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32291
Socio-Technical Information Systems Design
Leseprobe

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1 Introduction

1.1 Motivation | Why study socio-technical information systems?

Quote: *"research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomena that emerge when the two interact. This embodies both a research perspective and a subject matter that differentiate the academic field of information systems*[1] *from other disciplines. In this regard, our field's so-called "reference disciplines" are actually poor models for our own field. They focus on the behavioral or the technological, but not on the emergent socio-technical phenomena that set our field apart. For this reason, I no longer refer to them as reference disciplines, but as "contributing disciplines" at best."*

Lee, 2001, p. iii

Every day, the life of individuals is influenced by technology – both directly and indirectly. Whether we talk to our friends on messengers, clock into work using a time and attendance system, hold virtual meetings, do online shopping or order food using an online delivery service, information technology plays a central role in our everyday life (see Figure 1). Even the fridges in our grocery stores wouldn't be running without digital cooling systems. This central role is exacerbated through repeated, reinforcing interaction, constituting an ongoing relationship between humans and technology – between the social and the technical (Orlikowski & Iacono, 2001; Yoo, 2013). It is about the joint optimization of these two sub-systems, providing the most effective way to achieve a goal while keeping in mind technical and social costs – the quality of life of the human actors in this interaction. Due to the social and the technical aspects being inextricably intertwined in to achieve a common goal, it is not sufficient to study these aspects in isolation.

Figure 1: Everyday Interactions with Technology

[1] The quote originates from an editorial in MIS Quarterly, one of most prestigious journals in the field of Information Systems. The field of Information Systems is primarily concerned with technical systems that human actors utilize in dealing with information, and the boundaries and integration of these systems within private or organizational life. The discipline thus differs from other disciplines, such as computer science and organization studies, through the focus on the role and usage of technology within a context.

case study

Social Aspects of Technology – The Case of Google Maps

Consider the recent example of Google Maps updating their color scheme in 2023. In this change, Google has changed the color palette, making roads gray (formerly yellow), bodies of water light blue (formerly dark blue), and parks mint green (formerly a darker green). The new and the old design can be seen in Figure 2. This change has sparked controversy among users, with a former Google Maps designer criticizing the new design as "colder, less accurate and **less human**" (Laraki, Elizabeth, Twitter, 2023, emphasis added). While the app might have featured many improvements on the technical side, the "frame of reference" of the designers might not fit with those of the prospective users (Bostrom & Heinen, 1977), rendering the system less usable, and thus less effective in attaining its goal, helping users find places and navigating to them.

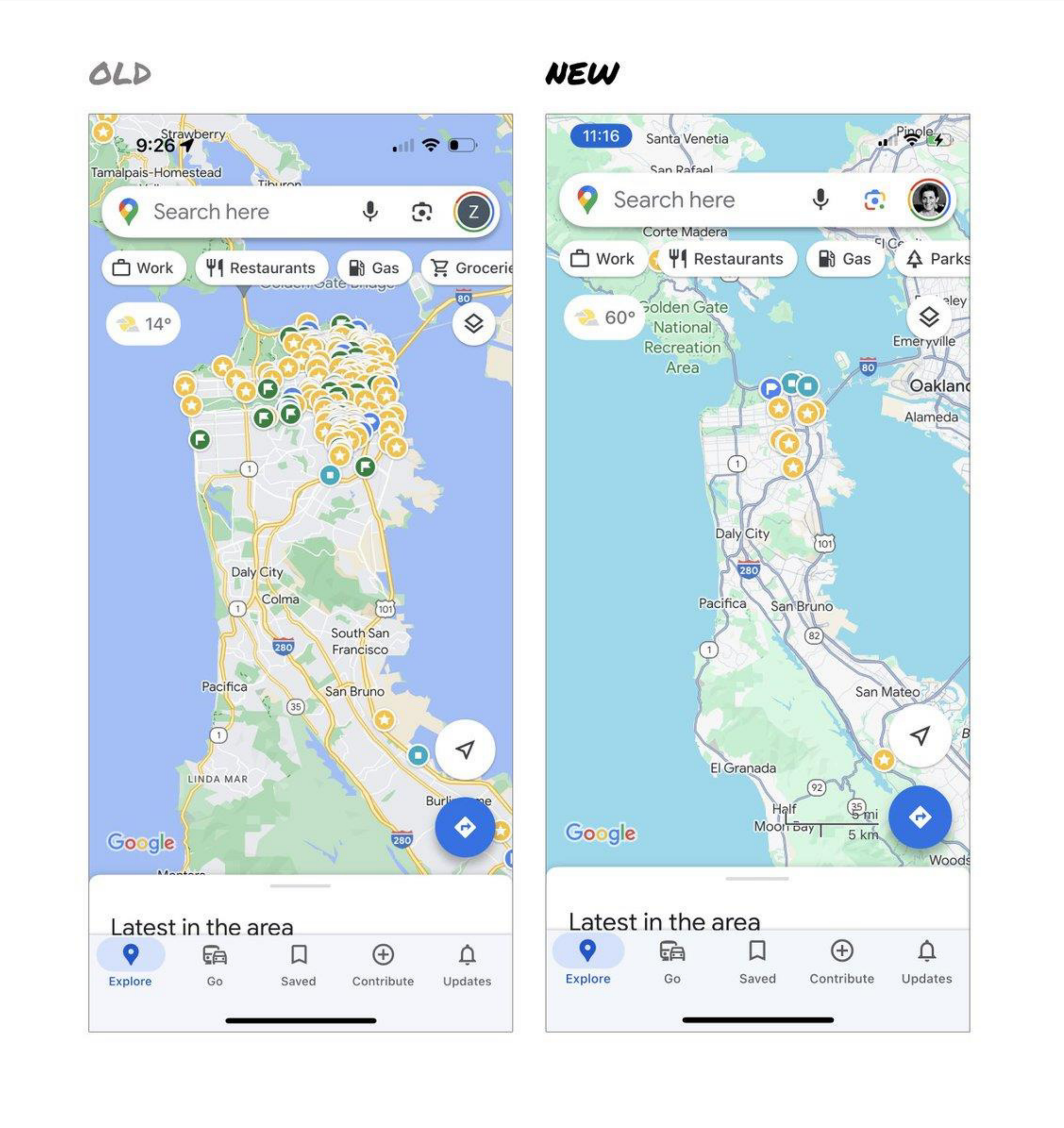

Figure 2: Old and New Google Maps Design

A solely technical focus is not sufficient in achieving effectiveness in information systems in which humans and technology need to work together. These systems are also called socio-technical information systems, putting emphasis on the intertwining of both aspects, the social and the technical, creating an interplay of (1) individual human actors, (2) structures they are embedded in (e.g., organizations), (3) technology and (4) tasks that need to be done (Figure 3).

