Chapter 4
The Enterprise Engineering Theories

Abstract The foundations of the discipline of enterprise engineering (EE), as envisioned by the Ciao Network, consist of the CIAO Paradigm and a number of theories. After the discussion of the paradigm, which has its origins in the communication-centric view on information systems engineering which emerged around 2000, the role of the EE theories and their relationships with the EE methods and the practice of EE is explained. After having been arranged in a suitable classification scheme, each of the following theories is briefly discussed: the EE information theory, the EE model theory, the EE function-construction theory, the EE organisational operation theory, the EE system theory, the EE organisational construction theory, the EE organisational essence theory, the EE organisational design theory, the EE organisational implementation theory, the EE normalisation theory, and the EE governance and management theory.

Whether you can observe a thing or not depends on the theory that you use. It is the theory that decides what can be observed

(Albert Einstein)

4.1 Introduction

In this chapter, the reader is introduced to the theoretical foundations of the discipline of Enterprise Engineering (EE), as it is developed and practised by a group of researchers and practitioners called the Ciao Network[1] [1]. The Italian word Ciao[2] is an acronym for Communication, Information, Action, and Organisation. They are the key concepts in the CIAO Paradigm, which constitutes the basic understanding of the operation of enterprises. It also sets our engineering perspective. Even if an

[1]For more information, visit www.ciaonetwork.org

[2]The Italian word 'Ciao' can mean both 'hello' and 'goodbye', depending on the context. The shared characteristic is that one confirms to someone else to consider him/her as a trustworthy fellow human being.

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enterprise has not been designed consciously, changing can be considered as redesigning and re-implementing it. At the same time, the highest appreciation is given to the 'pearls' of every enterprise: the people. Invested with the right authority, based on competence, and exerted with responsibility, they are the cornerstones of an enterprise's organisation. Without people, there is no organisation.

Fig. 4.1 The CIAO tree

In order to portray the role of theories and methods in the field of EE, the Ciao Network uses the tree metaphor, as exhibited in Fig. 4.1. The EE theories constitute the roots of the tree. They feed the trunk, which represents the EE methods, with their juices. After having been made fit for consumption by the methods, the juices ultimately reach all branches, where they cause the growth of leaves and flowers, representing the flourishing enterprises that EE aims to achieve.

As the tree grows, the need may arise to develop new methods, or to graft external ones on the trunk. There is no objection against it; on the contrary, every useful contribution is welcome. The only prerequisite is that the methods are (made) compliant with the EE theories. In addition, a need may occur to develop new theories, or to add external ones to the root structure. Again, the only prerequisite is that they are (made) compliant with the existing set of theories.

Section 4.2 contains an explanation of the CIAO Paradigm. In Sect. 4.3, an overview of the currently existing EE theories is presented, followed by a brief summary of each of them in Sect. 4.4.

4.2 The CIAO Paradigm

4.2.1 From Information-Centric to Communication-Centric

Up to about 1975, there were no information systems and there was no field of information systems engineering. The application of programmed computers in

enterprises, for the sake of assisting the workers and the managers, was called EDP (Electronic Data Processing). Around 1975, EDP was replaced by ISE (Information Systems Engineering) or like names, referring to the field that concerns the application of ICT[3] in organisations. The primal and core notion became information, generally defined as the representation of knowledge. Communication was defined as the exchange of information. The notion of action was something rather 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. Let us call this point of view the *information-centric* view on information systems (engineering).

One of the consequences of the information-centric view is that developing (automated) information systems is considered as something that ICT professionals do 'to the side', after having elicited requirements from the people in the organisation, basically by interviewing these people. Once the system is built, it is 'implanted' in the organisation. A widely acknowledged drawback of this 'waiter' approach is that the delivered systems rarely meet the expectations of the users. In hindsight, the main reason for this failure is that requirements determination was ill-understood. Asking the members of an organisation what information they need, presupposes that these people have such a comprehensive understanding of their tasks, that they are able to provide complete, consistent, and coherent answers. As a counter example, embedded software engineers will start to get an appropriate understanding of the system or machine for which they are going to build supporting software. Based on this understanding they will specify the requirements for the software system to be built.

