

Faculty of Information Technology

**Enterprise Engineering theories
Introduction and overview**

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Enterprise Engineering theories

Introduction and overview

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Abstract

In order to illustrate the basic idea of the Ciao! Network concerning the development of the discipline of enterprise engineering (EE), the tree metaphor is presented. The roots of the tree are the theories, the trunk contains the methodologies built on these roots, and the leafs and flowers stand for the flourishing enterprises that are achieved by applying the methodologies. The common theoretical basis for establishing EE, is the Ciao! paradigm that has its origins in the communication-centric view on information systems (engineering) that emerged around 2000. It replaces the information-centric view, which increasingly fails to support the theory and practice of information systems engineering effectively. The Ciao! paradigm provides a coherent and integrated understanding of these four core notions: communication, information, action, and organisation. After the discussion of the paradigm, the current seven EE theories are discussed briefly, after having been ordered in an appropriate classification scheme.

Keywords Enterprise engineering, enterprise ontology, system ontology, enterprise architecture, system architecture, enterprise design, system design, organisation design, information system design, enterprise management, enterprise governance

1 The tree metaphor

There is nothing as practical as a good theory (Kurt Lewin)

This document provides an introduction to and an overview of the theories in the discipline of enterprise engineering (EE), as it is currently developed and practised by the Ciao! Network. In the tree metaphor, shown in fig. 1, these theories constitute the roots of the tree. The trunk comprises the EE methodologies, whereas the leaves and flowers stand for the flourishing enterprises that EE aims at. They are achieved by applying one or more EE methodologies, as the juices that feed the leaves and flowers reach them through the trunk and the branches (which must be viewed as extensions of the trunk).



Figure 1: The Ciao! tree

As the tree grows, the need may arise for developing new methods, or to graft ones from outside on the trunk. The only prerequisite is that these external methods are compliant with the EE theories. In addition, a need may occur to develop new theories, or to add ones from outside to the root structure. Again, the only prerequisite is that they are (or are made) compliant with the existing EE theories.

In section 4, the seven EE theories that have been developed up to now, are briefly discussed. Here they are (with their alternative names):

FI theory	(ϕ -theory)	the EE information theory
TAO theory	(τ -theory)	the EE function-construction theory
PSI theory	(ψ -theory)	the EE organisation theory
DELTA theory	(δ -theory)	the EE system theory
MU theory	(μ -theory)	the EE model theory
BETA theory	(β -theory)	the EE design theory
SIGMA theory	(σ -theory)	the EE governance & management theory

The documents TEE-1 through TEE-7 contain an extended summary of each of the theories. Every summary is divided in three parts: foundations, elaborations, and discussions. The foundations part regards the theoretical basis of the theory, its core ideas. It is presumably the most stable part. In the elaborations part, the link to practice is established (examples, methods, techniques, tools, etc.). It is presumably less stable than the foundations part, because new elaborations may come up in the course of time. The discussions part serves particularly to compare the EE theory with similar other approaches. Therefore, it is presumably also less stable than the foundations part, as new comparisons may be needed in the course of time.

2 From information-centric to communication-centric

We can't solve problems by using the same kind of thinking we used when we created them (Albert Einstein)

Enterprise engineering, as conceived by the CIAO! Network, builds on a paradigm shift in the information systems field, that started to take place in the nineties. This paradigm shift is very well comparable with the one that took place in astronomy, some five centuries ago; it is made visible in fig. 2.

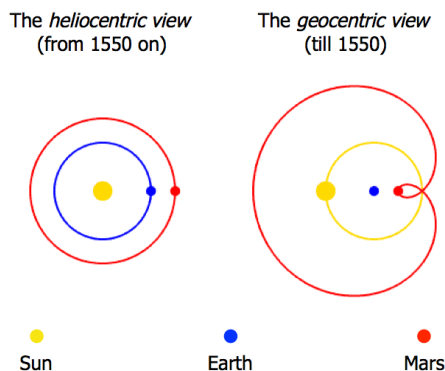


Figure 2: The paradigm shift in astronomy

Probably from the very beginning of mankind, people assumed that the Earth is the centre of the universe, and that the Sun, the Moon, and all other celestial bodies are orbiting it. The Greek astronomer Ptolemy presented mathematical models, based on (naked-eye) observations, that served to confirm the geocentric view, around 150 AD. It was the Polish astronomer Copernicus who challenged it because it had become unsustainable in the light of the much more accurate (telescope) observations that he and contemporary astronomers were making. This led to the adoption of the heliocentric view, which is still the dominant paradigm in astronomy.