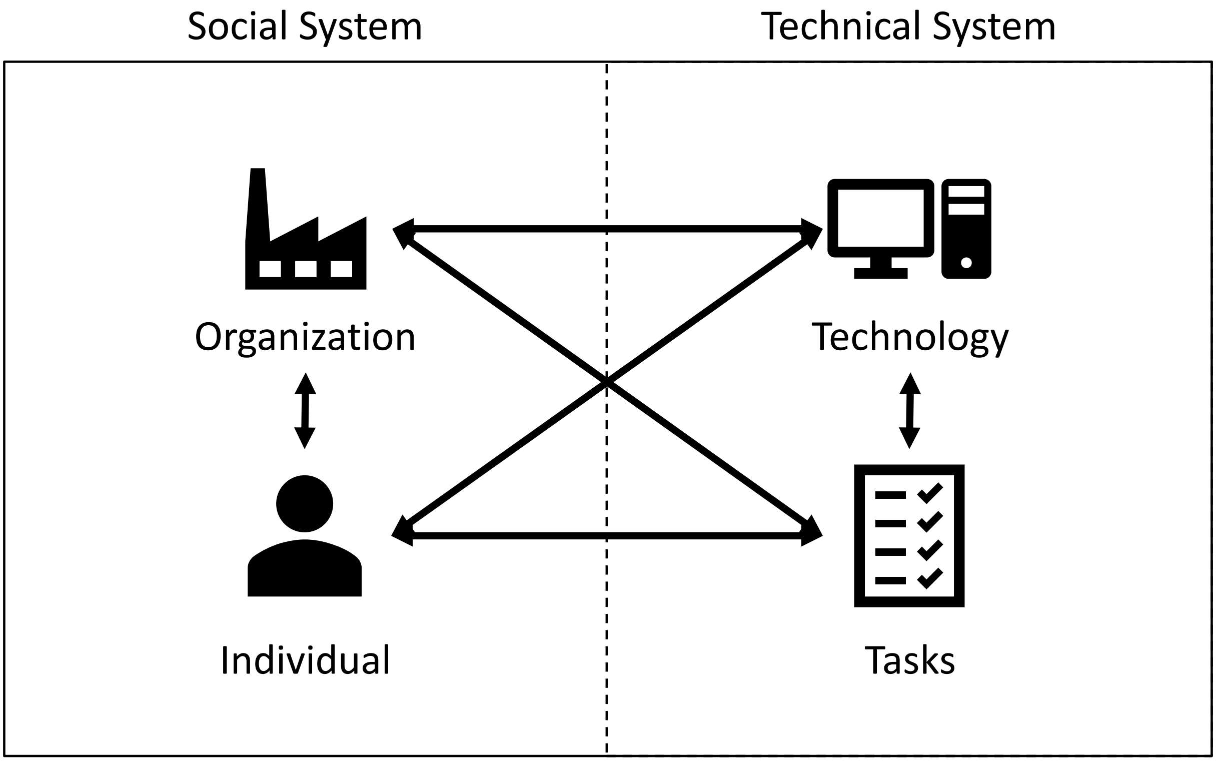

Figure 3: A Schema of Socio-Technical Systems

1.2 Module Structure

In this module, we will explore the complex interactions between the multiple social and technical actors in a socio-technical information system. The module is divided into multiple units focusing on the individual parts of a socio-technical information system, which can be seen in the following figure. Chapter 2 – Systems Theory & Information Systems – introduces basic terminology and defining the important terms for this module. Chapter 3 –Background and History – explains the historical background of the socio-technical approach originating in the Tavistock Institute in Great Britain. Chapter 4 – Theoretical Perspectives and Lenses – explores theoretical perspectives on socio-technical systems. The chapters 5 (The Organization), 6 (Information Technology), and 7 (The Individual) then focus on each of the building blocks of the socio-technical information system, with chapter 5 covering the organization, chapter 6 addressing the technology, and chapter 7 investigating the role of the individual in a socio-technical context.

The module is divided into 7 units. The units encompass the following topics:

1. **Introduction:** This chapter shows the motivation for socio-technical information systems

2. **Systems Theory:** This chapter covers important basic terminology and shows why it is important to study socio-technical information systems. Through a deep dive into systems theory, the theoretical framework for the following units is set.

3. **Historical Background:** This chapter explains the origins of the socio-technical paradigm. Starting from a purely technical view with Frederick Taylor's Scientific Management, the negative consequences of a purely technical paradigm are shown with the aftermath of the Second World War. The socio-technical approach as well as its evolution over the following years is explained.

4. **Theoretical Perspectives and Lenses on Socio-Technical Information Systems**: This chapter shows how the socio-technical systems approach in Information Systems relates to various theories.

5. **The Organization**: This chapter investigates how organizations act as socio-technical systems and serve as the surrounding structure to the individuals' work with socio-technical information systems. It explores the importance of organizational structure and organizational processes.

6. **Information Technology:** This chapter covers the socio-technical design of information technology and information systems. Ingrained in theoretically-based design frameworks, crucial steps in a human-centered design as well as different tools are shown.

7. **The Individual:** This chapter covers perspectives on the individual within socio-technical information systems. Individuals, through their motivations, attitudes, and behaviors impact the successful application and use of socio-technical information systems to a large extent. This chapter covers different psychological factors of the individual that influence information system adoption and use.

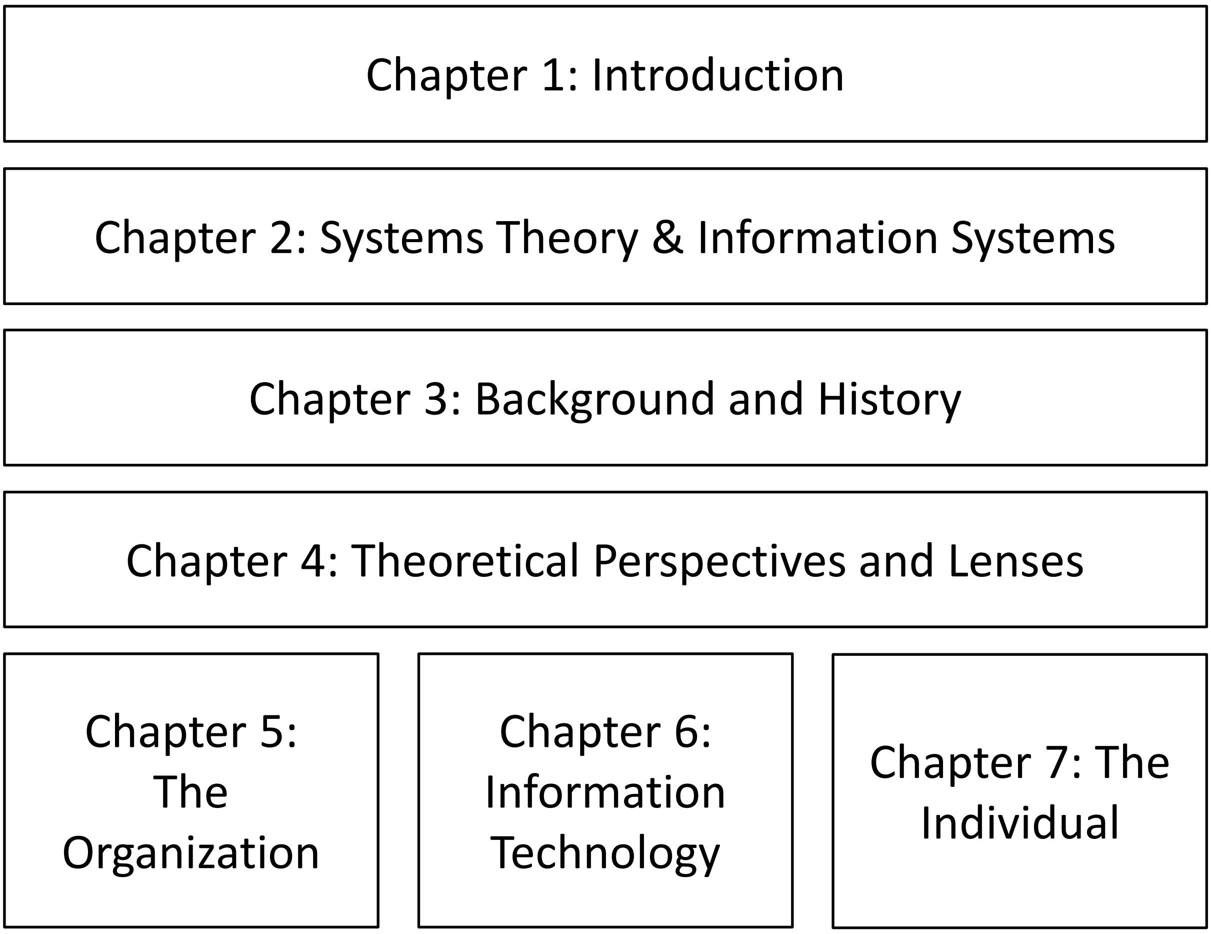

Figure 4: Module Structure

Exercise

1. Think about two examples in which you interact with socio-technical information systems. Think about the social and technical systems involved in this interaction.

    a. What is the task?

    b. Which actions are performed by individual human actors, including yourself and other participating individuals?

    c. Which actions are performed by technological components?

    d. What is the role of the surrounding structure or organization?

2. Based on the example of Google Maps presented earlier, think about other instances in which an optimization or change to the technical system had a negative impact on the social system and thus reduced the performance of the socio-technical information system?

2 Systems Theory & Information Systems

Overall, the module "Socio-Technical Information Systems Design" seeks to explore the facets of socio-technical information systems, what makes them effective and how to optimally develop and design such systems. However, in doing so, it is important to understand what exactly one is dealing with when talking (or writing) about a socio-technical information system. The term "socio-technical information system" consists of several components. Throughout this chapter, these different components will be explained. First, the term "system" based on Niklas Luhmann's system theory (Baecker & Luhmann, 2004) will be defined (2.1 What is a System?), to provide an understanding of what a system is, how it is constructed and how it comes into being. By splitting the social and technical components of a socio-technical system, this chapter will provide explanations on the technical (2.2 Technical Systems) and the social subsystem (2.3 Social Systems). Afterwards these concepts will be combined to show what a socio-technical system (2.4 Socio-Technical Systems) is. Then, this chapter takes a look at the concept of information (2.5 What is Information?), and how it relates to information technology (2.6 What is Information Technology?) and information systems (2.7 What is an Information System?). Finally, combining all these perspectives, this chapter closes with a definition of a socio-technical information system (2.8 Socio-Technical Information Systems).

2.1 What is a System?

In a colloquial sense the term system is used ubiquitously. In our everyday life, we are confronted with many different kinds of systems. When we pay in a supermarket and pay by card, we are interacting with a payment system. When we go to the doctor, he or she might talk to us about our immune system. When getting a new computer, we have to choose between Windows, macOS, and all the different flavors of Linux, all being different operating systems. Even in sports, we encounter systems such as 5-3-2 system in association football and the 4-3 defensive system in American football. The term system is omnipresent and often used with shifting or no strictly defined meaning. For that reason, the following section will describe what a system is and how it should be understood in the context of this module. The following explanations are based on the systems theory of the sociologist Niklas Luhmann. However, due to the complexity of the theory, simplifications are necessary.