For obscure reasons, the developers of 'embedded' software for organisations, thus the information system engineers, have never recognised the necessity to acquire an appropriate understanding of the objects of interest they want to support: organisations. As a consequence of the 'waiter' approach to requirements determination, relevant requirements are often missing, and irrelevant ones are included.

In the nineties of the past century, an awareness emerged that the information-centric view was not sustainable anymore. The number and size of failures in information systems engineering kept increasing, and the proclaimed benefits of standard packages, notably ERP[4] systems, came along with the feeling of being armoured by the people that had to use these systems. Based on the achievements in language philosophy, notably Speech Act Theory [2, 3] and in (social) action theory, notably the Theory of Communicative Action [4], a community of researchers in information systems engineering, called LAP (Language/Action Perspective), proposed a paradigm shift [5]. By taking communication as the primal notion, the path was paved to a more appropriate and more integrated understanding of the other

[3]ICT stands for Information and Communication Technology. It refers especially to the modern practice of applying digital electronic, optical, etc., means to process, store, and transmit data.

[4]ERP stands for Enterprise Resource Planning. It evolved in the 1990s from MRP (Materials Requirements Planning). ERP is a manufacturing and logistics approach to business processes and data management.

three key notions: information, action, and organisation. Later, the name CIAO Paradigm (CIAO stands for Communication, Information, Action, and Organisation) has been coined for this *communication-centric* view on information systems (engineering). *Communication*[5] is now defined as the sharing of thoughts between subjects (human beings), and *information* as the means for communication. People, in organisations and in society at large, have a need to communicate, generally for the sake of making known what they are doing. Because it is impossible to do this directly, for example, by connecting brains, they have to use the vehicle of information.

4.2.2 Communicative Action

In addition to the sharing of thoughts, communication became (also) understood as a form of *action*, by virtue of the intention in every communicative act, as explained by Habermas' Theory of Communicative Action [4]. Figure 4.2 exhibits the four constituting parts of a communicative act: the performer, the intention, the addressee, and the proposition.

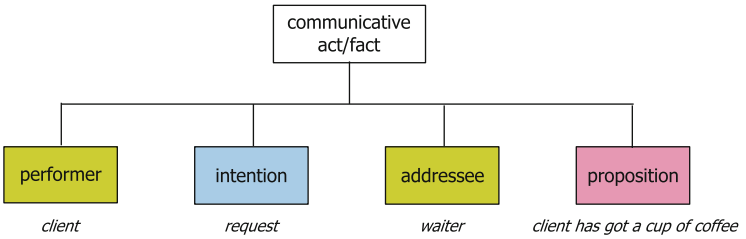

Fig. 4.2 The structure of a communicative act/fact

The *performer* and the *addressee* are subjects, that is, human beings, particularly in their quality of social individual, which means: being capable to engage in mutual commitments. The *proposition* is a state of affairs that is or can be the case. An example of a proposition in the context of a café is that a client has got a cup of coffee. The *intention* is the intent of the performer (the client) towards the addressee (a waiter), with respect to the proposition. If the intention is 'request', the performer wants the addressee to make the proposition become true. In this case, the client wants the waiter to bring her a cup of coffee. Habermas [4] tells us that, in performing a communicative act, the performer raises three validity claims towards

[5]The English word 'communicate' comes from the Latin word 'communicare', which means 'making something common', 'sharing something with somebody'. In a more specific sense, it means 'sharing thoughts'.

