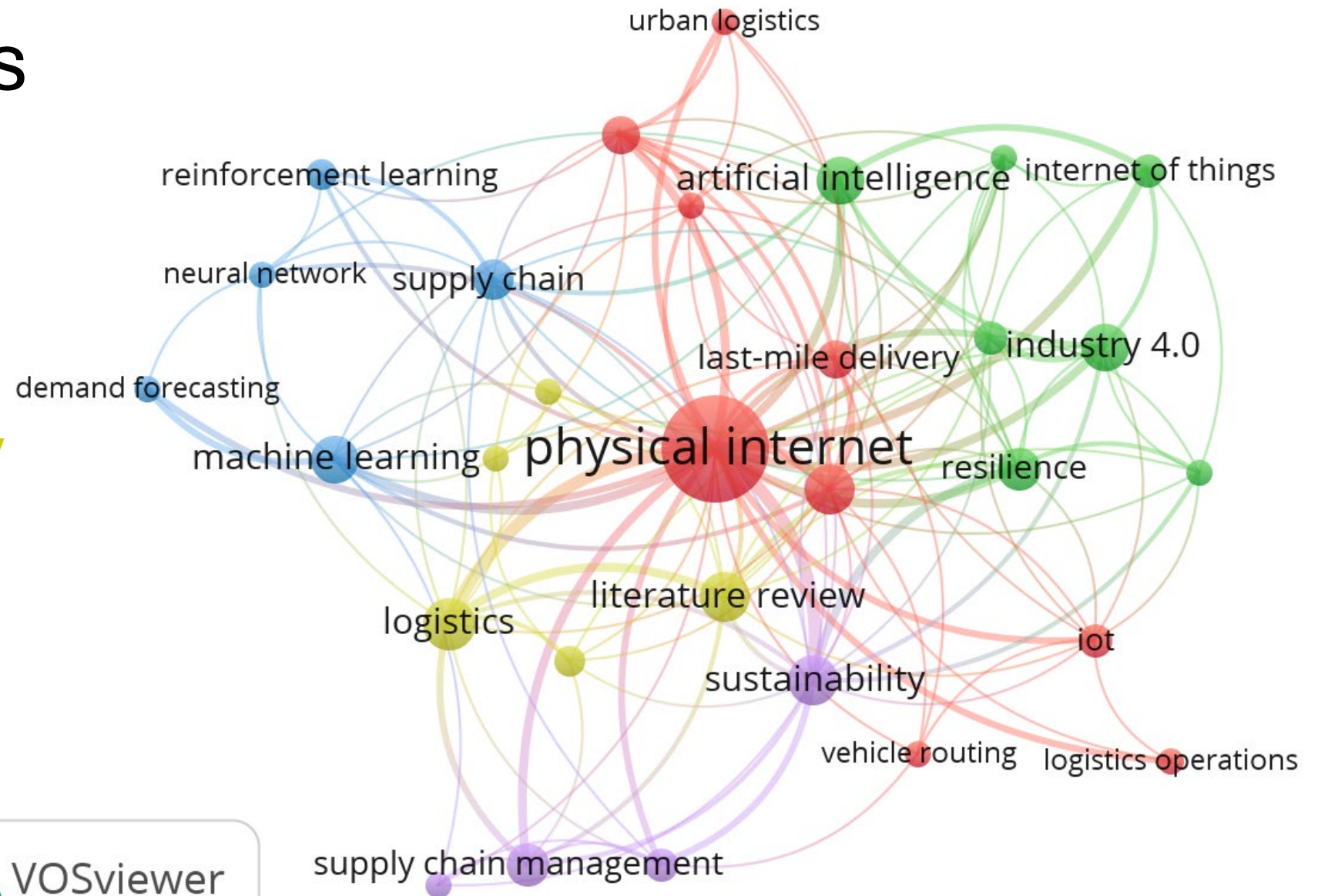
Timeline Trend



Keyword Analysis

Clusters:


- **Logistics Operations**
- **Cyber-Physical Systems**
- **Data Analytics**
- **Research trends and Methodology**
- **Sustainability and Management**



VOSviewer

Bibliometric exploration

Publication themes and metrics (Top 10)

Source	Impact factor	Cite Score	Count 	Focus	Type	Citations
International Journal of Production Economics	12	19	7	Operations Research & Management Science	Journal	286
IFAC-PapersOnLine		1.8	7	Electrical and Electronic Engineering, Computational Mechanics, Control and Systems Engineering	Journal	80
International Physical Internet Conference			6	Interconnected freight transport, logistics and supply networks	Conference	7
International Journal of Production Research	9.2	18	5	Manufacturing, Industrial Engineering, Operations Research and Management Science	Journal	107
Dissertation			5		Dissertation	1
Transportation Research Procedia		3.2	4	Social science area of transportation research	Journal	114
International Journal of Logistics Research and Applications	6.6	10	3	Logistics And Supply Chain Management	Journal	280
Transportation Research Part E: Logistics and Transportation Review	10.6	15	3	Logistics and Transportation	Journal	272
Sustainability	3.9	5.8	3	Sustainability	Journal	117
Computers & Industrial Engineering	7.9	12	3	Computer Science, Interdisciplinary Applications	Journal	71

Content analysis

• ***Literature Reviews***

- PI and Digital Transformation in Logistics
- AI and Advanced Technologies in L & SCM
- Digital Twins, Omnichannel, and Warehouse Management in Logistics

