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LOGISTICS THINKING: METHODS AND INTERDISCIPLINARITY

Elke Glistau
Prof. h. c. Dr.-Ing. Dr. h. c. (UCLV), Otto von Guericke University Magdeburg, Germany
39106 Magdeburg, Universitätsplatz 2, e-mail: elke.glistau@ovgu.de

Norge Isaias Coello Machado
Prof. Dr.-Ing., Prof.-h.c. Dr. h.c., Universidad Central „Marta Abreu" de Las Villas, Cuba
CP 54830 Santa Clara, Carretera a Camajuani km 5,5, e-mail: norgec@uclv.edu.cu

Sebastian Trojahn
Prof. Dr.-Ing., Anhalt University of Applied Sciences Bernburg, Germany
06406 Bernburg Strenzfelder Allee 282, e-mail: sebastian.trojahn@hs-anhalt.de

Abstract
This paper is part of a series of papers dedicated to academic logistics thinking in the context of metacognition. It builds on the first foundational paper by (Glistau et al., 2023). The purpose of this paper is to answer the following research questions: 1. How should the stock of methods in logistics be classified according to research activities, and what are the important research methods in logistics? 2. What knowledge is relevant to logistics as an interdisciplinary research? 3. What new research areas and exemplary research questions can be derived from the interdisciplinarity of logistics? The research results presented here are based on the empirical knowledge of the authors supplemented by selective, complementary literature analyses of relevant literature.

Keywords: *Logistics thinking, research activities, Smart Logistics Zone, interdisciplinary research, metacognition*

1. Introduction

Logistics has evolved into an applied science since the mid-20th century. There is a significant demand for logisticians with academic training. The following paper builds on the publication by (Glistau et al., 2023). In this first publication, the following issues were discussed:

- Procedure model of the research work (image),
- Definitions of "logistics", "thinking" and "ways of thinking",
- Characterizing the types of thinking in logistics via three approaches:
  - General ways of thinking, (82 kinds of thinking)
  - Ways of thinking, which are used by logistics from the other individual sciences, (more than 20 involved sciences)
  - Special "logistics ways of thinking". (special profile)
- Design and description of a thinking constellation (image),
- Categories with reference to logistics exemplarily filled in tables to illustrate.

In this paper, following research questions should be answered: 1. How should the stock of methods in logistics be classified according to research activities, and what are the important research methods in logistics? 2. What knowledge is relevant to logistics as an interdisciplinary research? 3. What new research areas and exemplary research questions can be derived from the interdisciplinarity of logistics? To take up a current trend, AI is considered and some research areas and research questions are characterised in this context.

2. Methodology

The research findings presented here are founded on the authors' extensive empirical expertise, complemented by targeted and supplementary reviews of predominantly German literature.

The literature analysis carried out can be characterized as follows:

- Language: German,
- Search Terms:
  Denken; Sinne; Denkart;
  Denkart + Wissenschaftsdisziplin;
  Logistikdenken, Logistisch* Denken,
  Denken in der Logistik, Denkmodelle der Logistik
- Period: 1990–2023,
- Search locations: Google Scholar, SpringerLink, ResearchGate,
- Explanatory model: Conceptual research work,
- Ideas to understand and explain logistics thinking: creative research work.

3. Research Results

3.1. Research Result 1: Research activities and methods in logistics

As a science, logistics serves to gain knowledge and to communicate knowledge. Recognized objects of knowledge in logistics are [Cf. (Glistau, et al., 2023) and (BVL, 2011)]:

– Flows in networks (BVL, 2011) (= material, information, financial and energy flows and their synergetic linkage),
– Logistics business models,
– the life cycle of logistical objects (material, goods, packaging, logistical aids),
– the life cycle of logistics systems including networks as human-technology-organization systems,
– the life cycle of logistic infrastructures,
– Linking the design objects (business models, objects, processes, systems, infrastructure) to holistic logistics solutions,
– Academic qualification and training of logisticians.

Important research activities in logistics are perceive & inform, describe, invent, analyze, modeling, planning, optimize, improve, explain, execute, evaluate, reflect, recognize and decide. The research activities in logistics mentioned are methodically substantiated, exemplified in *Table 1*.

