NOMIS: A Socio-Technical Approach to Human-Centered Information Systems Development

José Cordeiro[1,2]

[1] *Instituto Politécnico de Setúbal, Escola Superior de Tecnologia de Setúbal, Campus do IPS - Estefanilha, 2910-761 Setúbal, Portugal*

[2] *Centro ALGORITMI, University of Minho, Campus Azurém, 4800-058 Guimarães, Portugal*

Abstract

In this paper, we introduce NOMIS (NOrmative Modelling of Information Systems), a novel human-centred approach to Information Systems (IS) modelling, that integrates insights from Organizational Semiotics, the Theory of Organized Activity, and Enterprise Ontology. NOMIS emphasizes the centrality of human observable actions and interactions in modelling and developing IS, grounded in the philosophical stance of Human Relativism. We present a comprehensive overview of the theoretical foundations of NOMIS and demonstrate its practical application through a case study. This case study highlights the differences between NOMIS and traditional business process modelling, showcasing the advantages of a human-centred approach in capturing real-world activities and interactions. The findings suggest that NOMIS provides a more accurate and effective framework for IS development, ensuring better alignment with organizational goals and user needs.

Keywords

NOMIS, Human-centred Information Systems, Socio-Technical Approach, Organizational Semiotics, Theory of Organized Activity, Enterprise Ontology, Human Relativism, Business Process Modelling.

1. Introduction

The development of Information Systems (IS) has traditionally been dominated by technical approaches that often overlook the inherently human aspects of these systems. As organizations increasingly rely on IS to support complex business processes, the limitations of these traditional methods have become more apparent. The failure to adequately address human factors in IS development has led to numerous issues, including user dissatisfaction, system inefficiencies, and project failures.

To address these challenges, this paper introduces NOMIS, a human-centred approach to IS development that integrates the strengths of Organizational Semiotics, the Theory of Organized Activity, and Enterprise Ontology. NOMIS focuses on *observable human actions* and interactions, ensuring that IS are designed and developed with a deep understanding of the human elements involved and its context. By doing so, NOMIS aims to create systems that are not only technically robust but also socially and organizationally effective.

The 10th International Conference on Socio-Technical Perspectives in IS (STPIS'24) August 16-17 2024 Jönköping, Sweden.

jose.cordeiro@estsetubal.ips.pt (J. Cordeiro)

0000-0001-9071-8873 (J. Cordeiro)

This paper is structured as follows: Chapter 2 reviews the existing literature on soft and socio-technical approaches to IS development. Chapter 3 discusses the socio-technical foundations of NOMIS, detailing its theoretical underpinnings. Chapter 4 presents the NOMIS approach in detail, highlighting its core concepts and modelling techniques. Chapter 5 illustrates the application of NOMIS through a case study on "Order Fulfilment and Procurement," comparing it with traditional business process modelling. Finally, Chapter 6 concludes the paper with a discussion on the implications of NOMIS for IS development and future research directions.

2. Soft and Socio-Technical Approaches to Information Systems Development

In this chapter, we delve into the existing literature on Information Systems (IS) development methodologies, focusing on soft and socio-technical approaches. We explore the evolution of these approaches, their underlying principles, and their limitations. This review provides a foundation for understanding the need for a new paradigm in IS development, setting the stage for the introduction of NOMIS in subsequent chapters.

2.1. Soft and Hard Approaches to Information Systems Development

In the field of Information Systems Development during the late 20th and early 21st centuries, there was a common distinction between soft and hard approaches [1]. Hard approaches were understood to be technically oriented, often neglecting the inherently human nature of Information Systems. As Fitzgerald et al [1] described, hard approaches tend to treat people in mechanistic terms, viewing them as processing devices that can undertake tasks that could equally be done by machines. Hard approaches were associated with characteristics such as mechanistic, rational, technical, scientific, predictable, formal, ordered, objective, quantitative, deterministic, realist, positivist, functionalist and more. These terms were frequently used by proponents of soft approaches to criticise hard approaches, highlighting the contrasting qualities of human and organizational contexts [2]. In contrast, soft approaches recognise the centrality of human activity in Information Systems, seeking to understand the complex interplay between technology and its social context.

One of the pioneering soft approaches is ETHICS (Effective Technical and Human Implementation of Computer-based Systems), developed by Enid Mumford [3]. ETHICS emphasises the alignment between technological and social systems within organisations, treating ISD as a change process involving both technical and social elements. It focuses on employee job satisfaction and quality of work life through participative design processes. Key aspects of ETHICS include actively involving stakeholders in the design process to ensure their needs and expectations are met, simultaneously optimising both social and technical systems, and empowering workers by considering their roles and satisfaction in IS development. However, some have argued that ETHICS does not fully integrate the social and technical aspects, instead treating them as distinct elements that need to be "aligned". This separation can lead to difficulties in fully optimising the interplay between the technological and human factors throughout the development process [4].

Another significant soft approach is the Soft Systems Methodology (SSM), developed by Peter Checkland [5] and [6]. SSM is grounded in systems theory, particularly the concept of human activity systems. It views organisations as complex, adaptive systems where human activities and interactions play a central role. This methodology emphasises understanding the rich context of human activities and the purposeful actions of individuals and groups within organisations. By focusing on human activity systems, SSM aims to uncover the underlying patterns and structures that influence organisational behaviour and outcomes, enabling more effective and sustainable improvements. SSM is particularly effective in addressing ill-structured or ambiguous problems typically encountered in organisations. It utilises a seven-stage process to transition from an unstructured problem situation to actionable improvements. These stages involve understanding the problem from multiple stakeholder perspectives, defining the core issues and systemic nature of the problem, creating conceptual models based on root definitions to explore potential changes, and comparing these models with the real-world situation to identify feasible improvements.

Several other soft approaches to ISD have emerged, each contributing unique perspectives and methodologies. For example, [7] analysed SSM and four other soft approaches that sought to overcome the limitations of hard approaches and their narrow view of Information Systems:

- The Interactionist approach, or social informatics, originated from the work of Rob Kling and his colleagues [8]. This approach focuses on the broader organizational issues related to computer-based information systems (CBIS) as institutions rather than simple tools. It emphasizes the social and political choices made by organizational actors over time and how these choices shape and are shaped by CBIS.
- The Professional Work Practice approach, pioneered by Lars Mathiassen and colleagues [9], advocates for the empirical analysis of actual work practices of system professionals before implementing changes. This approach uses action learning and organizational learning theories to enhance ISD methodologies by incorporating best practices derived from real-world experiences.
- The Scandinavian Trade Unionist approach emerged in some Scandinavian countries where labour unions were powerful and involved in the design and decision-making processes of computer systems. This approach integrates social and human factors brought by users and unions into the design process, evolving into what is known as 'cooperative design' described in [10].
- The Speech-Act based approach views information systems from the perspective of human communication. Grounded in the philosophy of language by John Searle [11] and further developed by philosophers like J. L. Austin [12], this approach focuses on how language is used to perform actions and create commitments. Searle's work on speech acts categorizes communicative actions into types such as assertives, directives, commissives, expressives, and declarations, each performing a different function in communication. By understanding how language functions in social interactions, designers can create systems that better support collaborative work and communication.