• ***Conceptual Frameworks***

- PI and Hyperconnected Logistics Systems
- AI and Automation in L & SCM

• ***PI problem – AI solution***

AI in PI framework

AI in PI framework

Physical Internet domain		Artificial Intelligence									
		Machine Learning				NLP	Computer Vision	Expert Systems	Robotics	Cognitive Computing	Generative AI (Boltzmann Machines, GANs)
		Supervised Learning	Unsupervised Learning	Deep Learning	Reinforcement Learning						
Logistics & Supply Chain Management	City Logistics / Urban Freight Logistics/ Last Mile Delivery	T [Locating service area] Locker	B [Performance improvement]	C [Demand forecasting; Joint replenishment; platoon organization; Container trading]							
			T [Locating service area]	T [Locating service area]	C [Delivery trading; Self Organization] T [Task Assignment]						
			Parcel Delivery	V [VRP; Truck Loading]	*Drone/Bike/Robot						
	Maritime Ports										
	Indoor Positioning Systems (IPS) and Indoor Location-Based Services (ILBS)			T [Monitoring; Inbound container forecasting]							

PI Theme addressed := B: Business Models; C: Cooperation Models; M: Modular Container; T: Transit Centers; V: Vehicle usage utilization
 [] := PI problem

- Hyperconnected City Logistics / Urban Freight Logistics/ Last Mile Delivery
- Manufacturing /Material Handling Systems

Discussion

RQ1: What are the most prevalent AI methods?

- **Reinforcement Learning**

- Platoon organization
- Container/delivery trading
- Self-organization

- **Metaheuristic-based AI techniques**

- Vehicle routing
- Locating service areas
- Performance improvement

- **Deep Learning**

- Monitoring
- Forecasting
- Truck loading

- **Other ML techniques/active learning**

- Joint order fulfillment and replenishment

RQ2: What are some PI-Theme-specific AI enhancements?

PI Theme	Problem	Available/ Potential
Modular containers	Container Packing Problem	Potential
	Bin-packing	Potential
Vehicle usage utilization	Adoption (drones, robots, e-bikes)	Potential
	Heterogenous Fleet VRP	Available
	VRP	Available
	Truck Loading	Available
	Co-modality	Available
Transit centers	Joint order fulfillment and replenishment	Available
	Location service area	Available
	Task assignment	Available
	Location service area	Available
	Monitoring	Available
	Inbound container forecasting	Available
Data exchange		
Cooperation models	Joint Replenishment problem	Available
	Demand forecasting	Available
	Platoon organization	Available
	Delivery trading	Available
	Container trading	Available
Legal framework		
Business models	Cost and Lead time improvement	Available
	Demand forecasting	Potential
	Adoption	Potential

RQ3: What are the potential AI methods for PI?

- **ML** [Demand Forecasting, Predictive Maintenance, Fraud Detection]
- **RL** [Dynamic Routing and Scheduling, Inventory Management, Resource allocation]
- **DRL** [Optimizing multiple interconnected components simultaneously, Autonomous Vehicles and Robots]
- **Natural Language Processing** [Seamless communication and information exchange]
- **Computer Vision** [Object recognition and tracking]
- **Expert Systems** [Insights based on complex data analysis and domain expertise]
- **Robotics** [automation and autonomy in tasks ranging from warehouse operations to last-mile delivery]
- **Cognitive Computing** [capabilities to interpret and respond to dynamic environmental conditions]
- **Generative AI** [generate synthetic data for simulation and optimization purposes, facilitating scenario testing and decision-making]

Conclusion

- **The SLR presented here offers** an assessment of recent studies (2010-2024), accompanied by an **analytical discourse, synthesis framework**, and suggestions for **future research directions**, highlighting the numerous contributions that AI brings to PI.
- **AI can significantly enhance** the implementation of the **PI roadmap** developed by the SENSE project (Ballot et al., 2020).
- The potential benefits of AI for adopting the PI are substantial and multifaceted.
- Future research must improve AI decision-making methods within the PI context.

References

- Ballot, E., Barbarino, S., Bree, B. Van, Liesa, F., Franklin, J. R., Hooft, D., Nettsträter, A., Paganelli, P., & Tavasszy, L. A. (2020). ALICE Roadmap to the physical internet. Alliance for Logistics Innovation through Collaboration in Europe (ALICE), 31.
- Cortes-Murcia, D. L., Guerrero, W. J., & Montoya-Torres, J. R. (2022). Supply chain management, game-changing technologies, and physical internet: a systematic meta-review of literature. IEEE Access, 10, 61721-61743.
- Kantasa-Ard, A., Bekrar, A., & Sallez, Y. (2019). Artificial intelligence for forecasting in supply chain management: a case study of White Sugar consumption rate in Thailand. IFAC-PapersOnLine, 52(13), 725-730.
- Klumpp, M. (2018). Automation and artificial intelligence in business logistics systems: human reactions and collaboration requirements. International Journal of Logistics Research and Applications, 21(3), 224-242.
- Montreuil, B. (2015). The Physical Internet: A Conceptual Journey, Keynote Presentation. 2nd International Physical Internet Conference (IPIIC), Paris, France.
- Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era. Sustainability, 12(7), 2789.
- Powell, W.B. (2011). Approximate Dynamic Programming: Solving the Curses of Dimensionality. John Wiley & Sons.
- Powell, W.B. (2022). Reinforcement Learning and Stochastic Optimization: A Unified Framework for Sequential Decisions. John Wiley & Sons.
- Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. Production Planning & Control, 27(5), 408-420.
- Treiblmaier, H., Mirkovski, K., Lowry, P. B., & Zacharia, Z. G. (2020). The physical internet as a new supply chain paradigm: a systematic literature review and a comprehensive framework. The International Journal of Logistics Management, 31(2), 239-287.

Thank You

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