the addressee: the claim to rightness, the claim to sincerity, and the claim to truth. These claims have to be assessed by the addressee, and the result of this assessment will guide him/her in the way he/she will respond. By accepting the *claim to rightness* in the above example, the waiter recognises the authority of the client to make the request. By accepting the *claim to sincerity*, the waiter expresses that he considers the client sincere in making the request. By accepting the *claim to truth*, the waiter expresses that the proposition can be made true. If all three claims are accepted, the communicative act is said to be successful. In the café example, the waiter will then respond by a promise. In case of failure, he will decline the client's request. In every communicative act, one of the validity claims is dominant. Based on this dominance, Habermas [4] distinguishes three categories of communicative acts, as well as three worlds in which these acts have effect. Figure 4.3 shows the distinctions. The dominance of a claim, as well as the related world, is indicated by the grey-coloured rectangles.

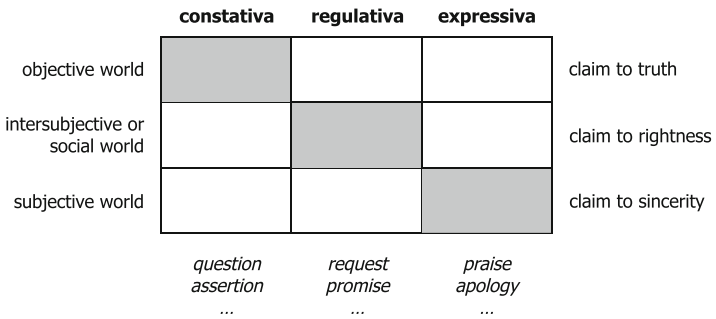

Fig. 4.3 Categories of communicative acts

In the category of *constativa*, the dominant claim is the claim to truth, and the world with which they are primarily concerned, is called the *objective world*. Examples of intentions in this category are question and assertion. If a railway passenger asks a railway officer for the departure time of the next train to Amsterdam, the dominant claim is the claim to truth, that is, that the fact exists (in their shared objective world). This holds also for the answer by the officer (which would be the assertion of a fact). Facts like the departure time of trains are considered to exist in our common objective world, like the fact that the sun is shining, and the current price of a glass of beer in your favourite pub. But, the other two (non-dominant) validity claims must also be satisfied. In the train example, this means that the railway passenger respectively trusts the railway officer that he/she is authorised to provide the answer, and that this officer will provide the correct answer.

In the category of *expressiva*, the dominant claim is the claim to sincerity, and the world with which they are primarily concerned, is everyone's private *subjective world*. Examples of intentions in this category are praise and apologise. If the railway passenger starts his/her conversation with the railway officer by saying

"I'm sorry to disturb you, madam, but . . .", then the dominant claim of this phrase is the claim to sincerity. If the officer feels that the passenger is insincere, she will most likely utter a sincerity checking sentence, and she may even ignore the passenger. Facts like feeling sorry are considered to exist in everyone's subjective world. The claim to sincerity represents the most fundamental condition for human cooperation in the broadest sense of the word, which is mutual *trust*. At the same time, it is the hardest one to verify. Moreover, trust emerges from shared values and norms among people, which do change over time. In language philosophy [6] and social action theory [4] it is assumed that people constantly check and adjust their values and norms when they are communicating. In [7] we have called this second-order communication, and we have suggested that this is the lubricating oil of organisations and of society at large.

In the category of *regulativa*, the dominant claim is the claim to rightness, and the world with which they are primarily concerned, is the intersubjective or *social world*. Examples of intentions in this category are the request and the promise. If the client in the café asks the waiter for a cup of coffee, the dominant claim is the claim to rightness, that is, the client claims that she has the authority to make the request, and that she considers the waiter to be authorised to fulfil it. This holds also for the response by the waiter. Facts like being authorised to do something are considered to exist in our common intersubjective or social world. Moreover, we have created them ourselves. Assigning each other authorities (and expecting that they will be exerted in a responsible way) is the way in which we build organisations and societies [6]. This insight has important consequences. One of them is that people are basically autonomous in deciding how to respond to (intersubjective or social) events. This is the case in every enterprise and in society at large. The fundamental autonomy implies that one may disobey rules and laws if the situation asks for it. At the same time, they must act responsibly, and they can be held accountable for their deeds. Another consequence is that all facts, or all data if one likes, are basically social or intersubjective facts. As will be elaborated in the PSI theory (cf. Chap. 8), a fact is either a coordination fact, like having requested a cup of coffee, or a production fact, like having brought a cup of coffee, or having observed the temperature in a room. Even in the upcoming era of the Internet of Things, the facts that we use in our institutionalised society are always social facts.