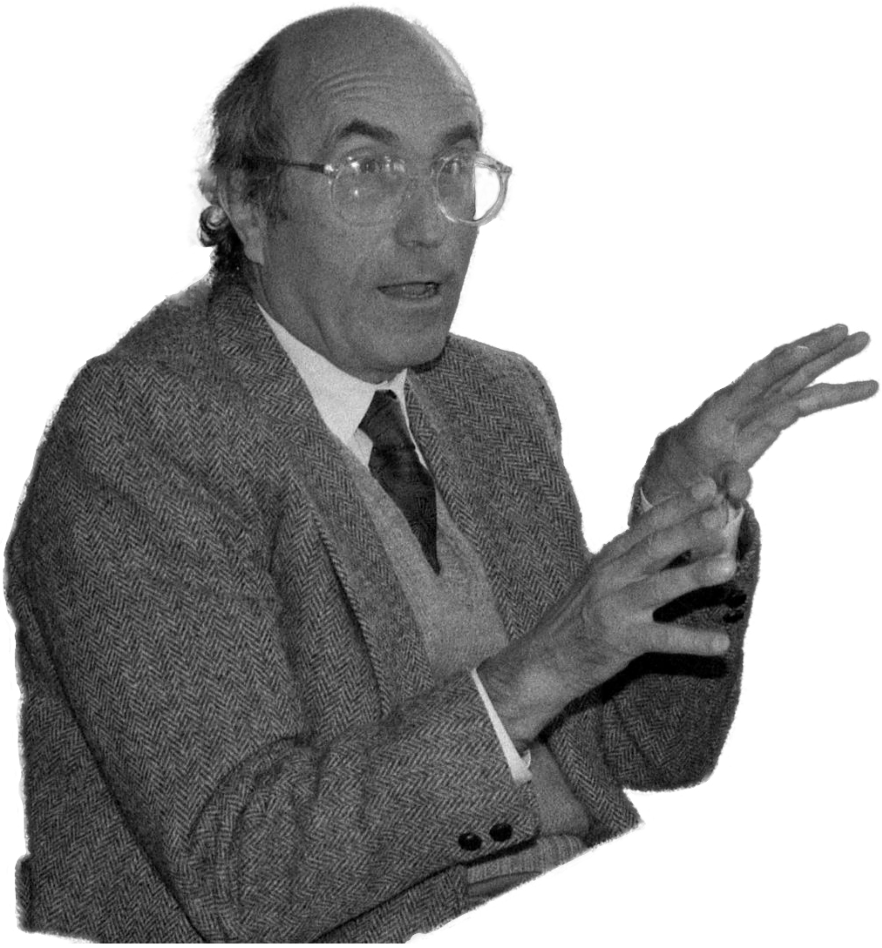

Figure 5: Niklas Luhmann (HSG, 1989)

The term “system” stems from the Greek word “systema”, which means “a whole composed of several individual parts” (Zweig et al., 2021). Luhmann himself defines a system as the difference between the system and the environment. This paradox and self-referential description might seem confusing at first and requires some elaboration and examples (Baecker & Luhmann, 2004). For now, it is important to know that a system according to Luhmann only becomes apparent in contrast to its environment. A more accessible definition of a system sees it as the “entirety of a set of elements and their relations to each other” (Kneer & Nassehi, 2000). A system consists of several components that interact with each other, forming and maintaining the system through their repeated interaction. These interactions are crucial. While one could reasonably assume that the actors and objects constitute the system they are located in, it is the communications between the actors and objects that constitute the elements of the system. While this might be irritating at first, consider the following example:

A soccer team consists of eleven players[2] playing soccer on a soccer field. What is the factor that matters when assessing this situation? When are those players on the field considered as a "system" acting as a soccer team? Does it matter who they are or how they interact? While a certain number of objects might indicate a sense of allegiance and belonging together – such as matching jerseys – whether we consider those eleven people a soccer team or something else is dependent on how they interact. If they are on the field, passing a ball, playing against an enemy team, and trying to score goals, we will identify them as a soccer team. However, the same eleven players – in the same matching jerseys – might constitute a completely different system if they would just act differently. For example, they just might be a men's choir in soccer jerseys – serving as a halftime entertainment program – in a women's soccer game. The human actors in this whole situation have not changed. There are still eleven people on the same soccer field. However, the communication between the components is different (see Figure 6). **Please note:** Luhmann's definition of communication is not congruent with the everyday, colloquial use of the word communication. Luhmann's understanding of the word communication includes all kinds of interactions between a system's components and is not restricted to the spoken word (Baraldi et al., 2021; Kienle & Kunau, 2014). It is the communication that defines a system, making the difference between a soccer team and a choir. Furthermore, as an extreme case, these eleven people might not even constitute a system at all. They just might randomly happen to be there at this moment, each individual minding their own business, and not interacting in any way. One might play a ball, another one might sing, a third one might think about Niklas Luhmann's system theory[3], and a fourth one might do nothing at all.

Figure 6: Same Actors – Different Systems

At this point, one might wonder: Why is the concept of a system needed? What purpose does it serve? What is the potential benefit of systems? In line with Luhmann's definition from earlier, in that systems are the difference between the system and the environment, systems serve as a frame of reference against the surrounding environment. They define what is part of the scope of the system and what is not (and therefore part of the environment). Thinking through the concept of systems allows us to organize the world around us. A system has a certain kind of order,

[2] While a team normally has more players than those active on the field, we simplify the circumstances in this situation.

[3] Although unlikely.

differentiates itself from its environment, and serves a certain purpose. For example, a soccer team serves as a way to play the sport, a system of government enacts laws and regulates the affairs of a country, and a healthcare system treats the sick and wounded. In each of these systems, there is a certain way of communication and explicit and implicit rules that help us to understand how these systems – and thus these aspects of the world – work. In contrast, the environment consists of all things that are currently not part of any system we know. The environment is thus infinitely more complex and chaotic than any system we know (Baecker & Luhmann, 2004; Baraldi et al., 2021). While each system has certain rules and typical ways of communication (for example while haggling is a part of the system "bazaars", it is not part of the system "supermarket"), the environment has endless possibilities and no order. Without systems as a frame of reference, the world would appear infinitely more complicated to humans, stressing and overwhelming us through the sheer number of possibilities in any situation (Baraldi et al., 2021). Thinking in systems allows us to reduce the complexity of the world through certain explicit and implicit rules in every situation, within each system, such as the corporations, associations, and even traffic.

The following paragraphs will explain key aspects of systems according to Niklas Luhmann's system theory.

Communication:

Communication is central to Luhmann's systems theory. As explained earlier, on the example of the soccer team, the elements of a system are not its components, as one might think (such as the players of the soccer team), but the communications happening within the system. A system exists as long as the communication within the system is happening. It does not matter whether a single actor joins or leaves the system. An actor is part of a system as long he or she communicates within the system. Thus, systems might exist for a very long time, even though all original actors within the system have long left it (Kienle & Kunau, 2014). Consider a large corporation with a long and rich history, such as Siemens. Although organization has been founded in 1847 and all its original actors have long left, the system Siemens still persists.