Notably, many of the soft approaches described so far have their origins in Scandinavia [13]. This region has been a significant contributor to the development of Information Systems theories and methodologies, largely due to the pioneering work of Börje Langefors, a Swedish professor who established several IS research communities across the Scandinavian countries. Langefors is also the author of the infological approach, another relevant soft approach [14]. A key idea of the infological approach is the differentiation between information and data. While information is related to the organizational and user context, data is related to the IT context, being used respectively in system design and operation. Langefors emphasises this distinction by using a sophisticated vocabulary, referring to infology and datalogy.

There are many other soft approaches [15] that are worth exploring, each offering unique insights and perspectives on the development of Information Systems. These approaches recognise the centrality of human activity and social context within information systems, in contrast to the more technical, positivist paradigms that have historically dominated the field. The underlying commonality among these soft approaches is their focus on understanding the complex interplay between technology and its social, organisational, and human factors. By emphasising the alignment of technological and social systems, these approaches aim to optimise both the technical and human elements for effective and sustainable information systems design and implementation.

2.2. Socio-Technical Systems

Building on the foundations laid by soft approaches, socio-technical systems theory further integrates the social and technical dimensions of ISD. Socio-technical systems theory originated from the pioneering work of the Tavistock Institute in the 1950s, particularly their research in coal mining, which highlighted the need for joint optimization of social and technical systems to improve organizational performance and employee satisfaction [16]. This theory emphasizes that organizational effectiveness depends on the congruence between social and technical systems. It advocates for designing systems that enhance both technical performance and the quality of work life for employees, thereby fostering organizational resilience and adaptability, thereby fostering organizational resilience and adaptability.

Central to the socio-technical perspective is the idea that information systems are inherently socio-technical in nature, as they involve the interaction between people, technology, and the wider organizational and social environment [17].

One such theory is Activity Theory, which originates from the work of Russian psychologists in the 1920s and 1930s, notably Lev Vygotsky (1896-1934), see [18]. Vygotsky is considered the founder of this school of thought, which uses activities as the basic unit of analysis. According to Activity Theory, an activity is directed towards an objective or motive, known as the 'object of the activity'. These activities are carried out by subjects through purposeful, goal-oriented actions that can only be understood in the context of the overall activity. Actions are composed of well-defined operations and routines and are always mediated by tools and artifacts. Alexei Leont'ev, a disciple of Vygotsky, further developed Activity Theory by emphasizing that activity is socially mediated. He argued that consciousness and meaning are formed through joint, collective activities. This social mediation is crucial, as it recognizes the importance of social context in shaping human cognition and behaviour [19].

Yrjö Engeström, another key figure in the development of Activity Theory, expanded the framework by introducing a more detailed structure of activities. In his model, Engeström included three types of mediators: *tools*, *rules*, and the *division of labour*. These mediators interact within a community context to influence the subject and the object of the activity. Tools mediate the relationship between the subject and the object, rules mediate the relationship between the subject and the community, and the division of labour mediates the relationship between the community and the object. Engeström’s model provides a comprehensive view of how various elements within an activity system interact and shape each other, offering a valuable lens for analysing information systems [20].

Another significant perspective is the Language Action Perspective (LAP), which is grounded in the philosophy of language developed by John Austin and further expanded by John Searle. LAP focuses on how language is used to perform actions and create commitments, an essential element for understanding the communicative aspects of information systems. This approach emphasizes the role of communicative actions in organisational settings, aiming to design systems that facilitate effective communication and coordination.

LAP was developed as a response to the limitations of traditional information systems approaches that primarily focused on data processing and technical functionalities, often neglecting the importance of communication and social interactions. John Searle's Speech Act Theory provided the foundation for LAP, asserting that language is not just a medium for conveying information but also a means of performing actions. This perspective is crucial for understanding how people use language to establish agreements, make promises, and coordinate actions within an organization [11].

Fernando Flores and Terry Winograd further advanced LAP by applying it to the design of information systems [21]. They emphasized that information systems should support the communicative actions that underpin organizational processes. This involves designing systems that not only capture and process data but also facilitate the interactions and commitments made by individuals as they perform their work. Their book presents and proposes a design of computer systems based on a linguistic model of conversation for action, which includes stages such as preparation, negotiation, performance, and acceptance. This model provides a framework for understanding and designing systems that support these communicative processes, ensuring that information systems are more aligned with the actual practices and needs of users.

Organisational Semiotics (OS) is one more important perspective that helps understand how signs and symbols are utilised within organisations to create, communicate, and interpret information. [22] classify it as a data modelling approach within the rule-based school. They explain that "in the rule-based approaches, a data model describes rules which govern the uses of signs and symbols in organizational behaviours and thereby attach meanings to the organizational vocabulary". This aligns with Ronald Stamper's seminal analysis of information and its use in organizations, outlined in his foundational book on information [23].

Initially, OS had a formal orientation, as Stamper aimed to develop a formal technique of information analysis based on rules that define operational meanings for use in ISD. The most notable practical outcome was the LEGOL language [24] and [25], which was applied to legislative and administrative systems. This was later succeeded by NORMA, a language of social norms and physical affordances for knowledge representation [26], reflecting a shift in how information systems were perceived and designed.

OS is grounded in a radical subjectivist philosophical stance, positing that reality is socially constructed by agents through their actions. According to this view, an agent accesses reality only in the present, with the past and future accessible solely through signs. This concept of a sign is borrowed from Semiotics, the foundational theory of OS. Building on this ontological basis, OS proposes a set of methods known as the MEASUR methods [27], which are applied to business problems to achieve accurate designs and implementations of information systems. These methods aim to generate systems that are more precise, stable, and easier to maintain.

Beyond Activity Theory, the Language Action Perspective and Organisational Semiotics, several other socio-technical theories offer unique insights into information systems development. Actor-Network Theory (ANT), for instance, explores the relational dynamics within networks of human and non-human actors, highlighting the interconnected roles of these actors in technological systems [28]. Human-Computer Interaction (HCI) focuses on the design and use of computer technology, particularly user interfaces and the interaction between humans and computers [29]. Additionally, Computer-Supported Cooperative Work (CSCW) examines how collaborative activities and their coordination can be supported by computer systems, addressing the interplay between technology and social arrangements in organizational settings [30].

In conclusion, socio-technical systems theory provides a comprehensive framework for understanding and designing information systems that integrate both social and technical dimensions. While Activity Theory, the Language Action Perspective, and Organizational Semiotics offer detailed examinations of human activities, communication, and meaning, the broader spectrum of socio-technical theories, such as Actor-Network Theory, Human-Computer Interaction, and Computer-Supported Cooperative Work, collectively contribute to a richer understanding of the complex interplay between technology and social context in ISD. These approaches collectively highlight the necessity of a holistic view that addresses the multifaceted nature of information systems, ensuring that both human and technological factors are effectively integrated into the design and implementation processes.

3. Socio-Technical Foundations of NOMIS

NOMIS is built upon a theoretical foundation that integrates different socio-technical perspectives, ensuring a comprehensive approach to information systems development. This chapter delves into the three key theories underpinning NOMIS: Organizational Semiotics, the Theory of Organized Activity, and Enterprise Ontology/DEMO. These theories provide the necessary framework to understand and design information systems that align with both organizational goals and human activities.