Based on recent developments in language philosophy [1], [2] and in (social) action theory [3], a community of researchers in information systems, called LAP (Language/Action Perspective), proposed a similar paradigm shift in the field of information systems. It is exhibited in fig. 3.

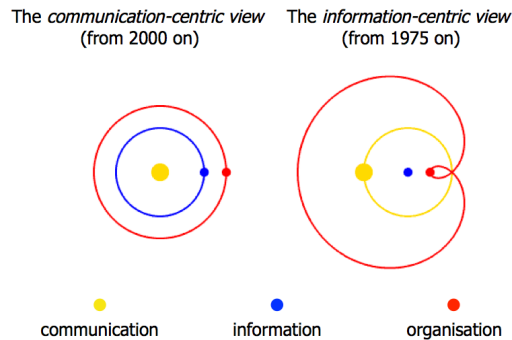


Figure 3: The paradigm shift in information systems

Up to about 1975, there was no talk yet about a field of information systems or information systems engineering. The application of computers and software to assist the operations and the management of organisations was called EDP (Electronic Data Processing). Around 1975, EDP was replaced by ISD (Information Systems Development) or by similar names. The primal and core notion was information, generally defined as the representation of knowledge, in particular factual knowledge. By communication was generally understood the exchange of information. This relationship is expressed in fig. 3 (right side) as communication orbiting information. The notion of action was something quite disconnected from information and communication, as was the notion of organisation, although there was the general recognition that organisation somehow implies action, communication, and information. But, as shown in fig. 3, organisation certainly did not “properly” orbit information.

One of the corollaries of the information-centric view is that developing (automated) information systems was, and still is, considered as something that IT professionals do “to the side”, after having elicited the requirements from the people in the organisation. Once the system is ready, it is “implanted” in the organisation. A major drawback of this approach is that the delivered system rarely meets the expectations of the future users. The main reason is that requirements determination is ill-understood. Consequently, relevant requirements are often missing, and on the other had, irrelevant ones are taken into account.

In the late nineties, an urgent need was felt in several research communities, like the mentioned LAP community (but also in Organisational Semiotics), that the information-centric view was not sustainable any more. The number and the size of failures in information systems engineering kept increasing, and the proclaimed benefits of standard packages, notably ERP systems, came along with the feeling in the enterprises that use them, of being armoured. By taking communication as the primal and core notion, the path was paved to a clear and integrated understanding of the other two: information and organisation. Communication is now defined as the sharing of thoughts, and information as the means for communication. Moreover, and thanks to the Speech Act Theory [1, 2], and the Theory of Communicative Action [3], communication is also understood as action, through the intention that is present in every communicative act. The atomic communicative act and the resulting fact each

consist of four parts (cf. fig. 4): performer, intention, addressee, proposition. The proposition is a predication of an entity. The intention is the intent of the performer towards the addressee, with respect to the proposition.

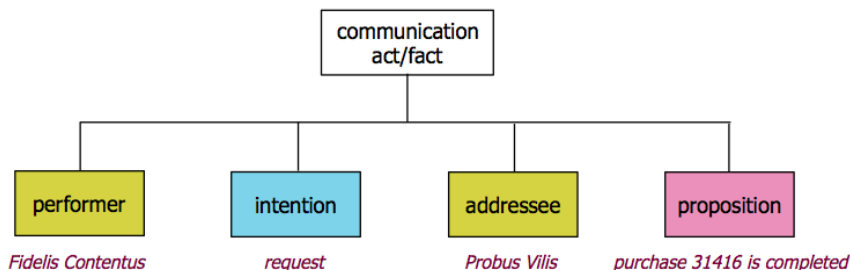


Figure 4: The atomic communicative act/fact

In the given example, Fidelis Contentus, a purchaser at the company HORTUS, requests Probus Vilis, a salesperson at the company MALUM, to bring about the proposition that purchase 31416 is completed. This proposition entails, for example, the becoming owner of 10 wheelbarrows of type Quadra 75, for the price of 165 ksi each, on day 731.513 [4].