Table 1. *Important research activities and methods in logistics*
Cf. (Lucke, 2022) and (own elaboration, 2023)

Research activity	**Categories of methods**	**Some, concrete examples to illustrate method pool**
Perceive/ Inform	– Training of senses – Data collection – Data collection by people – Experiment	– Learning to see "logistically", learning to hear "logistically" – Operational data collection, media, file and document analysis, scientific literature analysis – questioning, observation – thinking experiment, software experiment, laboratory experiment, practical test
Describe	– Technical language – Formulas – Symbolism – Key Figures – Special description models	– Technical terms: container, supply chain network – Process capability: Cpk = min (CPL, CPU) – Symbolism of eEPK, symbolism of flowcharts – Delivery capability, time, logistics cost, emissions – "8 right of logistics" – model
Invent	– Creativity techniques – TRIZ	– Mindmap, morphological box, destructive-constructive brainstorming, synectics, Idea Engineering – TRIZ-methods-pool to Altschuller and pupils (Gadd, 2016)
Analyze	– Statistics – Stochastics – Class formation – Algorithms – Pattern Recognition	– Position & Scatter Measures, Boxplot – Probability distributions – ABC-XYZ, risk classes, clusters – Calculation of ratios – Syntactic M., Statistical M., Structural M.
Modeling	– Logistics overall models – Individual logistics models: > Customer requirements & restrictions > Business Model > Object model > Process model > System model > Infrastructure model – Drawing – Graph theory	– Model "Smart Logistics Zone" cf. (Schmidtke et al., 2019) – Kano-Modell, QFD, checklists – Business Model Canvas, Terminal Operator, Freight Carrier, SCM Specialist, SaaS, IaaS – Object characteristics (qualitative/quantitative), – Object classification methods, Object KPIs – Process delineation, profile, structure, process models (SCOR-Modell, eEPK), process KPIs – System delimitation, description (qualitative/quanti-tative), characteristics, structure, System KPIs – Infrastructure characteristics (qualitative/quantitative), I.-morphology, Infrastructure KPIs – 2D und 3D

Research activity	Categories of methods	Some, concrete examples to illustrate method pool
	– Operating model – Network models – Reliability theory – Simulation models – Animations – Digitalization	– Sankey Diagram – Open operating model, Closed operating model – Network model: nodes (e.g. factories, distribution centers, ports) and edges (transports) – Series and parallel connection, redundancy, – MTBF calculation – Discrete, mesoscopic & macroscopic simulation – Video, AR, VR – Digital twin
Planning	– Scenario Technique – Forecasting methods – Estimation methods – Structural models – Process organization – Calculation methods – Variant formation	– Best case, trend case, worst case – 2nd order exponential smoothing – Estimate: Top-down., Bottom-up., Analog., Parametric., Expert assessment – Net, Point, Line, Island, Matrix, Ring – Logical, Functional, Temporal, Spatial – Division costing, overhead costing, Dome calculation – Dimensioning of manpower, resources, areas, times, costs, etc. – Morphological box (extension of characteristic values & new or special combination)
Optimize	– Inventory theory – Linear optimization based on objective functions; often multicriteria optimization – Design of experiments (DoE)	– Minimization of inventory costs while ensuring delivery capability – Minimization of number, distances / routes, handling operations, time, area, volume, personnel, etc., min. of emissions (avoid, reduce, compensate, CO_2 balance), min. of costs (activity-based costing) – Classic DoE, DoE according to Taguchi and to Shainin
Improve	– Kaizen – Business Process Reengineering (BPR) – Lean practices – Standards – Benchmarking – Six-Sigma – References – Logistics 4.0	– 3-Mu-Checklist, 5-S-Method, 6-W-Method, 5-M-Checklist, 7 Statistical Tools – TOWS, Radical redesign, idealization – 7 types of waste, value stream mapping, value stream design – Standardization, generalization, rules – Company B., Industry B., General Benchmark – Six-Sigma-Toolbox – Visions, strategies, trends, goals, reference solutions – Smart logistics Zone