3.1. Organisational Semiotics

Organizational Semiotics (OS) is a pivotal perspective in understanding how signs and symbols are utilized within organizations to create, communicate, and interpret information. Developed by Ronald Stamper and his colleagues [31], OS extends semiotic theory to organizational contexts by emphasizing the importance of norms and practices in shaping information representation and understanding. Stamper's significant contribution includes the Semiotic Ladder, which builds on Charles W. Morris's foundational semiotic distinctions of syntactics, semantics, and pragmatics, and extends them by adding three additional levels: the physical world, empirics, and the social world [32]. This multi-level framework allows for a comprehensive analysis of information and communication within organizations, ensuring that information systems are designed to align with both social and technical dimensions.

OS perspective emphasizes the social nature of information systems, proposing that reality and knowledge are continually constructed and altered by human agents through their actions. This approach led to the introduction of several key concepts in Organizational Semiotics, such as social norms, information fields, social affordances, and ontological dependency.

3.1.1. Affordances and Ontological Dependency

One of the core concepts in OS is the notion of affordances, borrowed from Gibson's theory of perception [33]. Gibson's theory posits that affordances are opportunities for action provided by the environment to an agent, which are directly perceived without requiring cognitive processing. Affordances are the invariants that the agent recognizes from the flux of information perceived from the environment, offering a way to understand how people interact with their surroundings.

In OS, affordances represent the states of affairs within an organization that enable or constrain certain behaviours. For instance, a pen affords the capability of writing, and a pen with a piece of paper affords the ability to write a letter [26].

Furthermore, OS introduces the concept of ontological dependencies, which describe the relationships between affordances. An ontological dependency indicates that one affordance cannot exist without the presence of another. For instance, it is not possible to write a letter without simultaneously having both the affordance of a pen and the affordance of paper during the writing process. Losing either of these affordances would render writing impossible. These dependencies help in understanding the interconnected nature of organizational elements and ensure that the information systems designed are aligned with the real-world constraints and requirements of the organization.

3.1.2. Norms and Information Fields

In Organizational Semiotics (OS), norms play a crucial role in shaping organizational behaviour and ensuring coherent communication. Norms are the rules and conventions that govern how information is created, interpreted, and acted upon within an organization. These norms can be formal, such as policies and procedures, or informal, such as cultural practices and social expectations. Ronald Stamper emphasized that understanding these norms is essential for designing information systems that are aligned with organizational realities and user needs [34].

Information fields, a concept closely related to norms, refer to the contextual spaces within which these norms are applied. An information field encompasses all relevant data, processes, and the social norms that govern their use in a specific organizational context. For example, in a customer service department, the information field would include customer records, communication protocols, and the norms guiding employee interactions with customers.

3.1.3. Overview of the MEASUR Methods

Stamper’s OS introduces the MEASUR methods to analyse and design information systems by focusing on these norms and information fields [27]. The MEASUR methods include:

1. PAM (Problem Articulation Method) - Helps in defining and understanding the problem domain by identifying the relevant norms and information fields.

2. SAM (Semantic Analysis Method) - Focuses on analysing the semantics of the organizational terms and their relationships within the information fields.
3. NAM (Norm Analysis Method) - Involves analysing the norms to understand how they influence behaviour and information use within the organization.

By applying these methods, OS aims to create information systems that are not only technically robust but also socially and organizationally effective. This approach ensures that the systems align with both the technical requirements and the social realities of the organization, making them more stable and easier to maintain .

3.2. Theory of Organized Activity

The Theory of Organized Activity, conceived and proposed by Anatol W. Holt in 1997 [35], offers a novel perspective on information systems. At the core of this theory lies the concept of 'Organized Activities', which Holt describes as a universal human phenomenon, akin to language, present wherever people exist. These organized activities manifest themselves in various forms of enterprises, ranging from small social groups to large corporations, and spanning across diverse cultural and technological stages.

3.2.1. Fundamental Elements and the Theory of Units

The fundamental elements of the Theory of Organized Activity (TOA) revolve around actions, bodies, and the concept of units. A key aspect of TOA is the Theory of Units, which posits that every organized activity consists of units that are identifiable by the community involved in that activity. These units can be actions or things, and they are characterized by specific criteria maintained by the community. For instance, in a programming community, the term 'inheritance' is considered a unit with a shared understanding among its members.

TOA emphasizes that every action involves an effort by human actors, who perform these actions both personally and organizationally. This dual performance means that actions are driven by the interests of the performers, encompassing both personal and organizational interests.

The central role of human action in TOA is illustrated through several dichotomies:

- Actions and Bodies: Actions are efforts involving material things (bodies). Actions extend in time, while bodies extend in space.
- Persons and Organizational Entities: Actions are performed by individuals (persons) and organizational entities (OEs), reflecting both personal and organizational responsibilities.

3.2.2. States and Information

In the Theory of Organized Activity (TOA), actions can create, use, or destroy bodies, support the existence or improvement of bodies, and change the states of bodies. The concept of state in TOA is specific to bodies and is understood within particular domains of action.

According to TOA, *information is used exclusively for making decisions* that determine subsequent actions. Information is carried by bodies and is context-dependent, varying with different actors and contexts. This perspective on information is unique as it relates directly to human decision-making, promising compatibility with Claude Shannon's measures and explicating real-world operations on information.

3.2.3. Diplan

The Diplan language, described in [36], is the diagrammatic language used by TOA to represent organized activity plans [35]. Adapted from Petri Nets, Diplan enables the simulation and analysis of action sequences. Each organized activity is composed of a series of connected human actions, and its plan is depicted using a Diplan diagram. In this way, Diplan serves as a planning language used to describe operational plans in human organizations. These diagrams reveal the coordination structure of human activity, with the components comprising human actions, material elements (bodies), and their involvement relationships.

Diplan diagrams offer a clear and comprehensive visualisation of the interconnected activities within an organisation. By mapping these relationships, Diplan helps to identify potential issues, optimise coordination, and ensure that the design of information systems aligns with organisational goals and realities. This approach enhances understanding and communication among stakeholders, contributing to the development of information systems that are both technically robust and socially relevant.

3.3. Dynamic Essential Modelling (DEMO) and Enterprise Ontology

DEMO, initially known as Dynamic Essential MOdelling, is now an acronym for Design and Engineering Methodology for Organizations [37]. This approach views organizations at an *essential level*, as *networks of communicating people*, stripping away extraneous material and technical considerations to reveal the core of communicative actions. These actions are driven by human intentions, commitments, obligations, and responsibilities, thereby emphasising the social aspects over the production aspects.

DEMO employs a business transaction pattern comprising three phases: order, execution, and result. This pattern follows a basic request-promise-execute-accept sequence, with the order and result phases involving performative conversations that lead to changes in the social world. The execution phase entails objective actions fulfilling the commitments made in the preceding phases. This pattern underscores the distinction between communicative acts, occurring in the intersubjective world, and objective acts, taking place in the objective world.

As a major improvement and evolution of DEMO, there is a new theory—the Ψ-theory—that provides the theoretical foundations of DEMO [37]. This theory, known as Enterprise Ontology (EO), defines its own modelling aspects and methods, as well as its own ontology of the world. EO may be recognized as the new 'DEMO' methodology and approach.