Habermas [3] tells us that Fidelis Contentus raises three validity claims towards Probus Vilis in performing this act: the claim to justice, the claim to sincerity, and the claim to truth. These claims are assessed by Probus Vilis, and the result of this assessment will guide him in the way he will respond to the request. By accepting the claim to justice, he recognises the authority of Fidelis Contentus to make the request to him. By accepting the claim to sincerity, he conveys that he trusts the sincerity of the other in making the request. By accepting the claim to truth, he conveys (in this case) that he is able to bring about the proposition. If all three claims are accepted, Probus Vilis will most likely respond with a promise. Otherwise, he will most likely decline the request.

3 The ciao! paradigm

Communication is the thread of which organisation is woven

Performing communicative acts, like requests and promises, implies the entering into and complying with commitments by the participating people, and thus links communication to organisation. As Mintzberg [5] puts it, organisation emerges from every cooperative of people, because it gives rise to a division of what has to be done into (smaller) tasks, and consequently to the coordination of these tasks. The PSI theory [TEE-3] makes this more general and precise, by stating that the division of labour is actually a division in (elementary) actors who perform (elementary) production acts, that coordination comes down to performing specific communicative acts, and that production and coordination take place in transactions, which are processes through a universal pattern. In the order as discussed, the first letters of the key notions in the communication-centric view (communication, information, action, and organisation), form the word “ciao”, which is why the community of scientists

and practitioners who strive to develop the discipline of enterprise engineering, is called the Ciao! Network.

The (new) concept of communication in the communication-centric view, is sufficiently discussed in the previous section. Let us point out here what its consequences are for the other three concepts: information, action, and organisation.

For the concept of information, it means that there isn't something like neutral information. If someone tells you (in response to your explicit or tacit question), that the Earth orbits the Sun, then he or she performs a communicative act that has the structure as shown in fig. 4. The person is the performer and you are the addressee. The intention is the assertion, and the proposition is that the Earth orbits the Sun. Moreover, the person raises the three validity claims that you have to assess, and subsequently to accept or not. By accepting the claim to justice, you recognise the authority of the other to make the assertion to you. By accepting the claim to sincerity, you convey that you trust the other to be sincere. By accepting the claim to truth, you convey that you believe in the truth of the proposition, i.e. that you take it as a true fact. The purpose of this example is to illustrate that the truth or validity of a piece of information is not something absolute, but something relative: it is dependent on our acceptance of the authority and sincerity of the one that asserts the truth. This is the (only) way that we can talk about truth in our highly institutionalised society [6]. A major contemporary problem is that traditional authorities (parents, teacher, etc.) have largely vanished, and that there are no clear substitutes. At the same time, people tend to assign authority to parties (like the world wide web, and social media) of which it is questionable that they deserve it.

For the concept of action, the communication-centric view means that communicating is also acting, next to the production-related (material and immaterial) acting that we have always known. As John Austin [1] puts it: we can do things with words. In the PSI theory [TEE-3], this is accentuated by distinguishing coordination acts and production acts, but also by bringing them together in the concept of transaction. In this way, the concept of action is connected to and reconciled with the concept of information: the resulting product of a transaction is the case, i.e., is true, if and when it is accepted by the initiator of the transaction (i.e., is the performer of the request, cf. fig. 4). Consequently, every (production) fact is the result of a successfully completed transaction.

The (new) concept of organisation, as discussed above, refers primarily to the network of actor roles and corresponding transaction kinds that emerges as the effect of identifying tasks, and the need for coordinating them. The accentuation that the PSI theory [TEE-3] adds to it, is that every actor role, together with the transaction kind of which it is the executor, constitutes a unit of authority, responsibility, and competence in an organisation. Actor roles are assigned to people, and these people basically act autonomously. It means that the response to a coordination act, like a request, may violate the applicable (business) rules, i.e., the rules for assessing the three validity claims in a coordination act. However, the responsible actor will be accountable for it. This emphasises the human and social nature of organisation. Next, these human actors permanently carry on what is called secondary communication in [4]. In this type of communication, appropriately called the lubrication oil of or-

organisations, actors constantly check the social and cultural norms that they apply, and the values that they assign, and adapt them when deemed necessary or appropriate. The concept of organisation, as discussed, conforms to the construction perspective on enterprises (cf. TAO theory [TEE-2]). The function perspective on enterprises, which EE certainly also discerns, is commonly signified by the term “business”.