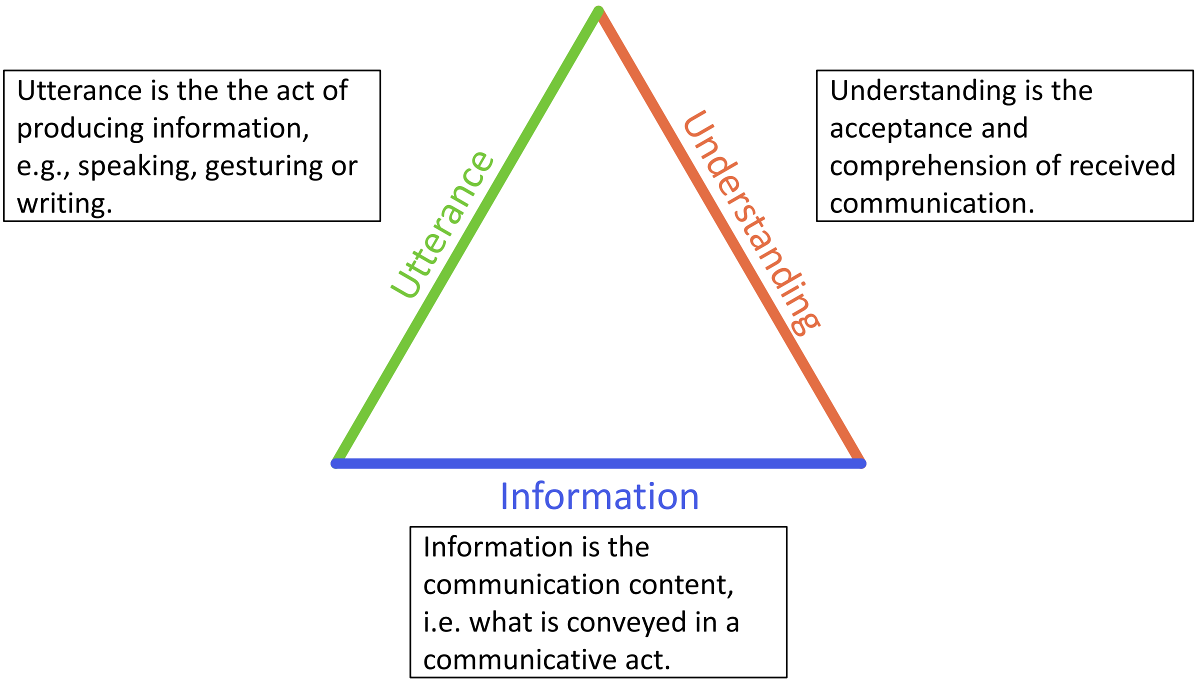

Figure 7: The Three Sides of a Message

Communication according to Luhmann's system theory is different from the everyday usage of the word. Communication consists of three components: information, utterance, and understanding (see Figure 7). Communication is only happening if all three components are present in an interaction. Information is what is conveyed through an interaction. This information might be conveyed through, for example, spoken word, gestures, or text. Utterance is the act of producing said information in front of an audience. This includes speaking, gesturing, or writing. Understanding is taking in the uttered information, facilitating further conversation. All these components are selections from the environment, in the sense that the respective component of a conversation only represents a subset of the different possibilities. To illustrate this, consider the following example: The information component of a communication is a selection, as the sender of the information is actively selecting what he or she communicates. If they communicate the information "It is raining", they exclude an infinite amount of other information they could include in their message at the same time. The sender could have produced a completely different information, such as "I am hungry", but opted for information about the weather instead. Similarly, the utterance component is also a selection, as the utterance shows intention or reason for the communication. By uttering, a sender takes responsibility for sending information. However, communication is only realized once this information is understood, once it is received by someone else. Understanding again is a selection, as the information recipient selects which pieces of information and the uttering of said information he or she comprehends. For example, in the case of "it is raining", understanding (through both information and utterance) might include the conclusion that the sender might prefer to stay inside as he or she does not want to get wet (Baraldi et al., 2021).

Functional differentiation:

Systems are characterized by functional differentiation. Tying back to Luhmann's original definition that a system is the difference between the system and the environment, functional differentiation means that a system fulfills a specific function. It is different from the environment in that it fulfills this specific function while the environment does not. It is also different from other systems that fulfill other functions.

With regard to the difference between system and environment, there are a few things to note. The difference between system and environment is the starting point of Luhmann's system theory. As every system is embedded in an environment, system boundaries to this environment define what a system is, where it is located, and how it draws its boundaries from the surrounding environment. Without the environment to contrast to the system, a system could not be established. The system defines a space in which certain rules and conditions apply, as compared to the environment that features far more possibilities than the system itself. The environment encompasses everything that is not part of the focal system. As explained earlier, the utility of Luhmann's system theory lies definition of a reduced scope, that defines what is part of a system and what is not, allowing us to organize the world around us. A system fulfills a certain function, has certain order, and differs from the environment. Inside a system, there are certain norms and rules, defining how communication and interaction within this system work. In comparison, the environment has no such function or order. Encompassing everything that is not part of the system, the environment is far more complex and chaotic than a system (Baraldi et al., 2021).

It is important to note that the environment of a system is not an absolute term but a relative one. The environment is always viewed with respect to a specific system. When we know what is part of system, we also know that everything else is not part of the respective system. Everything that is not part of the respective system constitutes the environment of this specific system. The environment may be part of other systems, to which the focal system might be part of its environment. To illustrate this, let's again turn to our system "soccer team". While the soccer team (consisting of the eleven players on the field) is a system and the soccer couch is outside of this system and thus part of the environment, we can also shift our focus towards the system "coach's bench", including for example the head coach, several assistants, and positional coaches. The system "coach's bench" has its own system order and communication, and also differs from its environment. So, while the head coach is part of the environment of the system "soccer team", he or she may be part of another system, such as "coach's bench". Conversely, to the system "coach's bench", the eleven players on the field constitute part of its environment.

The environment does not communicate according to system rules, and poses an infinite number of possibilities. It is therefore completely unpredictable. This results in a complexity gap between system and environment. Due to the sheer number of possibilities the environment offers, the environment will always be more complex than the system itself. Any attempt of the focal system to control its environment will be met with changes in surrounding systems, making the environment of the focal system even more complex. As these other systems change the environment in unexpected ways (see also "Operational Closure"), the system's environment can never be controlled (Baraldi et al., 2021). The differences between the system and the environment are shown in Table 1.

	System	Environment
Size	Defined space	Everything else
Purpose	Serves a certain function	Does not serve a certain function
Communica-tion	Communicates according to its own system logics	Does not communicate according to any system rules
Scope	Rules and norms define how communication and interaction work, restricting the number of possibilities.	Endless possibilities
Predictability	To a certain extent	Chaotic

Table 1: Differences between System and Environment

With regard to the difference to other system, a system always fulfills a certain function, while other systems fulfill other functions. Every system has its own domain, its own form of communication and its own space of possibilities. Thus, each system differs from all other systems. To illustrate this, while our earlier example of the system "soccer team" has the function of playing soccer, other systems fulfill purposes. The healthcare system is concerned with caring for the sick and injured. The political system is concerned with state affairs. Banking systems are concerned with payment flows and the provision of money. Every system has its own purpose and its own, specific rules.

Operational closure:

Systems are operationally closed. The system is different from the environment as determined by the amount of complexity inside and outside the system. As indicated earlier, the purpose of thinking in system lies in the reduction of complexity, by reducing the number of possibilities, compared to the environment. Through this differentiation, there exists a clear boundary between system and the environment. Operational closure means that the system maintains its communication only within itself. There is no communication (in Luhmann's sense) from or into the environment. That does not mean that there is no information exchanged between the system and the environment, rather it means that the communication within a system cannot be influenced from the outside through a linear causal relationship. Thus, a system cannot be changed or manipulated from the outside. In other words, an outsider that wants to change a system and thus inserts information into that system from the outside cannot change a system at will according to his or her expectation. While outside information may lead to changes within a system, one cannot expect or predict these changes. Resulting changes are not deterministic and a system might respond in an entirely unexpected fashion (Baraldi et al., 2021; Kienle & Kunau, 2014).