3.3.1. Enterprise Ontology and the **Ψ**-Theory

The **Ψ**-theory underpins Enterprise Ontology and DEMO, providing a theoretical foundation defined by four axioms and a theorem:

1. Operation Axiom: The operation of an enterprise consists of the activities of actor roles, fulfilled by subjects. These activities produce coordination acts (C-acts) and production acts (P-acts), resulting in coordination facts (C-facts) and production facts (P-facts).

2. Transaction Axiom: This axiom extends the basic transaction pattern by including cases where requests or acceptances are declined or rejected. It also defines a cancellation pattern for requests, promises, or statements, establishing a universal transaction pattern viewed as a socionomic law of organizations.
3. Composition Axiom: Transactions can enclose other transactions within a composite structure, and transactions can self-activate, automatically triggering requests without requiring an actor role.
4. Distinction Axiom: This axiom concerns the operation of actors divided according to three fundamental human abilities: performa (bringing about new things through communication), informa (content aspects of communication and information), and forma (form aspects of communication and information).
5. Organization Theorem: This theorem states that the organization of an enterprise is a heterogeneous system comprising three homogeneous subsystems: the business organization (B-organization), the intellect organization (I-organization), and the document organization (D-organization). These subsystems differ in their production aspects: B-organization focuses on ontological production, I-organization on infological production, and D-organization on datalogical production.

3.3.2. Model Representation and Application

EO provides a structured methodology for developing enterprise models, starting with identifying business transactions and progressively detailing the model through various aspect models. These aspect models include the construction model (CM), process model (PM), action model (AM), and state model (SM). Each model focuses on different aspects of organizational knowledge and activities, using diagrams and textual descriptions to capture the intricacies of enterprise operations and support the creation of effective and sustainable information systems.

4. The NOMIS Approach to Information Systems Development

Chapter 4 provides an in-depth look at the NOMIS approach, detailing its theoretical foundations, its vision and its representation. We discuss the core concepts of NOMIS, including its focus on *observable human actions*, the integration of socio-technical perspectives, and the use of specific modelling techniques.

4.1. The Path to NOMIS

The development of NOMIS is grounded in a thorough analysis of the foundational socio-technical theories presented in the preceding chapter [38] and [39]. Despite their differing perspectives, the core concepts of these theories share a common focus on human actions and interactions. All three theories conceptualize information systems as networks of people connected through their activities and communications, emphasizing the social contexts within which these actions occur.

The three theories of Organisational Semiotics (OS), Theory of Activity (TOA), and Enterprise Ontology (EO), each consider human actions from distinct yet complementary perspectives. Responsibility is a central concept across these theories, with EO emphasising authority, TOA focusing on the interests of human performers, and EO highlighting the role of intentions. Each theory offers a unique viewpoint: EO concentrates on communication, TOA examines the effects and sequences of actions, and OS underscores the conditions necessary for actions, known as affordances. Additionally, TOA introduces the important concept of "units" - the fundamental elements within activities that are socially recognised and validated.

Context is another crucial aspect across the three theories. TOA uses activities to define context, the OS approach defines information fields, and EO employs an organisational or system context. Meaning and information are seen as contextually bound: OS utilises semiotic signs, TOA views information as essential for decision-making, while EO derives information from communicative acts. Despite these differing perspectives, they all acknowledge the fundamental significance of context in understanding and utilising information.

The role of technology is supportive across all three theories, though in different ways. In TOA, technology is employed to indirectly support human actions through computational means, with the focus primarily on the actions themselves rather than the technological tools. In contrast, OS integrates technology through norms and affordances, emphasising the necessary conditions for human actions. EO, on the other hand, views technology as facilitating communicative actions, highlighting its role in enabling effective communication and transactions within organisations. This shared perspective across the theories reinforces the idea that technology is integral but subordinate to human activities and social context.

The comparisons demonstrate that these theories are complementary and offer an opportunity to be used together to provide a holistic approach to information systems development (ISD). This integrated perspective serves as the starting point and inspiration for NOMIS. Table 1 summarizes the key concepts of OS, TOA, and EO, highlighting their complementarities and how they collectively inform the development of NOMIS.

Table 1
Comparison of OS, TOA, and EO Key Concepts

Aspect	Organisational Semiotics	Theory of Organized Activity	Enterprise Ontology
Core Elements	Signs, norms, and affordances	Human actions, units, and activities	Communicative actions and transactions
Context	Information fields	Activities and their contexts	Organizational or system context
Meaning and Information	Socially constructed through signs	Used for decision-making, mediated by tools	Derived from communicative acts
Technology	Supports activities through norms and affordances	Supports human actions indirectly through computers	Facilitates communicative actions
Human Action	Central to norms and affordances	Core of activities and decision-making	Central to communicative transactions
Responsibility and Authority	Emphasizes responsibility within norms	Focuses on interests and actions	Highlights authority and commitments

4.2. The Need for a New Philosophical Stance: Human Relativism

Human Relativism (HR) emerges as a necessary philosophical stance for addressing the complexities and intricacies involved in developing and modelling information systems [40] and [41]. Traditional scientific and technical approaches often prioritize objectivity and universality, which can overlook the inherent human elements within information systems. These systems are socio-technical ensembles involving human interpretation, decision-making, and interaction.

One of the critical challenges in developing information systems is the need to effectively address human factors. Unlike conventional scientific methods that achieve precision through repeatability and empirical validation, information systems must contend with the unpredictability and variability introduced by human elements. Individual perceptions, interpretations, and experiences give rise to variability that cannot be easily mitigated using technical methods.

HR posits that reality is inherently human-related and closely tied to human observability and social construction. This perspective shifts the focus from a purely objectivist view to one that considers subjective interpretations and interactions. A core concept in HR is observability, which helps distinguish between perception (acknowledging external reality through senses) and interpretation (creating meaning from perceptions). This distinction is crucial for developing information systems that are both precise and human-centric.

HR Assertion: "Anything that is observable will be more consensual, precise and, therefore, more appropriate to be used by scientific methods."

Observable elements provide a stable and precise basis for modelling information systems. HR emphasizes the use of measurable and observable elements, which can be material or physical things existing independently of human interpretation. This approach aims to reduce ambiguities and enhance precision.

In practical terms,

HR Assertion: "By adopting observable elements or high-precision elements under a human relativistic view, it is possible to derive a scientifically and theoretically well-founded approach to IS."

HR advocates for using observable human actions as the central focus of information systems. This provides a concrete and measurable foundation, reducing ambiguity and variability from subjective interpretations. By grounding systems in observable actions, NOMIS enhances reliability and validity, ensuring systems are both technically sound and relevant to real-world human activities. This approach facilitates clearer communication, more accurate requirements gathering, and better alignment between system functionality and user needs.

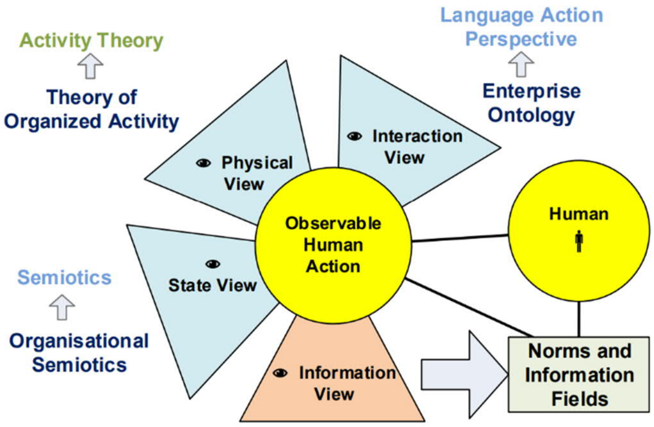

Figure 1: NOMIS Vision of Human Centred Information Systems.