Research activity	Categories of methods	Some, concrete examples to illustrate method pool
Research activity	**Categories of methods**	**Some, concrete examples to illustrate method pool**
Explain	– Theorize – Formulate hypotheses – Define laws – Formulate rules – Design case studies – Design sample solutions	– Empiricism, logistic thinking – induction, deduction – knowledge of language, expression – “Rules” for rules (as commandment, short, understandable) – Classification methods, type representative selection – Ensuring representativeness, generalization
Execute	– Supply Chain network model Sourcing-Methods – PPS – Traffic flow theory – Organization theory – Control loops – Project management	– Design, Plan, Execute, Control, Improve, Optimize, ... – Single Sourcing, Dual Sourcing, Global Sourcing – Classic PPS (JIT, JIS, priority rules), agile PPS – Simulation – Disposition, availability control, progress control, fault control – Kanban, ConWIP – Classic and Agile Project Management
Evaluate	– Valuation methods	– Validation, verification, – Sustainability (economic, ecological, social)
Reflect	– Self-reflection – Scientific feedback – Theory-practice-reflection	– Hand formula, reflection spiral, funneling, – conversation, workshop, presentation, interpretation – Procedure model of theory-practice-reflection
Recognize	– Awareness	– Metacognition (think about logistics thinking and about problem solving process and results)
Decide	– Target systems – Decision-making methods	– SMART, goal pyramid, goal hierarchy, goal weighting – Game theory, decision methods under certainty, risk and uncertainty

Table 1 provides an overview of the scientific repertoire of the scientific discipline of logistics as an overall statement. On the one hand, *Table 1* forms a systematising framework; on the other hand, it contains a few illustrative examples and is thus an open list that invites re-use, expansion and adaptation.

3.2. Research Result 2: Interdisciplinarity in Logistics

Logistic thinking is roughly characterised in *Figure 1* according to (Glistau et al., 2023). The foundation of this discussion lies in the comprehension of the term “logistics” and its interpretation as “logistics as an applied science”.

Figure 1 provides a broad overview of logistical thought, encompassing three key categories: typical and frequently employed models of thought in logistics (terms), common modes of thinking (characteristics), and current objectives (goals), which concurrently serve as evaluative criteria. The illustrative breakdowns within these three categories offer significant examples but can, of course, be abridged, expanded, or adapted as needed. *Figure 1* is rooted in the authors' empirical expertise. Additionally, (Glistau et al., 2023) provides further validation through references to literature, demonstrating that many other scholars share this viewpoint. Thus, this publication is cited as a source of literature-based evidence.

Furthermore, it's essential to acknowledge that all other general forms of thinking and those specific to the various sciences involved are equally pertinent to logistics. The comprehensive list of these types of thinking is included in (Glistau et al., 2023), and for brevity's sake, it is intentionally not reiterated here.

Within the right-hand cluster, the term "interdisciplinary" prominently emerges as the second concept. This facet of logistical thinking warrants further elaboration. Interdisciplinarity in particular opens up a very wide scope for logistics and interdisciplinarity is a basic academic attitude: "in which openness, context awareness and recognition of one's own disciplinary boundaries, dialog interest as well as the ability to cooperate and integrate are combined." (Blankenburg et al., 2005)

For instance, to illustrate this point, consider the connection between "quality management and logistics," as elaborated in the textbook of the same title (Illés et al., 2012).