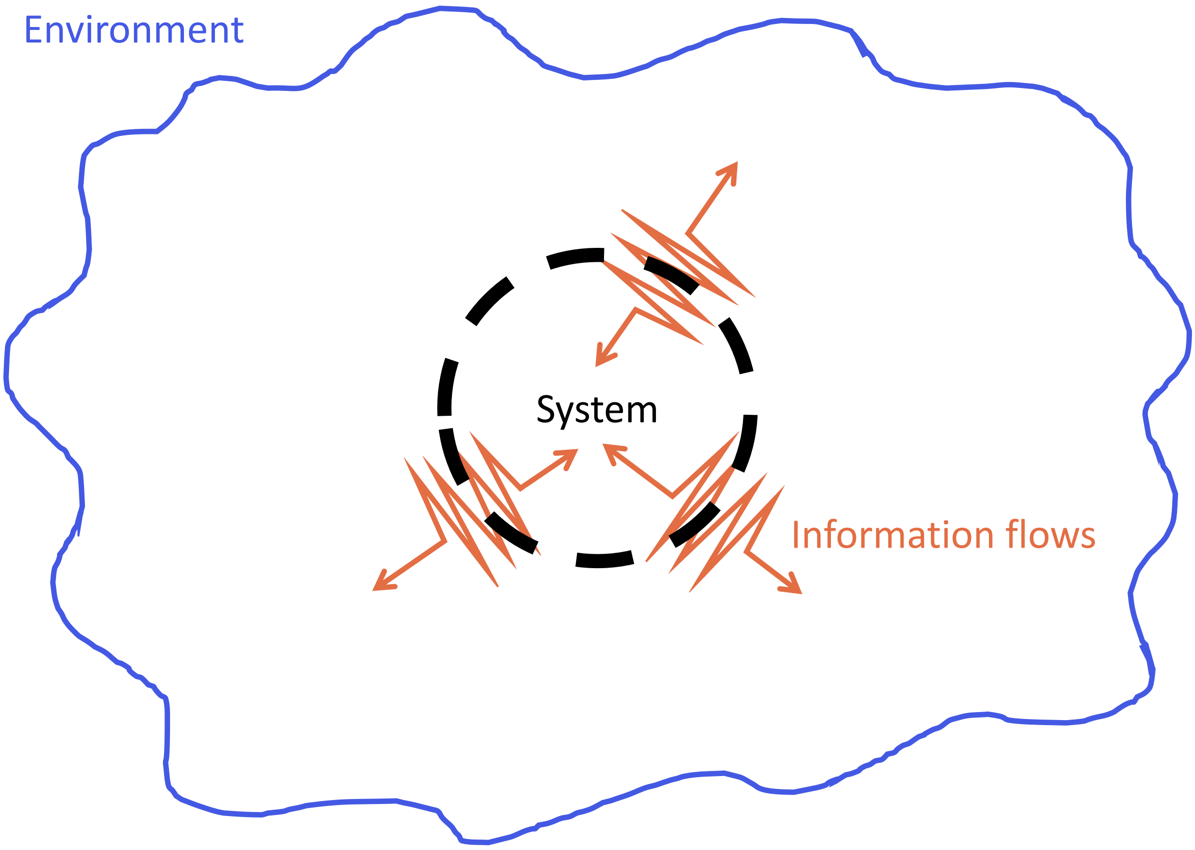

Figure 8: Information Flows between System and its Environment

To illustrate the idea of operational closure, consider the example of a soccer team again. This time, also consider the coach of the soccer team. The role of a soccer coach can be described – in simple terms – as an outside actor that provides some kind of guidance to the eleven players on the field. However, contrary to commonplace thinking, the coach is not part of the system "soccer team". The coach is not on the field, not directly interacting or communicating (in Luhmann's sense) with the players on the field. In other words, the coach is not on there, kicking the ball, directly participating in the system. The coach is just providing outside information. Whether this information is helpful or guiding the players in the right direction is not important at this point. This outside information serves as input to the system "soccer team". However, although some coaches would very much like it, they cannot directly influence the system "soccer team" in a deterministic fashion. Whether the players act according to the commands the coach is giving them is entirely up to the players. They might follow the commands and play according to them. They might also disregard and continue playing how they think is best. As the coach cannot go into the field (ergo into the system), the coach also cannot make the system change at his or her will.

Observation:

The act of observation is fundamental to the understanding of systems in Luhmann's system theory. Observation allows us to understand and communicate within systems and to differentiate them from the environment. At its basic level, observation allows us to identify distinctions, permitting us to separate the information we perceive. Simply put: Observation allows for the statement "X is different from Y". Each further step of observation allows to gather more details, making further distinction to identify and order the world around. Through observation, we can gather information to understand what is part of system and what is not (and thus part of the environment). Observation also allows us to understand the communication within a system. In this fashion, observation serves as a way to understand to processes of communication and to respond accordingly. Through observation, we can make distinctions regarding the way communication works in a system works, as opposed to all other forms of interaction. In other words: Observation allows us to understand the norms and rules within a system. As an example, it allows us to understand that haggling is not part of the communication in the system supermarket, while paying by card is (Baraldi et al., 2021).

Structural Coupling:

While the previous sections were primarily concerned with internal workings of systems and how these systems are different from their environment, this section is concerned with structural coupling, the interaction between systems. As already mentioned, systems are operationally closed in their communication. Thus, it is not possible for the environment to directly influence the operations and the communications within a system. Conversely, it is also not possible for a system to actively change its environment in a planned fashion. However, that does not entail that systems are completely isolated. Systems are adjacent to each other and influence each other in various ways. Information can flow from one system to the other. This incoming information is received by another system, and the system then produces a so-called irritation. This irritation represents a reaction to the outside information and allows this information to lead to changes within the focal system. These changes are not predictable to outsiders of the focal system. Every system has its own ways to react to outside information. As the processes within a system are not directly accessible to its environment, the environment cannot consciously influence the system toward a certain goal.

To illustrate structural coupling, consider the systems "soccer team" and "coach's bench" again. When the score of a soccer a game indicates that a loss is most likely (e.g., the team is down 0:4 in the 60th minute), the coaches within the system "coach's bench" might discuss strategies for turning the game around. When that system has reached a consensus, the head couch might shout several commands to the players on the field, thus providing new outside information to the system "soccer team". This outside information produces irritation within the system "soccer team". Through communication (which includes speaking, but also other game actions), the players react to this irritation. They might change their playstyle according to the coach's commands. But, the players might also get frustrated and do something else on purpose, perceiving that they can no longer win anyways. The two influence each other, creating irritations. However, the results are not always predictable. Consider another example: In the year 2024, farmers in Germany have organized protests against the federal administration of Germany due to changes in taxes and subsidies for the farmers. The farmers have organized themselves in order to influence the political landscape in their interests. However, how likely is it that their protests will directly lead to the changes they demand? From a systems theory standpoint, they cannot directly influence the political system with their protests. Their protests thus only serve to create an irritation in the system "federal government".

Poiesis:

The term poiesis, rooted in the ancient Greek word for “to make”, describes how systems are created and maintained. Luhmann borrowed this term from the works of the Chilean biologist Humberto Maturana to explain how systems are similar to living organisms. While the work of Luhmann is predominantly concerned with social systems, which are autopoietic (self-creating), the socio-technical approach is also concerned with technical systems, which are allopoietic (created by “others”) (Baraldi et al., 2021).

Social systems are autopoietic. The term autopoietic is derived from the Greek words “auto” for “self” and “poiein” for “to make”. Social systems are "self-made". They create and maintain themselves through a characteristic process. This process is the communication within the system, specific to this system, and is the basic element from which the system is built. As long as there are actors within the system continuing to communicate within the system, the system maintains itself. However, once communication ceases, the system stops to maintain itself (Baraldi et al., 2021; Kienle & Kunau, 2014).

Technical systems are allopoietic. The term allopoietic is derived from the Greek words “allo” for “foreign” and “poiein” for “to make”. Technical systems are "made strange". They are created and maintained by others, from the outside. Usually, with a technical system, there are plans and instructions that dictate how the technical system is built and maintained (e.g., blueprints for a machine). Architects and engineers define ex-ante how the technical system should be built. There is no component of the system creating or changing itself (Kienle & Kunau, 2014), although such assessments might no longer hold, with systems such as Artificial Intelligence that increasingly rely on learning and changing themselves.

Communication	A system is defined by the ongoing communication within it rather than its individual components. Communication, involves three components: information, utterance, and understanding, and it is only considered complete when all three elements are present in an interaction.
Functional Differentiation	A system fulfills specific functions distinct from its environment and other systems. Each system has a unique purpose, communication style, and space of possibilities.
Operational Closure	Operational closure mandates that a system maintains communication only within itself, and although information can be exchanged between the system and its environment, external influence cannot determine or predict changes within the system.
Observation	Observation makes it possible to identify differences in order to differentiate between systems and their environments, to understand communication processes, and to identify norms and rules within a system.
Structural Coupling	Structural coupling describes interactions between different systems. Information flows from one system to another create irritations, causing (unpredictable) reactions within and by the latter system.
Poiesis	Poiesis explains how systems are created and maintained. Social systems are autopoietic, created and maintained by themselves. Technical systems are allopoietic, created and maintained by others, from the outside.

Table 2: Definition of Key Aspects of Systems according to Luhmann

The key aspects of systems are summarized in Table 2. The following two sections will separately describe technical and social systems, before combining them to a socio-technical systems description.

Exercise

exercise

1. What is a system?
2. What is communication?
3. What is the difference between a system and its environment?
4. What is the difference between allopoiesis and autopoiesis? What are allopoietic systems? What are autopoietic systems? Name three examples for each type of system.

2.2 Technical Systems

Quote: *"The technical component is "primarily a human-created tool whose raison d'être is to be used to solve a problem, achieve a goal or serve a purpose that is human defined, human perceived or human felt" (Lee et al. 2015, p. 8). It consists of hardware and software, by some accounts, data sources, and associated techniques necessary to carry out organizational work (Ryan et al. 2002)."*

SARKER ET AL., 2019, p. 698

One type of systems are technical systems. Although they have not been at the center of Luhmann's system theory, who – as a sociologist – has primarily concerned himself with complex social systems, his system theory is nonetheless applicable to this kind of systems. Following the general understanding of systems theory, technical systems consist of technical components that interact (communicate) with each other. The specific properties of technical systems are best illustrated using examples: A heating system in a house or a software system. As a counter-example to the term system, imagine a bag of marbles. The marbles do not form a system because they (1) do not communicate with each other and (2) do not serve a specific function (Kienle & Kunau, 2014). Two things are important to note.

Figure 9: Technical Systems Require Communication and Serve a Specific Function

On the one hand, although this module is primarily on information systems, technical systems are not necessarily digital or need to deal with information. A technical system might also be a purely mechanical thing, such as complex machine in a manufacturing line or an automobile[4], which consists of mechanical elements to facilitate acceleration, braking, and the shifting of gears (Lee et al., 2014).

On the other hand, technical systems do not need to be physical (Lee et al., 2014). For example, IT systems, while typically relying on hardware such as computers and servers, are based on algorithms, software, and data. While some physical components are undoubtedly necessary to run an IT system, the algorithms and protocols are far more important for the maintenance of the

[4] Although modern cars contain a number of digital components. Imagine an older car in this case.

system. As an example, consider international payment systems, such as VISA. While card readers are necessary to initiate transactions, the rest of the system is solely virtual, managing payment flows and realizing transactions. Although this technical system is not physical, it is still a human-created tool that strives to achieve a certain predefined goal (Lee et al., 2014).