4 The EE theories

The theories as listed in section 1, are classified in the scheme in fig. 5, which is discussed in [7]. The main associations between the theories are from bottom to top. So, philosophical theories are the foundation of all others, and ontological theories are the basis of both technological and ideological theories. The presented classification is disputable, but in the way they are classified, we think we do justice to their main character.

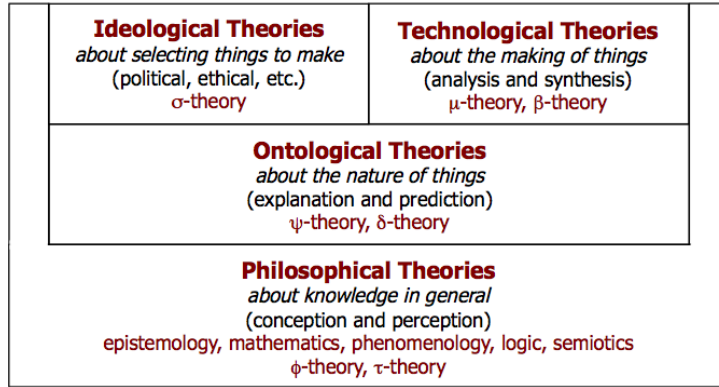


Figure 5: Theory Classification Scheme with the EE theories

The ϕ -theory and τ -theory are put in the class of philosophical theories for two reasons. One is that they are not about the nature of things but truly about conception and perception. The other reason is that the majority of papers and books in these fields are published in philosophical journals or book series. The ψ -theory and the δ -theory are put in the class of ontological theories because they are about the nature of things, in particular the nature of systems, although the δ -theory has also a substantial mathematical part. Next, the β -theory is undoubtedly a technological theory. The μ -theory is also put in this class because its main practical use is to bridge ontology and technology. Lastly, the σ -theory is, for the largest part, undoubtedly an ideological theory.

Hereafter, a summary of each of the theories is provided.

4.1 The FI theory [TEE-1]

The FI theory (ϕ -theory) or EE information theory clarifies the notions of (factual) knowledge and information (FI stands for Factual Information). It is rooted in the semiotic triangle, which distinguishes thoughts (in the mind) from the things (in the concrete or abstract world) they refer to, and from the

signs that signify them. Based on the semiotic triangle, the semiotic mill is developed, and subsequently the ontological mill. They serve to understand accurately what conceptualisation is about.

An important notion in conceptualising (factual knowledge of) a world, is the notion of type. Type is defined as a prescription of form, where form is the totality of properties of a thing. If and when a thing conforms to a type, a new instance of the type is created in the mind, called a fact. Examples of facts are <the Earth orbits the Sun> and <Charlie Chaplin is a~human>. The first one is a binary fact and the second one a unary. Unary facts are often called entities, and then mostly rephrased as <the human Charlie Chaplin>. Facts are predications of (single or multiple) conceptual objects. These objects are members of a conceptual class, which is the extension of the type of which the fact is an instance. The referent of a fact is a feature (set of properties) of a thing, e.g. the being human of Charlie Chaplin. The referent of a conceptual object is a concrete object, which constitutes the identity of a thing, and the referent of a conceptual class is a concrete class of (featured) things.

Next to declaring types “from scratch”, types can be constructed from other types in three ways: by specialisation, by generalisation, and by aggregation.

4.2 The TAO theory [TEE-2]

The TAO theory (τ -theory) or EE function-construction theory, is a theory about the way subjects (people) perceive the things that surround them (TAO stands for Teleology, Affordance, Ontology). Most people appear to perceive the affordance(s) that things offer to them first. Affordances emerge from the perception by subjects (with needs) of objects (with properties). As an example, if you walk in the woods and feel the need to sit, you may perceive that (some properties of) a tree trunk offers you the corresponding affordance. Next to using the affordances that existing things offer, people design and make things with particular affordances in mind. We mostly then speak of the function(s) of a thing. For example, we can design and build chairs, which have the function to sit on. In addition, we assign new functions to existing things. For example, we can assign the function of parking lot to the market place, for particular periods in a week.