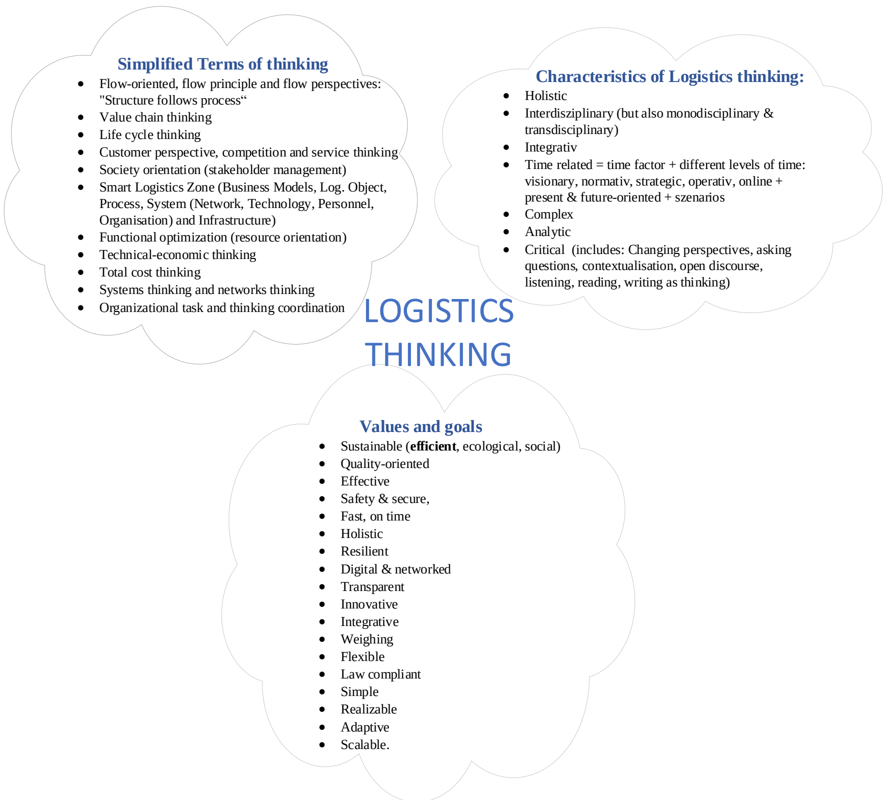

Figure 1. *Logistics thinking* [Compare (Glistau et al., 2023) and literature sources in this paper]

The fundamental domains of logistics encompass transportation, handling, and storage. Notably, logistics is inherently interdisciplinary. To underscore and elucidate this characteristic, *Table 2* enumerates twenty-seven scientific disciplines closely intertwined with logistics. In column 2, a representative illustration of the link between each of these individual scientific disciplines and logistics is provided, serving as a demonstrative example of their interconnection.

Interdisciplinarity extends beyond a mere summation of these components, giving rise to synergy effects that amplify the overall impact. In addition to bilateral relationships (as indicated in *Table 2*), the adoption of multilateral configurations is both commonplace and encouraged when addressing scientific inquiries and tasks.

Table 2. *Examples of bilateral linking of logistics with another science*

Logistics	Examples of bilateral linkage
+ Mathematics	Route planning, tour planning
+ Physics	Calculation of centers of gravity of loads
+ Mechanics	Calculation of movements on conveyors
+ Construction	Construction of loading aids and packaging
+ Production engineering	Production of packaging, production logistics
+ Traffic and + material flow technology	Planning of logistics centers
+ Electronics/Electrical Engineering	Traffic control systems
+ Quality Management	Logistics of complaints, returns and rework, process capability, compare (Illés et al., 2012).
+ System Engineering	Logistics systems as MTO systems
+ Automation Technology	All types of autonomous driving e.g. AGVs
+ Environmental Technology	Waste disposal logistics
+ Power Engineering	Planning of charging infrastructure for e-mobility
+ Safety engineering	Safety logistics
+ Maintenance	Spare parts logistics
+ Materials technology	Intelligent materials
+ Cybernetics	Control cards, KANBAN control, ConWIP
+ Economics	Logistic activity-based costing
+ Computer science	Software for logistics, logistics 4.0 solutions
+ Law	Supply chain law
+ Organizational Science	Supply of matrix production
+ Social science	Securing mobility in rural areas
+ Industrial science	Work organization in logistics
+ Ergonomics	Design of picking workplaces

Logistics	Examples of bilateral linkage
+ Artificial Intelligence	Forecasting of ship and truck arrivals
+ Pedagogy	Efficient forms of teaching and learning for logistics
+ Psychology	Acceptance of autonomous driving, motivation to realize

This perspective lays the foundation for numerous promising research endeavors, driven by the potential for synergetic enrichment.

3.3. Research Result 3: Systematic fields of future research

The third research question revolves around uncovering new research domains and presenting illustrative research inquiries that stem from the interdisciplinary nature of logistics. This inquiry unveils a vast realm of research opportunities within the field of logistics.

Table 3 provides documented examples of how to address this challenge by examining the interplay between three distinct scientific disciplines: logistics, the contemporary trend science of artificial intelligence (AI), and an additional discipline specified in *Table 3*, column 1.