The following paragraphs will illustrate how the key aspects of Niklas Luhmann's system theory, (1) communication; (2) functional differentiation, (3) operational closure, (4) observation, (5) structural coupling, and (6) poiesis, apply to technical systems. The application of these principles will be explained upon the example of a heating system in a house (Kienle & Kunau, 2014).

Communication: Inside the heating system, there is communication between its components. Sensors measure temperature and send signals to other components. Control units receive intended temperature settings and communicate them to other components, such as heating elements. Hot water is transported from the boiler to the heating units, transporting the heat to its intended location.

Functional Differentiation: The heating system fulfills a certain function within its environment. Its purpose is to generate heat and transport it to the intended locations in order to warm up rooms. Thus, the system has certain rules according to which it operates. Heat is generated in a heating unit, such as a boiler and then transported to the radiators in order to fulfill its purpose. The heating unit will not suddenly serve a different purpose, such as generating electricity. There are only a few options the system can take, indicated by the different temperature settings.

Operational Closure: The heating unit is operationally closed to its environment. It operates only according to its internal workings. Sensors and settings dictate the intended temperature, the heating unit responds to these instructions by burning more or less fuel. There is no way to directly influence the system from the outside. The system is thus only taking limited input from its environment. For example, if the owners of the house would leave for vacation and forget to turn down the heating, the system has no way to work with this change of environment. Another example would be in the reaction to weather. When it suddenly becomes summer, the system does not react to the change in weather, but still listens to its own programming. The system's response is not a direct, unmediated reaction to external stimuli but is filtered through its own operational processes.

Observation: The heating system observes itself in relation to its environment. If the sensors observe that the temperature within a room is above a certain threshold, it reacts by turning down the heating unit and decreasing the throughput of hot water. If the sensors observe that the temperature within a room falls below a certain threshold, it reacts by turning up the heating unit and increasing the throughput of hot water. As such, the system has an observatory component that initiates a feedback loop within the system. If there exists a difference between current and desired state, the system adjusts accordingly (Kienle & Kunau, 2014).

Structural Coupling: The heating reacts to changes in its environment. For example, it may react to external temperature changes resulting from weather or from other systems that might also produce heat, such as electrical appliances. The heating systems adapts to its environment through observation and internal feedback loops. However, as previously mentioned these other systems, such a computer that also produces does not directly interact with the heating system but only indirectly.

Poiesis: The heating system, like all other technical systems, is the result of a design and production process. It has been developed according to plans that precisely describe and prescribe its structure and behavior. Engineers have planned in advance what the heating should accomplish and how it should do this. The heating system is therefore allopoietic, meaning that they are created and maintained by others, from the outside. The work of these engineers is successful if the technical system behaves predictably as planned. If it does not behave as planned by the engineers, the heating system can be described as defective (Kienle & Kunau, 2014).

exercise

Exercise

1. What is a technical system? What are the components of technical systems?

2. Are technical systems primarily physical? Are technical systems primarily information systems?

3. Take the key aspects of Niklas Luhmann's system theory, (1) communication; (2) functional differentiation, (3) operational closure, (4) observation, (5) structural coupling, and (6) poiesis, and apply and explain them upon a technical system of your choice. If no particular system comes to your mind, take the example of a fully automated coffee machine.

Figure 10: A Fully Automated Coffee Machine

2.3 Social Systems

Quote: *"The social component can be defined as consisting of individuals or collectives, as well as "relationships or interactions between or among individuals [or collectives] through which an individual [or collective] attempts to solve one of his or her [or their] problems, achieve one of his or her [or their] goals or serve one of his or her [or their] purposes" (Lee et al. 2015, p. 9). The social component thus includes humans (as individuals or social collectives) and their relationships and attributes such as social capital, structures, cultures, economic systems, and best practices (Ryan et al. 2002)."*

SARKER ET AL., 2019, p. 698

Another type of systems are social systems. Luhmann's system theory is predominantly concerned with these type of systems. Analogous to the technical systems, one might assume that social systems consist of human actors that interact (communicate) with each other. A single human actor would – in this case – be like a single technical component in a technical system. However, tying back to the explanations on communication (2.1), there are social systems that are far older than the human actors that communicate within them. Corporations rich in tradition, such as BASF, have persisted for decades or even centuries. Other institutions, such as political parties, old universities, and the roman catholic church, have had a similar or even longer period of existence (Kienle & Kunau, 2014). Thus, the question is: How can a system sustain the replacement of all of its human actors and still be identified as the same system? The replacement of all components of a whole is also an interesting philosophical thought experiment called the Ship of Theseus (see the following excursus).

digression

Digression – The Ship of Theseus

The Ship of Theseus is a thought experiment that explores the concept of identity and the nature of objects undergoing change. It raises questions about whether an object remains the same entity when its components are replaced over time.

The scenario involves a hypothetical ship that belongs to the ancient Greek hero Theseus. As the ship ages and its parts decay, they are gradually replaced with new, identical components. The key question then becomes: Is the fully repaired ship still the same Ship of Theseus, despite having all-new parts?

This thought experiment prompts philosophical inquiries about the persistence of identity. Does the identity of an object lie in its physical components, or is it something more abstract? If the Ship of Theseus is still considered the same ship after all its parts are replaced, it challenges the notion that identity is solely tied to physical continuity.

The Ship of Theseus paradox is often extended further by introducing another scenario: suppose all the removed original parts are gathered and used to build a new ship. Which of the two ships—the fully repaired original or the one assembled from the original parts—is the "real" Ship of Theseus?

This paradox has been discussed by philosophers throughout history, and it delves into broader questions about the nature of identity, persistence through change, and the role of continuity in defining an object's essence.

Figure 11: Ship of Theseus

As an interesting application of the Ship of Theseus thought experiment onto a social system, consider the Cleveland Browns relocation controversy that occurred in the NFL in 1995, colloquially known as “The Move” by NFL fans. In this event, an NFL team known as the Cleveland Browns relocated to the city of Baltimore due to financial disputes with the city of Baltimore, resulting in the dropping of the name Cleveland Browns and taking up the mantle of the “Baltimore Ravens”.

Applying the Ship of Theseus thought experiment to this event, we can draw the following analogy: Imagine the (original, pre-1995) Cleveland Browns as the original Ship of Theseus. Over time, due to various factors, the team faced challenges and underwent significant changes, both in terms of ownership and on-field performance. Eventually, the decision was made to relocate the team to Baltimore, resulting in the Browns becoming the Ravens.

Now, one could ask: Is the Baltimore Ravens the same franchise as the original Cleveland Browns? Just as with the Ship of Theseus, the question revolves around the continuity of identity. The components, in this case, include the team's name, colors, fan base, and even some of the key players and staff. Yet, the ownership, location, and many aspects of the team's identity have undergone transformation.

An interesting twist to the analogy is that after the Browns' relocation, Cleveland later regained an NFL team named the Cleveland Browns in 1999. The new Browns retained the original team's name, colors, and historical records. This adds another layer to the philosophical discussion – which is the "true" Cleveland Browns, the one in Baltimore or the one that emerged later in Cleveland?

Officially, to the NFL, the new Cleveland Browns, reestablished in 1999 have retained the legacy of the old Cleveland Browns, laying claims to their history and titles, including their league championships achieved during the 1950s and 1960s.

In the end, identity of team is not just tied to physical components (players, staff) but also to intangible aspects like fan loyalty, team culture, and historical legacy.

Figure 12: American Football

Per Luhmann's system theory, it is not the human actors but the communications between them that constitute the system. Social systems are comprised of communications that refer to and relate to each other. As long as human actors contribute communication and provide information, the social system persists, even though the human actors that engage in the communication might change. Due to the focus on communication, a social system needs to involve more than a single human actor. After all, the social system is concerned with the *social*, not with the *individual* (Lee et al., 2014). Social systems exist in all shapes and sizes, including corporations, teams, families, neighborhoods, and clubs (Lee, 2004). Larger social systems might be comprised of smaller social systems, resulting in a systems-of-systems design. For example, a corporation is a large social system that consists of smaller social systems such as departments, which in turn encompass even smaller social systems such as individual teams (Kienle & Kunau, 2014).

The following paragraphs will illustrate how the key aspects of Niklas Luhmann's system theory, (1) communication; (2) functional differentiation, (3) operational closure, (4) observation, (5) structural coupling, and (6) poiesis, apply to social systems. The application of these principles will be explained upon the example of a university (Kienle & Kunau, 2014).

Communication: At a university, communication takes place constantly: Faculty members teach students, students learn with each other, faculty members ask for learning goals by administering exams, new students express their willingness to learn by enrolling in a degree program, and so on. Both students and faculty change regularly. Nevertheless, the university survives as a social system. Only when communication ceases, when no one teaches, when no one enrolls, only then would the social system of the university cease to exist (Kienle & Kunau, 2014).