The foregoing leads to the distinction between the construction of a thing, and its possible functions (or affordances). The construction of a thing is something objective, i.e., independent of the possible affordances it may offer. Consequently, function is not a property of a system, but something relative to a stakeholder (or group of stakeholders). For example, to people with the need to drive, cars do offer this function. Next, subjects may have different experiences from using the functions or affordances that things are able to offer them. For example, you may assign to the sit-on-ability of a chair a higher value than to the same affordance offered by a tree trunk. Experiences are purely subjective impressions, which may, however, be shared among a group of stakeholders.

4.3 The PSI theory [TEE-3]

The PSI theory (ψ -theory) or EE organisation theory, is a theory about the construction and operation of organisations (PSI stands for Performance in So-

cial Interaction), firmly founded on the ciao! paradigm, discussed in section 3. It is split into the general PSI theory and the special PSI theory.

The general PSI theory, also called its human side, clarifies the operating principle of every organisation, which is that subjects enter into and comply with commitments. Based on the semiotic ladder, which is an elaboration of the semiotic triangle as discussed in the FI theory, three human abilities are distinguished: forma (the form of information), informa (what is in the form, so the content of information), and performa (what is brought about through the form, the commitments). They are present in every communicative act (cf. section 3). It gives rise to three levels of correspondence between communicating subjects: the forma level (notational correspondence), the informa level (cognitive correspondence), and the performa level (social correspondence). For successful communication, all three levels should be satisfied, i.e., be free of distortion. As discussed in section 3, the general structure of a communicative act or fact is: **<performer> <intention> <addressee> <proposition>**.

The products of an organisation are brought about in particular patterns of communicative acts, called transactions. These specific communicative acts (e.g., requests, promises, statements, and acceptances) are called coordination acts, and the proposition is called the product now. The complete, and universal, transaction pattern comprises 20 different coordination acts/facts concerning 1 production act/fact (which is the actual bringing about of the product).

In the special PSI theory, also called the system side of the theory, the performa-informa-forma distinction is applied to production, leading to a corresponding distinction between original (creating, deciding, judging, etc.), informational (remembering, recalling, computing facts), and documental (archiving, transporting, etc. documents or data) production. Consequently, every organisation consists of three aspect organisations: the O-organisation (O from original), the I-organisation (I from informational), and the D-organisation (D from documental). Next, the ontological model of an organisation is introduced. It is a conceptual model of the construction of the organisation, so composed of transaction kinds and actor roles, but fully abstracted from the implementation of its components, so fully abstracted of the technological means with which coordination acts and productions acts are performed, and with which the resulting coordination facts and productions facts are remembered and recalled, and in which derived facts are computed. The ontological model of the O-organisation is called the essential model of the organisation. It is an integrated whole of four sub models: the construction model (the network of transaction kinds and actor roles), the action model (the applicable business rules), the process model (the corresponding business processes and events) and the fact model (the corresponding business objects and facts).

4.4 The DELTA theory [TEE-4]

The DELTA theory (δ -theory) or EE system theory, is a theory about the construction and operation of systems (DELTA stands for Discrete Event in Linear Time Automaton). As a general definition of the notion of system, the one from systemic ontology is taken: a system is a triple $(\mathcal{C}, \mathcal{E}, \mathcal{S})$, where \mathcal{C} is a set of elements of some category, called the *composition* of the system; \mathcal{E} is a set of elements of the same category as the elements in \mathcal{C} , called the

environment of the system; \mathcal{S} is a set of influencing bonds among the elements in \mathcal{C} and between them and the elements in \mathcal{E} , called the *structure* of the system. Examples of categories are: physical, biological, social. Organisations fall in the category of social systems. With every system corresponds a *world*, in which the acts of the system have effects. At any point in time, a world is in some state, simply defined as a set of facts. Three kinds of conceptual systems are distinguished that may serve as models of concrete systems (cf. MU theory): the *black-box system*, the *grey-box system*, and the *white-box system*. As a specialisation of the grey-box system, the *discrete event system* is introduced and discussed. As specialisations of the white-box system, the *smartienet* (see SMART theory below) and the *crispinet* (see CRISP theory below) are introduced and discussed. The SMART theory is a formalised ontological theory that is particularly suited to study the construction and operation of technical systems. By technical is meant that the active elements are implemented by non-human agents. Two kinds of mutual influencing between agents are distinguished: interaction and interstriction. By *interaction* is understood that agents respond to the events that are the effects of acts (by other agents or by themselves). By *interstriction* is understood that agents, when being active (i.e., when responding to an event), take notice of the current state of the world. A conceptual system in the SMART theory is called a smartienet. The CRISP theory is a formalised ontological theory that is particularly suited to study the construction and operation of organisations, which means that the active elements are implemented by human actors. In addition to interaction and interstriction, intervention is distinguished. By *intervention* is understood that an actor has to wait for the occurrence of an event, before it can respond to an (other) event that it has to deal with. A conceptual system in the CRISP theory is called a crispinet.