4.3. NOMIS Vision of Information Systems

The NOMIS Vision of Information Systems builds on the integration of core concepts from the TOA, EO, and OS, centring around the concept of human observable action as the driving force within information systems [38]. Each of these foundational theories provides a distinct perspective on human actions and their contexts, which are central to NOMIS's approach. Human Relativism (HR) underpins these perspectives, ensuring that the inherent unpredictability of human behaviour is addressed through the concepts of observability and precision. Figure 1 presents the NOMIS Vision, showcasing the central element of observable human actions and the four distinct views: Interaction, State, Physical, and Information. These views are interconnected through norms and information fields, which regulate human actions and ensure consistency across the system.

4.3.1. The Interaction View

The Interaction View in NOMIS concentrates on the communicational aspect of human actions. It extends the Enterprise Ontology perspective, which models organisations as networks of communicative actions. While Enterprise Ontology utilises a single business transaction pattern, NOMIS permits a diversity of interaction patterns, potentially incorporating the richness of speech act types as described in Language Action Perspective. This view captures the core elements of organisational communication, specifying the actors involved, the nature of their interactions, and the communication channels employed.

4.3.2. The State View

The State View in NOMIS examines the environmental conditions and dependencies that enable and facilitate human actions, closely aligning with the principles of Organisational Semiotics. These conditions are termed Environmental States, akin to the concept of affordances in OS. An Environmental State represents a stable and observable state that enables and supports human actions. By focusing on these states and their dependencies, NOMIS ensures a stable and well-grounded foundation for modelling information systems, emphasising the contextual factors that underpin and sustain human activities.

4.3.3. The Physical View

The Physical View focuses on the material and observable aspects related to human actions, reflecting the principles of the Theory of Organized Activity (TOA). This view examines the relationships between actions and the physical elements involved, such as tools, instruments, and materials. It models business processes in terms of human actions, their sequence, and their physical context, adhering to expected behaviours regulated by norms.

4.3.4. The Information View

The Information View integrates insights from HR and semiotics. It acknowledges that information, as an essential aspect of human actions, depends on material support and human interpretation. Semiotics, the study of signs and meaning, plays a crucial role here. By understanding how signs are used to represent information, this view identifies and models the information required, produced, and consumed by human actions. The Information View ensures that the relevant information is provided to support human actions, aligning with the semiotic principles that govern meaning-making processes in organizations.

4.3.5. Norms and Information Fields

Norms, inherited from OS, play a vital role in regulating human actions within NOMIS. They provide a framework for expected behaviours, ensuring that human actions align with organizational goals. Information Fields (IFs) represent systems of norms shared by a community, defining the common terminology and facilitating consistent communication and understanding within the organization.

4.4. NOMIS Modelling of Information Systems

NOMIS Models are a means of representing the NOMIS Vision, capturing key elements and their interrelations through tables and diagrams. These models function as specific languages that shape how the world is perceived, how plans are established, and how actions are undertaken. Each NOMIS view, can be represented using a set of appropriate diagrams, in Table 2, and tables, ensuring a comprehensive and accurate depiction of each view.

The essential elements represented in NOMIS Models include Human Actions, Actors, Bodies, Information Items, Language Actions, and Environmental States. These elements and their relationships form the NOMIS Metamodel, which provides the abstract syntax for the modelling language [42]. This metamodel ensures that all elements and their interactions are comprehensively captured and accurately represented.

NOMIS also employs a specific notation to facilitate clear communication and understanding. For example, Human Interaction Diagrams (HID) illustrate human actors and their key interactions, Action Sequence Diagrams (ASD) depict business processes, and Environmental Dependency Diagrams (EDD) show the conditions enabling actions. This structured approach allows for the effective modelling and implementation of information systems, aligning technical and human factors.

By integrating these detailed models, organizations can ensure that all aspects of the system are considered, providing a robust framework for designing, developing, and implementing information systems that effectively support organizational activities and human actions [43].

Table 2
Diagrams Supported by NOMIS

Diagram Type	Description
Human Interaction Diagram (HID)	Represents human actors and their key interactions, similar to construction model diagrams in EO.
Action Sequence Diagram (ASD)	Shows typical business processes and sequences of actions, detailing interactions depicted in HIDs.
Body State Diagram (BSD)	Depicts different states of a body and their transactional relationships related to actions.
Existential Dependencies Diagram (EDD)	Illustrates Environmental States (ESs) and their existential dependencies, akin to Ontology Charts in OS.
Environmental State Diagram (ESD)	Details each ES by showing its elements and associated beginning and ending activities.
Action View Diagram (AVD)	Shows all elements related to a single action, including bodies, human performers, and information items.
Action Body Diagram (ABD)	Similar to DIPLANS, showing action sequences and state changes of bodies.
Information Connection Diagram (ICD)	Depicts information items in relation to their producers and consumers, including human actions where these items participate.

5. Using NOMIS: a case study

This chapter presents the NOMIS approach by contrasting it with traditional business process modelling through a simple case study, "Order Fulfilment and Procurement." The focus is on demonstrating how NOMIS models real-world activities, human actions, and interactions, providing clear points of connection to computer systems.

5.1. Case Study: Order Fulfilment and Procurement

To illustrate the application of NOMIS and highlight its differences from traditional business process modelling, we will use the "Order Fulfilment and Procurement" case study. This example, extracted from the "BPMN 2.0 by Example" document by the OMG [44], involves various roles, actions, interactions and decision points, making it a good choice for this purpose.

This order fulfilment process starts after receiving an order message and continues to check whether the ordered article is available. An available article is shipped to the customer, followed by financial settlement. In case the article is not available, the procurement sub-process is called to acquire the item.

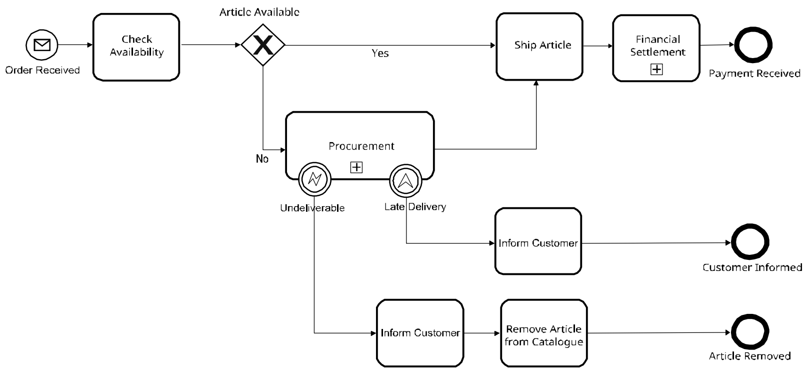

Figure 2: Order Fulfilment and Procurement BPMN Model.

Key steps include:

- Order Reception: The process starts with receiving an order message.
- Availability Check: The system checks if the ordered article is available in the inventory.
- Shipping: If available, the article is shipped to the customer.
- Financial Settlement: The process includes a collapsed sub-process for financial settlement.
- Procurement: If the article is not available, the procurement sub-process is initiated.