Functional Differentiation: The university fulfills a certain function within its environment. Its purpose is twofold. First, to educate university students and teach them in order to attain a certain degree that demonstrates their abilities. Second, to research phenomena and generate new knowledge that feeds into both the scientific community and the teaching that is conducted. Thus, the system has certain rules according to which it operates. Faculty members conduct both research to generate new knowledge and fulfill teaching duties in order to teach the university students. Students learn the content that is taught and show their achieved skills and knowledge in exams, demonstrating their capabilities in order to obtain their degree. University students will not suddenly do something else in the system university, such serving food and drinks. Although they might do other things, such as these, they do so not within the system university but maybe within another system, such as the system restaurant, where some students might take up a side job to finance their studies.

Operational Closure: The university is operationally closed to its environment. This means that the progress of communication is determined exclusively within the social system. Every communication in a social system refers to past communications in the same system. It is exclusively this self-reference that determines the further course of communication within the social system. Faculty members teach their lectures to students, while students work on their assignments and exams (Kienle & Kunau, 2014). From the outside, these processes cannot be directly influenced. For example, if the state or firms on the job market decide to stress the importance of certain content or capabilities that the university and its faculty members should teach, the university can respond in various ways. It can adapt to these preferences from the outside, implementing new lectures that teach the content. It can integrate these contents into existing lectures. Or, it can decide to completely ignore these outside demands and try to sit out the problem. In case of the last possibility, this is not only a de-facto reaction the system university can take, for German universities, it is also guaranteed de jure by article 5 of the German Basic Law (Grundgesetz): “Kunst und Wissenschaft, Forschung und Lehre sind frei.” (Art and science, research and teaching are free).

Observation: Social systems observe themselves and their environment. In contrast to technical systems, which are defined by the elements they contain and how they are put in a relationship to each other, a social system has no predefined boundaries. As social systems create and maintain themselves, there is no “social engineer”, who could ex-ante define what is part of a system and what isn’t. As social systems are operationally closed, they cannot be defined from the outside. Thus, social systems must draw their boundaries themselves. For the case of the university, consider the example of a prospective student. To begin their studies at the university, a student needs to formally enroll in a program. The communication with regard to the enrollment process is strictly defined. There are mandatory documents that need to be handed in, qualifications the student needs to provide, and certain deadlines that need to be met. Rules for the according communications are described in study regulations, which are an example of the self-description of a system (Kienle & Kunau, 2014).

Structural Coupling: Social systems also react to changes in their environment. Although operationally closed, outside information might disturb or change social systems, although not in a deterministic fashion. For the case of a university, the Bologna Process may illustrate how the social system of a university enacts structural coupling: The Bologna Process defines rules for the accreditation of study programs and the acceptance and grading of examinations. Any university wishing to award bachelor's and master's degrees must comply with these rules. Universities need to comply with these rules to become accredited. However, universities are still operationally closed in the sense that they are able to decide for themselves how they want to implement the rules prescribed by Bologna (Kienle & Kunau, 2014).

Poiesis: While technical systems are allopoietic, the university, just like all other social systems, is autopoietic. In contrast to a technical system, it is not possible to tell the system exactly how it should operate. As social systems are comprised of communications between human actors, and these human actors act undeterminable, every human actor might also change the system through the communications he or she contributes., it is not possible to create a social system ex-ante according to specific requirements. While it is possible to initiate a certain system through initial acts of communication, such a system might soon change as the communication goes on. Not only do social systems create themselves, they also maintain themselves. In social systems, communication always follows communication; every communication within the social system must be connectable in the sense that it allows for new communication within the system. As long as this sequence of communication is not interrupted, communication lays the foundation for further communication (Kienle & Kunau, 2014). For the case of the university, this social system is created and maintained by the acts of communication contributed by actors in the system, such as faculty members and university students. The system is created by faculty members teaching and students enrolling in courses. The system might be changed through changing of communication, such as through other lecture contents and changing input of students.

Exercise

exercise

!

1. What is a social system? What are the components of social systems?

2. Why are the components of social systems NOT the human actors that are involved in those systems?

3. Name a few examples of social systems you are involved in. By which rules and norms are these systems organized? How do the rules and norms between these social systems differ?

4. Take the key aspects of Niklas Luhmann's system theory, (1) communication; (2) functional differentiation, (3) operational closure, (4) observation, (5) structural coupling, and (6) poiesis, and apply and explain them upon a social system of your choice. If no particular system comes to your mind, take the example of a sports club (e.g., soccer, basketball).

2.4 Socio-Technical Systems

The socio-technical approach combines structural, social and technological aspects and allows for analysis at different levels (Wohlgemuth, 1991). Prior research and textbooks provide varying definitions of what exactly a socio-technical system is or what key characteristics it needs to fulfill. All definitions have in common that within a socio-technical system, there need to be both technical and social components, that the system needs to have an overall goal, and that the system performance stems from the combination of the technical and social subsystem (see Figure 13). Examples of socio-technical systems include organizations that provide services or strive for goals in the industrial world, encompassing both human actors and technical machinery. The key characteristics of the social system include human actors that (1) are guided by their own hopes, expectations, and disappointments; (2) have a varying scope of action; and (3) can react flexible to changes in the system and the environment. The key characteristics of the technical system include technical components that (1) act deterministic; (2) have a low scope of action; and (3) are less flexible (Häusler, 1970).

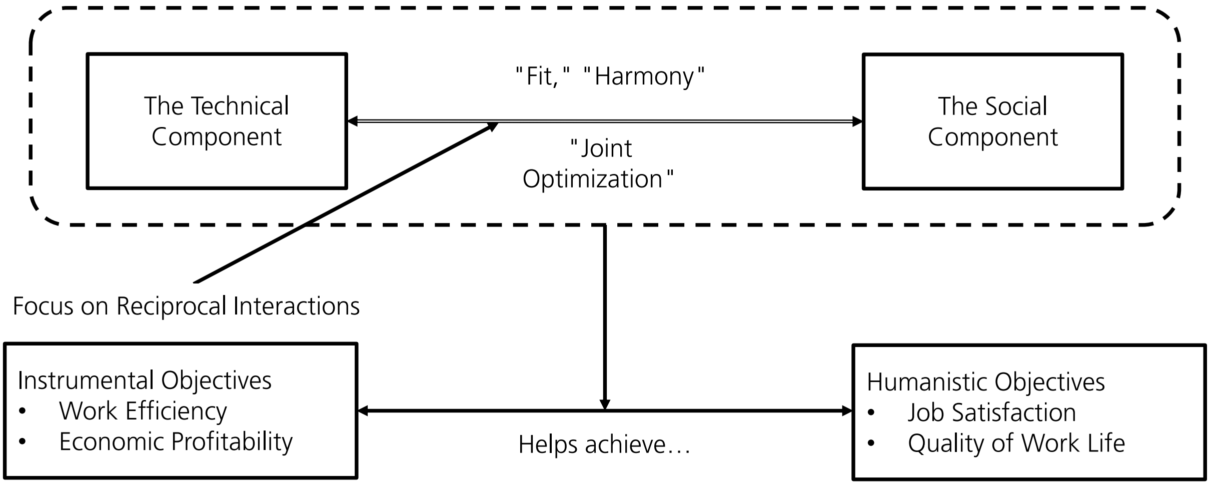

Figure 13: Technical and Social Components of Socio-Technical Systems (Sarker et al., 2019)

An example definition is as follows:

> ***Quote:*** *"The term socio-technical systems is nowadays widely used to describe many complex systems, but there are five key characteristics of open socio-technical systems (Badham et al., 2000):* ***(1)*** *Systems should have interdependent parts.* ***(2)*** *Systems should adapt to and pursue goals in external environments.* ***(3)*** *Systems have an internal environment comprising separate but interdependent technical and social subsystems.* ***(4)*** *Systems have equifinality. In other words, systems goals can be achieved by more than one means. This implies that there are design choices to be made during system development.* ***(5)*** *System performance relies on the joint optimisation of the technical and social subsystems. Focusing on one of these systems to the exclusion of the other is likely to lead to degraded system performance and utility."*
>
> *Baxter and Sommerville (2011), p. 5,* ***bold numbering added***

However, following Luhmann's system theory, which emphasizes the differences between the allopoietic technical systems and autopoietic social systems, these two types of system cannot simply be put together. The differences between the system types are not hard to spot: For example, communication within a social system is very different from communication within a technical system. Taking the earlier examples of a heating system and a university, the communication within a social system seems to be vastly more complicated and nuanced, with chances for misinterpretation. While technical system, such as a heating system, communicate through comparatively simple messages according to strictly defined standards (e.g., sensors signaling a low temperature in one room), social systems, such as a university, feature communication that may be rich and ambiguous (e.g., instructions on what to study for an exam may be understood differently by students). Furthermore, Luhmann himself highlights that the components of a system need to be homogenous. Thus, a technical system, consisting of technical components, and a social system, consisting of communicative acts, cannot be simply put together (Kienle & Kunau, 2014).

digression

In order to provide an adequate understanding of the term "socio-technical" in the context of this lecture, it is important to know to what "socio-technical" does not relate to in the context of this lecture. It is crucial to differentiate the usage of the term "socio-technical" in this lecture from possible other uses of the term in the literature. The following paragraphs will provide a disambiguation of the term, indicating how it is used in other scientific disciplines.