4.5 The MU theory [TEE-5]

The MU theory (μ -theory) or EE model theory, is a theory of models and modelling in general, and of conceptual modelling in particular (MU stands for Model Universe). The notion of model that is taken reads: any subject using a system A to obtain knowledge of a system B, is using A as a model of B. This formulation conveys the basic understanding of the notion of model as a role notion (or affordance notion). Combining this notion of model with the semiotic triangle from the FI theory, leads to the model triangle. It clarifies how complexes (systems and aggregates) of three major sorts (concrete, conceptual, and symbolic) can be used as models of each other. By adding two levels of abstraction (schema level and meta level), the General Conceptual Modelling Framework (GCMF) emerges. It clarifies the notions of conceptual complex, conceptual schema, and meta schema, for any Universe of Discourse or system's world.

The Generic Ontology Specification Language (GOSL) is introduced as a universal language for specifying conceptual complexes, conceptual schemas and meta schemas. Next, and corresponding with the distinction between the construction and the function perspective (cf. TAO theory), two sorts of conceptual models (of concrete systems) are distinguished: constructional models and functional models. A constructional model or white-box model is a conceptualisation of the construction of concrete complexes, e.g. of cars (cf. DELTA

theory). A functional model or black-box model is a conceptualisation of a function that a concrete complex may offer to someone, e.g. the driving function of a car.

4.6 The BETA theory [TEE-6]

The BETA theory (β -theory) or EE design theory, is a theory about designing artefacts in general (BETA stands for Binding Essence, Technology and Architecture). It starts with the introduction and discussion of the Generic System Development Process (GSDP). This is a general framework for understanding the activity or process of design, where an object system is designed (and completely developed) for the benefit of a using system. With reference to the TAO theory, a clear and sharp distinction is made between the function and the construction of the object system. In addition, the BETA theory clarifies how the function of the object system supports the construction of the using system. Next, an effective and appropriate notion of architecture is presented and discussed, as part of the GSDP. Architecture is defined as the conscious usage of the design freedom that is left after all requirements are met. It is expressed in design principles, which are generic requirements, i.e. requirements that hold for a class of object systems. Both functional and constructional design principles are considered.

Next, the Generic Requirements and Architecture Framework (GRAF) is introduced, as a framework for understanding architecture and requirements in an integrated way, and for making mission, strategy, etc., operational, by transforming them to (functional and constructional) design principles.

4.7 The SIGMA theory [TEE-7]

The SIGMA theory (σ -theory) or EE governance & management theory, is an ideological theory about how enterprises should be managed and governed in such a way that the people in the enterprise are maximally empowered (SIGMA stands for Socially Inspired Governance and Management Approach).

Traditional thinking about enterprises considers (executive) management the primary and exclusive custodians of enterprise performance. Employees, under management control, must behave instrumentally as parts of the enterprise machine. Hence, no employee variability: standard, predefined instrumental behaviour is required and expected. The SIGMA theory submits a fundamentally different perspective by arguing that variability in employee behaviour is crucial for operational and strategic performance. In our view, the instrumental approach to employee behaviour conflicts with moral and ethical considerations concerning employees and society at large. Current economic thinking, in which enterprises are merely seen as money-generating machines, reinforces the instrumental view on employees. It is argued that employee variability is an absolute prerequisite for aligning employee and social development interests with enterprise performance interests. This “unitarist” perspective rejects any supposedly “natural” opposition between these interests.

The SIGMA theory is made operational through the notion of “meaningful work”, which is seen as an affordance (cf. TAO theory): a relationship between employees with certain subjective needs and enterprises with certain objective properties of the work environment. The nature of these needs and properties

is elucidated, clarifying at the same time that the theory is firmly grounded in the organizational sciences. The employee-centric nature of this theory aims to counteract the narrow economic theories advanced by many business schools. The discussion of these current ways of thinking reveals the fundamentally different perspective on enterprises that the SIGMA theory entails.

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