The procurement sub-process includes attached events to handle spontaneous occurrences during execution. It distinguishes between interrupting and non-interrupting attached events. The procurement sub-process begins with checking the availability of the article at the supplier. If not deliverable, it throws an exception. If the delivery takes more than two days, an escalation event informs the top-level process about the delay. The order fulfilment process then continues with shipping the article and financial settlement after handling the escalation event.

Figure 2 presents the BPMN model for the order fulfilment process.

5.2. Modelling the Case Study with NOMIS

NOMIS offers a distinct perspective on business process modelling, centring on observable human actions. In contrast to traditional business models that prioritise system tasks, task ordering, and abstract representations, NOMIS models the real-world activities and interactions of people. In the context of any business process, NOMIS aims to capture the essential human activities, interactions, informational states, and information items that enable these actions.

5.2.1. Analysing the Business Process Elements

In the "Order Fulfilment and Procurement" process, NOMIS focuses on identifying the observable human actions and activities as the core components. By concentrating on these observable human actions, NOMIS aims to provide a greater degree of precision, as supported by the principles of human relativism. For example, a sales representative receiving an order from a customer is an observable human action that initiates the entire process and represents a commitment to fulfilling the customer's request.

By identifying human actions, NOMIS allows us to assign responsibility and commitment, which are often implicit in traditional business models. A second example, the availability check, typically performed by inventory managers or warehouse staff, is an observable action that determines the next steps in the process. If the item is available, the process moves forward to shipping; if not, it triggers the procurement sub-process. This explicit representation of human actions helps in understanding who is responsible for each part of the process and what their intentions and commitments are. The decision process itself is not explicitly represented in NOMIS, as it is not an observable action, only the outcome of the availability check.

Each observable human action can evolve into an activity if it becomes more detailed or complex, capturing the progression and development of business processes. In the case of the procurement action and the financial settlement action, these can be considered activities that involve more than one actor and potentially additional actions. We can use separate diagrams to illustrate them. We can also refine an action as an interaction, as demonstrated with "inform customer."

In contrast to typical business processes that often follow a mandatory sequence of tasks, NOMIS recognises that human actions are influenced by behavioural norms and therefore involve a degree of uncertainty. As such, the transitions between human actions in a NOMIS model cannot be rigidly prescribed, as they depend on the unpredictable nature of human behaviour.

The contrast between the traditional business process model and the NOMIS Action Sequence Diagram presented in Figure 3 for this example emphasizes these distinctions. The BPMN diagram offers an abstract depiction of the process, whereas the NOMIS ASD accentuates the observable human actions and their sequences. This analysis does not address the procurement sub-process, as there is nothing worthwhile to add.

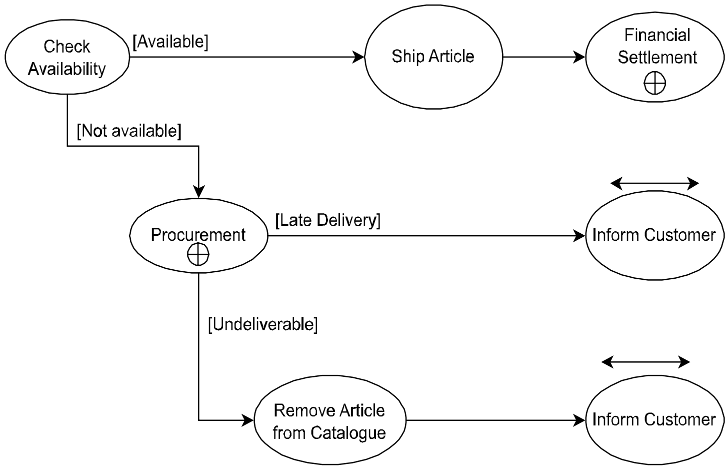

Figure 3: The Action Sequence Diagram of the Order Fulfilment and Procurement Business Process.

5.2.2. Contextual Dependencies and Environmental States

In NOMIS, environmental states define the conditions under which certain actions can take place. These environmental states establish the availability of actions. For example, the shipment of an item can only occur if the item is available in the inventory and an order has been received.

Environmental states in NOMIS not only establish the conditions for actions to be executed, but also clarify the dependencies between the states and the elements that each state relies upon. These states can apply to both informational elements, such as orders, and physical entities, like a person or an article. For example, the state "person {customer}" is defined by the physical presence of a person who has placed an order, along with additional information about their customer details. Similarly, an article in the state "article {available}" requires both the physical existence of the item and the associated information confirming its availability in the stock.

This changes the way we view action sequences in business processes. In fact, actions depend on states, as they are only available under certain conditions. Conversely, we may define different action sequences to reach the same states. From this perspective, relying on a specific business process is akin to relying on a volatile path, as we can define multiple paths to reach the same state. NOMIS contends that states are the most stable elements for modelling and developing information systems.

NOMIS uses environmental dependence diagrams to illustrate these relationships and dependencies. These diagrams highlight how stable states, such as the availability of an article or the reception of an order, enable specific actions. For instance, the state "article {available}" enables the action "ship article," while the state "order {received}" allows subsequent steps in the process, such as checking inventory and initiating shipment or procurement. The environmental dependency diagram of Figure 4 illustrates these dependencies and states, ensuring that all actions are contextually grounded and accurately represented.

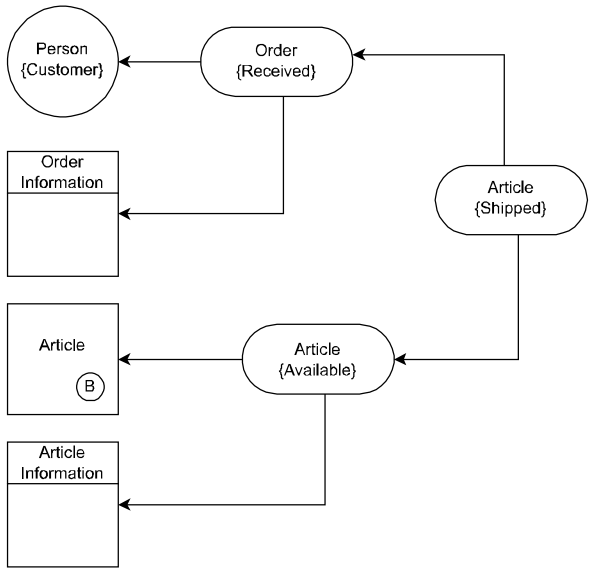

Figure 4: The Environmental Dependency Diagram of the Order Fulfilment and Procurement Business Process.

5.2.3. Uncovering Interactions

Interactions between individuals are central to the NOMIS approach, as they represent the collaborative and communicative aspects of business processes. In the "Order Fulfilment and Procurement" process, these interactions are not explicitly addressed and must be inferred in this specific case. To begin with, the interaction between the sales representative and the customer during order reception sets the stage for the entire process. This initial interaction involves communication, negotiation, and agreement, all of which are essential when adopting the perspective of the Language Action Perspective.

NOMIS models these interactions explicitly, using human interaction diagrams to map out the communication pathways and the language actions involved. These diagrams show how information and requests flow between individuals, such as the sales representative communicating with the supplier to place an order or informing the customer about the order status. This explicit representation of interactions helps in understanding the collaborative nature of business processes and the dependencies between different roles.