Apart from the usage of "socio-technical" in the context of socio-technical systems, the term is often found in sociology research. According to the work of Rölke (1983), the discipline of sociology generally sees three approaches to sociotechnics.

First, there is sociotechnics in the sense of Karl Popper's "piecemeal social engineering". Piecemeal social engineering refers to the gradual, small-scale, incremental, and continuous social engineering of society. Karl Popper proposed piecemeal social engineering as a response to grand societal prognoses on how the world will change in the future and attempts aimed to impose comprehensive, top-down social plans could lead to unintended consequences. The crucial point of Popper's "piecemeal social engineering" is a slow and gradual social change, based on trial-and-error (Roelke, 1983).

Second, there is sociotechnics in the sense of Adam Podgórecki, who refers to sociotechnics as the "planned control of societal activities", seeing it as a tool to plan purposeful rational action in relation to social problems. Podgórecki's view on sociotechnics is primarily concerned with the organization of societies, including political consulting and the design of societal architecture (Roelke, 1983). Schmidt (1983) sees the theory of socio-technical systems (following paragraph) as a part of Podgórecki's sociotechnics, although on another scale. In his view the theory of socio-technical systems is concerned with organizations rather than society as a whole, reasoning that Podgórecki was simply not interested in the organization level because he was no industrial sociologist.

Third, there is the theory of socio-techical systems, which originated from the Tavistock Institute in Great Britain after the second world war. It is primarily concerned with system in which a social and a technical subsystem interact, particularly in cases where technical components support the operation and communication of a social system.

For the context of this lecture, only the third usage of the term sociotechnics, in the theory of socio-technical systems is relevant. Other uses of the term, such as the ones of Karl Popper and Adam Podgórecki, are out-of-scope. Keep them in mind to differentiate between relevant and irrelevant literature for the topic of the lecture.

The following paragraphs attempt to describe socio-technical systems in a way that goes beyond the simple combination or interaction between social and technical system (Häusler, 1970), while remaining compatible with modern systems theory.

Consider, for example, a public transportation system within a larger city (Figure 14). Undoubtedly, public transportation encompasses many technical components, including but not limited to different forms of transportation (e.g., busses, subways, trains) and the accompanying supporting structure (e.g., train stations, bus depots, information terminals). However, a public transportation also includes social components, provided by human actors that are taking part in the system, including bus and train drivers, the ones creating train and bus schedules, and – of course – the passengers that use the public transportation system.

Figure 14: Public Transport is a Socio-Technical System

Now, after describing both the technical and the social side of the public transportation system, the question remains: What is the best way to describe the relationship between these two sides? The overall goal of the system is to transport people. Both sides are needed to accomplish this. Without busses and trains, the mode of transportation would be missing. Without the social elements provided by the drivers and passengers, nobody would get anywhere. One could argue that with technological evolution and self-driving means of transportation, the social part of the system might no longer be needed. However, passengers are also part of the social system. What would a public transportation system be without passengers?

In socio-technical systems, the technical system supports the social system. While one could argue that the technical components, such as busses and trains, are more important to the socio-technical system of public transportation than the social system, consider the following: Tying back to the section on social systems, social systems consist of the communications that happen therein, that are provided by human actors, not of the human actors themselves. As such, social systems may exist for a longer time than any human actor participating within them. In contrast, technical systems consist of technical components. When enough technical components are broken or outdated, the technical system itself is replaced (e.g., when a bus gets too old, it is replaced). However, the communications in the social system remain. Thus, a socio-technical system, such as the public transportation system, may renew and replace the components of its technical subsystem as often as necessary, the overall system, providing public transport, still remains. Even if the public transportation system were to replace all its means of transportation (e.g., busses, trains) with novel ones (e.g., air taxis), it would still be the same social system. Therefore, it is obvious that the technical system supports the social system and not the other way around.

Both the technical and the social system influence each other (Kienle & Kunau, 2014). As mentioned in the preceding paragraph, the technical system can influence the social system. Through changes in the technical systems, (e.g., the replacement of ticket offices with ticket machines and tickets via mobile apps), social structures of the socio-technical system are changed (e.g., the social interaction in the ticket buying process). The social system can also influence the technical system. For example, passengers can block the door of a train, forcing the technical system to keep it open and thus influencing train schedules.

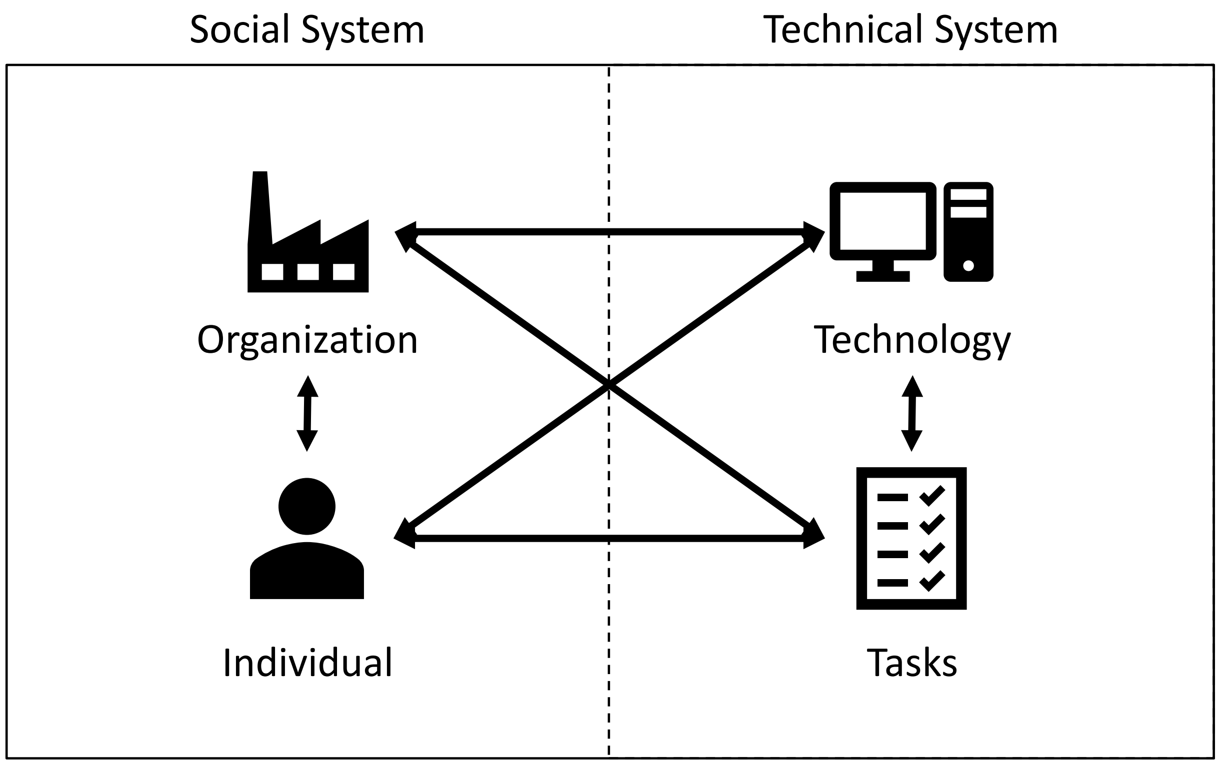

Figure 15: A Schema of Socio-Technical Systems

As mentioned in "observation" in the description of social systems, social systems observe and define themselves. By observing and describing, these systems create themselves in relation to their environment. Similarly, a socio-technical system also observes itself and creates a fitting description. In such observation and description, the technical system and its usage become part of the socio-technical system. Thus, in the autopoiesis of a socio-technical system, the system itself (the social part) creates and maintains rules on the role and usage of the technical components (Kienle & Kunau, 2014). For example, specifying that passengers must first acquire a ticket at a ticketing machine before entering public transport makes the ticketing machine a part of the socio-technical system "public transportation".

Figure 15 illustrates the parties, both social and technical, participating in a socio-technical system.

Summarizing: A socio-technical system has the following characteristics (Kienle & Kunau, 2014):

1. The social system utilizes the technical system. The technical system supports the social system.
2. The social and the technical system influence each other.
3. The technical system becomes part of the social system's observation.

Exercise

exercise

!

1. What is a socio-technical system?

2. Following to the modern systems theory according to Niklas Luhmann, why can't technical and social systems simply be put together to form a socio-technical system? In what relation do the social and the technical system stand?

3. How do the social and the technical part of a socio-technical system differ? What do the individual parts provide?

4. Take the key aspects of Niklas Luhmann's system theory, (1) communication; (2) functional differentiation, (3) operational closure, (4) observation, (5) structural coupling, and (6) poiesis, and apply and explain them upon a socio-technical system of your choice. If no particular system comes to your mind, take the example of an assembly line on the shop floor level of a car manufacturer (Figure 16).

Figure 16: An Assembly Line

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