Table 3. *Examples of trilateral research topics*

Logistics	Examples of trilateral research topics (Logistics, Artificial intelligence [AI] and one other more)
+ Mathematics + Physics/Mechanics	Use of existing calculation possibilities and known laws for dimensioning, evaluation, selection and operation of logistical objects, processes, systems and infrastructure
+ Construction	AI-supported, holistic development processes
+ Production engineering	AI-supported planning and control of production
+ Traffic and + material flow technology	AI-supported generation, evaluation and selection of transport variants
+ Electronics/Electrical Engineering	AI-supported, condition recording and evaluation of logistics solutions
+ Quality Management	AI-supported, quality-oriented design of logistics solutions
+ System Engineering	AI-supported rules for complex logistics systems
+ Automation Technology	AI-supported, automation-oriented design of logistics solutions
+ Environmental Technology	AI-supported, environmentally friendly design of logistics solutions
+ Power Engineering	AI-supported, energy-efficient design of logistics solutions
+ Safety engineering	AI-supported, safety-oriented design of logistics solutions
+ Maintenance	AI-supported, maintenance-friendly design of logistics solutions
+ Materials technology	Development and use of intelligent materials, parts, packaging and logistics aids
+ Cybernetics	AI-supported regulation of flows in networks

Logistics	**Examples of trilateral research topics (Logistics, Artificial intelligence [AI] and one other more)**
+ Economics	AI-supported calculation of costs and expenses of logistics solutions
+ Computer science	Development and introduction of AI-supported software and hardware solutions
+ Law	AI for legal information and jurisdiction regarding laws to be taken into account in the field of logistics
+ Organizational Science	New AI-based jobs and forms of organisation in logistics
+ Social science	AI-supported implementation of social sustainability in logistics
+ Industrial science	Establishment and improvement of AI-supported workplaces
+ Ergonomics	AI-supported ergonomic design of logistics workplaces
+ Artificial Intelligence	Establishment of digital colleagues in logistics
+ Pedagogy	AI-supported, digital education and training in logistics
+ Psychology	Motivation and acceptance for the use of AI-supported logistics solutions

Table 3 serves as a singular exemplification of how theoretical explorations can extend using applied intelligence. It also underscores that the conventional label “industrial engineer” for logisticians only partially encapsulates the broad-ranging profile of a contemporary logistician. In the present landscape, scientific domains like computer science, encompassing AI, alongside human and social sciences, as well as legal studies, must be accorded equal importance.

Furthermore, *Table 3* illustrates that individual considerations of discrete scientific disciplines may no longer suffice in the future. Instead, a comprehensive, interdisciplinary perspective will become not only feasible but imperative. This entails the simultaneous design and operation of technical and organizational solutions that adequately address aspects such as quality, maintenance, automation, control, ergonomics, and more. This holistic approach is precisely what AI enables and facilitates.

Taking literature as an example: (Woschank et al., 2020) identifies seven particularly promising areas where AI can make significant contributions in logistics, including strategic and tactical process optimization, cyber-physical systems in logistics, predictive maintenance, hybrid decision support systems, production planning and control systems, operational process improvement in logistics, and intelligent transport logistics.

However, it’s worth noting that Jha (Jha et al., 2023) and numerous other sources tend to focus on characterizing individual domains and potentials of AI. The interdisciplinary essence of logistics substantially broadens this perspective by leveraging the vital potential and realms of AI, including machine learning, data mining, computer vision, robotics, speech recognition and processing, creativity, text generation, evolutionary computations, multi-agent systems, applied intelligence, and more.

In this regard, *Table 3* merely serves as an illustration of the approach to expand the horizons for potential solutions by synergistically connecting various scientific disciplines, thereby adopting a holistic approach empowered by AI, which is still in its early stages of development.

4. Summary

The cultivation of “logistical” thinking stands as a crucial imperative within the realm of education and training at universities and colleges, particularly for aspiring scholars in the field of logistics. In this paper, the method of Metacognition, as outlined by Flavell (1979), is employed to render logistical thinking explicit. This approach enables individuals to exercise control over, monitor, and effectively structure their own cognitive processes.

The article is dedicated to the exploration of research methodologies, the importance of interdisciplinarity, and the emergence of novel research avenues resultant from interdisciplinary intersections. Its overarching goal is to systematize the existing body of knowledge in logistics, thereby illuminating lines of inquiry and unexplored frontiers within contemporary research. Furthermore, it aspires to catalyze collaborative research initiatives and foster participation in a unified scientific discourse among scholars in the field.

5. Acknowledgements

This paper is a constituent of a comprehensive series of publications that disseminate research findings within the domain of “Logistic Thinking – Metacognition” to a discerning professional audience. Its primary objective is to invigorate scholarly discourse and make substantive contributions to the foundational research within the scientific discipline of “Logistics”.

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