Furthermore, NOMIS highlights the importance of language actions in these interactions. Language actions, such as requests, commitments, and acknowledgments, are integral to the successful completion of tasks. In the procurement process, for instance, the procurement manager must request quotes from suppliers, commit to purchasing items, and acknowledge receipt of goods. NOMIS also enables adding details on how the communication or interaction is performed and the available means for it.

The interaction diagram provides a simple representation of the interactions within the business process under analysis (see Figure 5). In addition to highlighting these interactions, it also allows for a more detailed examination of the underlying processes required to support them.

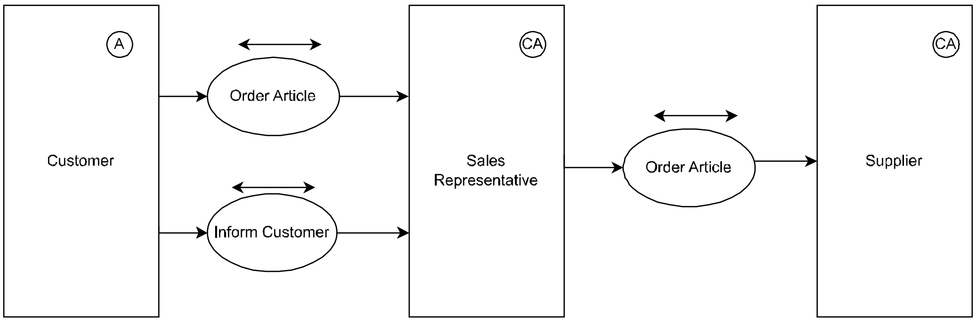

Figure 5: The Human Interaction Diagram the Order Fulfilment and Procurement Business Process.

5.2.4. Informational Dimension

In implementing NOMIS, careful attention is given to the management and structure of information. Information items are fundamental to the functioning of the system, supporting various human actions and environmental states, and ensuring that all necessary data is readily available and accurately represented. In Table 3 are represented two possible information items from our case study.

NOMIS makes a clear distinction between informational states and observable states. Informational states refer to the conditions defined by the availability and accuracy of data, such as order information or inventory status. Observable states, on the other hand, are the physical manifestations or conditions that can be directly observed, such as an article being available or shipped. This distinction is crucial as it highlights the different types of dependencies and supports necessary for action execution within a business process.

By structuring information in this manner, NOMIS enhances the robustness of the business process model. The emphasis on informational aspects ensures that all actions are supported by the relevant data, improving the clarity and efficiency of the process model. This structured representation of information flows and dependencies is a key advantage of using NOMIS for business process modelling, as it helps in identifying and addressing potential information gaps that could hinder the execution of actions.

Table 3
Information Items of the Order Fulfilment and Procurement Business Process.

Information Item	Content
1. Customer Information	Customer Details - Client's name - Contact details - Address
2. Article Information	Article details - Article name - Description - Price

5.2.5. Further Modelling

This case study serves as a simple example of the NOMIS modelling approach, demonstrating how it can effectively capture the essential aspects of business processes through observable human actions, environmental states, and informational aspects. By focusing on these elements, NOMIS provides a more accurate and human-centric representation of business processes compared to traditional BPMN models.

However, the potential of NOMIS extends far beyond this basic example. NOMIS can add more detail about the information systems from each view by employing additional diagrams. For instance, more detailed interaction diagrams can be used to map out complex communication pathways and language actions between various roles. Similarly, expanded environmental state diagrams can capture more nuanced dependencies and conditions, ensuring that all contextual factors are accurately represented.

Moreover, NOMIS can leverage comprehensive information connection diagrams to illustrate the intricate flow of data and how it supports the execution of actions. This ability to drill down into greater detail ensures that NOMIS is not only useful for high-level process modelling but also for in-depth analysis and development of robust information systems. By employing a variety of diagrams, NOMIS offers a versatile and detailed approach to business process modelling, making it a valuable tool for both analysts and developers.

5.3. Implementing Information Systems with NOMIS

Implementing information systems using the NOMIS approach involves focusing on human observable actions as the foundation for defining system functionalities [43]. This focus ensures that the system aligns closely with real-world activities and user interactions.

A key aspect of implementing systems with NOMIS is the platform architecture. The architecture is designed to separate technical aspects from human-related influences, ensuring that the system remains robust, precise, and adaptable. This separation allows for a clearer distinction between the functionalities driven by human actions and the underlying technical infrastructure, which supports these actions. As a result, the system can evolve and adapt to changing requirements without compromising its core functionalities.

Information storage in NOMIS-based systems is designed to be highly flexible and independent of the specific form in which it is stored. The schema is not fixed, allowing it to evolve over time as the system requirements and user needs change. This flexibility ensures that the system can accommodate new types of information and adapt to changes in the organizational environment without requiring extensive rework or redesign.

Temporal aspects are also taken into account in NOMIS implementations. The approach recognizes that actions and interactions occur within specific timeframes, and these temporal dimensions are integrated into the system design. This consideration allows for better planning, scheduling, and tracking of activities, ensuring that the system can respond effectively to time-sensitive requirements and provide timely support to users.

6. Conclusion

This paper introduces NOMIS (NOrmative Modelling of Information Systems), a human-centered approach to Information Systems (IS) development that integrates insights from

Organizational Semiotics, the Theory of Organized Activity, and Enterprise Ontology. By emphasizing the centrality of human observable actions, interactions, and states, grounded in the philosophical stance of Human Relativism, NOMIS ensures that developed systems closely align with real-world activities and user needs, enhancing their effectiveness and user satisfaction.

The analysis conducted in this paper, including a detailed case study, demonstrates the practical application and benefits of NOMIS. The case study highlights the significant differences between NOMIS and traditional business process modeling approaches, showcasing the advantages of a human-centered methodology in capturing and representing real-world activities and interactions accurately.

Looking forward, there is an ongoing project aimed at implementing NOMIS using a model-driven development approach [45]. This initiative seeks to leverage model-driven techniques as a proof of NOMIS's precision and effectiveness.

Future research should continue to explore the application of NOMIS in various contexts, further refining its modeling techniques and validating its effectiveness. By advancing this approach, we can better capture the complexities of human activities and interactions, leading to the development of more successful and sustainable information systems.

References

[1] B. Fitzgerald, N. L. Russo, E. Stolterman, Information Systems Development: Methods in Action, McGraw-Hill, Berkshire, UK, 2002.

[2] J. Iivari, R. Hirschheim, H. Klein, A Paradigmatic Analysis Contrasting Information Systems Development Approaches and Methodologies, Information Systems Research, volume 9, 1998, pp. 164–193. doi:10.1287/isre.9.2.164.

[3] E. Mumford, Effective Requirements Analysis and Systems Design: the ETHICS Approach, Red Globe Press, London, 1995. doi:10.1007/978-1-349-13774-9.

[4] R. Hirschheim, H. Klein, K. Lyytinen, Information Systems Development and Data Modeling – Conceptual and Philosophical Foundations, Cambridge University Press, 1995. doi:10.1017/CBO9780511895425.

[5] P. Checkland, Systems Thinking, Systems Practice, Wiley, Chichester, 1981.

[6] P. Checkland, J. Scholes, Soft Systems Methodology in Action, Wiley, Chichester, 1990.

[7] R. Hirschheim, J. Iivari, H. Klein, A Comparison of Five Alternative Approaches to Information Systems Development, Australasian Journal of Information Systems, volume 5, 1997, 1. doi:10.3127/ajis.v5i1.347.

[8] R. Kling, W. Scacchi, The Web of Computing: Computer Technology as Social Organization, Advances in Computers 21, 1982, pp. 1–90.

[9] Mathiassen, L. (1998). Reflective Systems Development. *Scandinavian Journal of Information Systems, 10*(1-2), 67-118. https://aisel.aisnet.org/sjis/vol10/iss1/5

[10] P. Ehn, M. Kyng, The Collective Resource Approach to Systems Design, in: G. Bjerknes, P. Ehn, M. Kyng (Eds.), Computers and Democracy: A Scandinavian Challenge, Avebury, 1987, pp. 17–58.

[11] J. Searle, Speech Acts, Cambridge University Press, London, UK, 1969.

[12] J. L. Austin, How to do Things With Words, 2nd ed., Harvard University Press, Cambridge, Massachusetts, U.S.A., 1975.

[13] J. Iivari, K. Lyytinen, Research on Information Systems Development in Scandinavia: Unity in Plurality, Scandinavian Journal of Information Systems 10, 1998, 1/2, pp. 135-186.
[14] B. Langefors, Theoretical Analysis of Information Systems, Studentlitteratur, Lund, 1966.
[15] D. Avison, G. Fitzgerald, Information Systems Development: Methodologies, Techniques, and Tools, 4th ed., McGraw-Hill, 2003.
[16] E. Trist, K. Bamforth, Some Social and Psychological Consequences of the Longwall Method of Coal-Getting, Human Relations 4, 1951, pp. 3-38.
[17] G. Baxter, I. Sommerville, Socio-technical systems: From design methods to systems engineering, Interacting with Computers 23, 2011, 1, pp. 4-17.
[18] B. A. Nardi, Context and Consciousness: Activity Theory and Human-Computer Interaction, MIT Press, Cambridge, MA, 1996.
[19] A. N. Leont'ev, Activity, Consciousness, and Personality, Prentice-Hall, 1978.
[20] Y. Engeström, Learning by Expanding: An Activity-Theoretical Approach to Developmental Research, Orienta-Konsultit, 1987.
[21] Winograd, T., and Flores, F. Understanding Computers and Cognition, Ablex Publishing Corporation, Norwood, NJ, USA, 1986.
[22] Hirschheim, R., Klein, H., and Lyytinen, K. Information Systems Development and Data Modeling – Conceptual and Philosophical Foundations, Cambridge University Press, 1995.
[23] Stamper, R. Information in Business and Administrative Systems, John Wiley and Sons, Inc., New York, 1973.
[24] Stamper, R. The LEGOL-1 Prototype Systems and Language, Computer Journal, Vol. 20, No. 2, 1977.
[25] Jones, S., Mason, P., and Stamper, R. LEGOL-2.0: A Relation Specification Language for Complex Rules, Information Systems, Vol. 4, No. 4, 1979.
[26] Stamper, R. Knowledge as Action: a logic of social norms and individual affordances, in Social Action and Artificial Intelligence, G. N. Gilbert and C. Heath (Eds.), Gower Press, Aldershot, Hampshire, 1985, pp. 172-191.
[27] Stamper, R., Althans, K., and Backhouse, J. MEASUR: Method For Eliciting, Analysing and Specifying User Requirements, in Computer Assistance During the System Life Cycle, T. W. Olle, A. A. Verrijn-Stuart, and L. Bhabuta (Eds.), Proceedings of the IFIP WG 8.1 Working Conference on Computerized Assistance During the Information Systems Life Cycle, CRIS 88, Egham, England, 19-22 September, 1988, North Holland, pp. 67-115.
[28] Latour, B. Reassembling the Social: An Introduction to Actor-Network-Theory, Oxford University Press, 2005.
[29] Carroll, J. M. HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science, Morgan Kaufmann, 2003.
[30] Grudin, J. Groupware and Cooperative Work: Problems and Prospects, in: Baecker, R. M. (Ed.), Readings in Groupware and Computer-Supported Cooperative Work: Assisting Human-Human Collaboration, Morgan Kaufmann, 1994.
[31] Liu, K. Semiotics in Information Systems Engineering, Cambridge University Press, Cambridge, UK, 2000.
[32] Stamper, R. Signs, Norms, and Information Systems, in Signs of Work, B. Holmqvist et al (Eds.), Walter de Gruyter, Berlin, 1996.
[33] Gibson, J. The Ecological Approach to Visual Perception, Houghton Mifflin, Boston, 1979.

[34] Stamper, R. New Directions for Systems Analysis and Design, in Enterprise Information Systems, J. Filipe (Ed.), Kluwer Academic Publishers, Dordrecht, The Netherlands, 2000.
[35] Holt, A. Organized Activity and Its Support by Computer, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997.
[36] Holt, A. Diplans: a new language for the study and implementation of coordination, ACM Transactions on Information Systems (TOIS), Vol. 6, No. 2, 1988, pp. 109-125.
[37] Dietz, J. Enterprise Ontology, Theory and Methodology, Springer-Verlag, Berlin Heidelberg, 2006.
[38] Cordeiro, J. Normative Approach to Information Systems Modelling, PhD Thesis, The University of Reading, UK, 2011.
[39] Cordeiro, J., Filipe, J., and Liu, K. NOMIS - A Human Centred Modelling Approach of Information Systems, in Proceedings of the 4th International Workshop on Enterprise Systems and Technology, Athens, Greece, 2010.
[40] Cordeiro, J., Filipe, J., and Liu, K. Towards a Human Oriented Approach to Information Systems Development, in Proceedings of the 3rd International Workshop on Enterprise Systems and Technology, Sofia, Bulgaria, 2009.
[41] Cordeiro, J. Revisiting Human Relativism – Guidelines for Precision in Information Systems Modelling, in Business Modeling and Software Design, B. Shishkov (Ed.), Lecture Notes in Business Information Processing, vol. 422, Springer, Cham, 2021. doi:10.1007/978-3-030-79976-2_15.
[42] Cordeiro, J. A. M. A New Way of Modelling Information Systems and Business Processes - the NOMIS Approach, in Business Modeling and Software Design, B. Shishkov (Ed.), Springer International Publishing, Berlin, Heidelberg, 2015, pp. 102-118. doi:10.1007/978-3-319-20052-1_6.
[43] Cordeiro, J. A. M. Applying NOMIS - Modelling Information Systems Using a Human Centred Approach, in Business Modeling and Software Design, B. Shishkov (Ed.), Springer International Publishing, Berlin, Heidelberg, 2017, pp. 27-45. doi:10.1007/978-3-319-57222-2_2.
[44] Object Management Group (OMG). "BPMN 2.0 by Example," 2010. URL: https://www.omg.org/spec/BPMN/2.0/.
[45] Cordeiro, J. A Model Driven Systems Development Approach for NOMIS – From Human Observable Actions to Code, in Business Modeling and Software Design, B. Shishkov (Ed.), Springer International Publishing, Berlin, Heidelberg, 2018, pp. 134-147. doi:10.1007/978-3-319-78428-1_7.