4.2.3 Implications for Information, Action, and Organisation

Let us point out next what the consequences of the communication-centric view are for the other three concepts: information, action, and organisation, starting from the basic understanding that *communication* is the sharing of thoughts by human minds. Because human beings are not able to directly connect their minds, some vehicle for transmitting thoughts is needed, and this vehicle is information, or the sign, which is the preferred term in semiotics (cf. Chap. 5). A major outcome of this study is the semiotic ladder, shown in Fig. 4.4. It clarifies the role of signs in the communication of human beings. *Information* then is the dyad of content and form,

meaning that the two parts are distinguishable but not separable. The *content* is the thought that one wants to share, and the *form* is the agreed-upon perceivable sign. The content comprises both the intention (or pragmatics) and the proposition (or semantics) of the thought, and the form comprises both the formalism (or syntax) and the coding (or empirics). Contrary to the definition in Fig. 4.4, the content of a sign is often equated with the notion of *information*, and the form with *data*. Precise definitions and their consistent use don't seem to have a high priority in current practice.

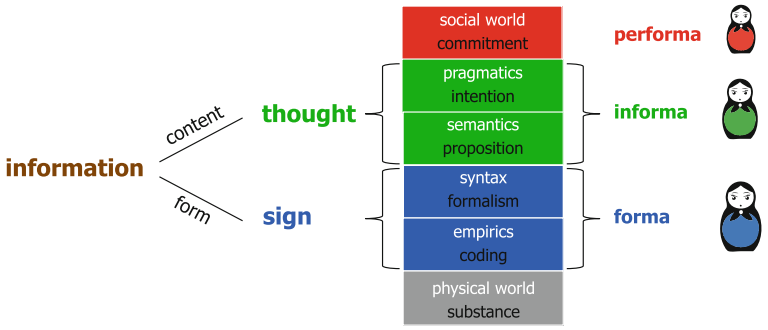

Fig. 4.4 The semiotic ladder

In the café example, the client has, at some point in time, got the thought that she wants a cup of coffee. In order to share this thought, she has to express it in a sign that is intelligible for the waiter. The proposition of the thought is "client has got a cup of coffee" and the intention is the request. By performing the request, she enters into a commitment towards the waiter, like the waiter enters into a commitment if he performs a promise or a decline in response. The client may have expressed her thought in this English sentence: "I'd like to have a cup of coffee, please", which constitutes the form part in Fig. 4.4. The applied formalism is the English grammar and the coding concerns the representation of the words. The substance in which the sentence is inscribed consists of the air vibrations that are produced by the client and then perceived by the sense of hearing of the waiter.

For the concept of *action*, the communication-centric view means that communicating is (also) acting, as discussed in Sect. 4.2.2. As Austin [2] puts it, people do things with words. In the PSI theory (cf. Chap. 8), this is accentuated by distinguishing coordination acts and production acts, and by combining them in the concept of the (business) transaction. The new concept of *organisation* that arises from the foregoing is: a network of actors who carry out transactions in cooperation. It is a new way of looking at Mintzberg's basic idea of organisation: the need to divide labour into tasks, and the need to coordinate these tasks [8]. The idea that organisation is somehow the outcome of the social interaction of cooperating human beings, is not new, by the way. Since Max Weber [9], several sociologists have studied this relationship, like, for example, Weick [10]. However, none of them has made the idea as operational as the CIAO Paradigm does.

Having this new understanding of organisation, a new and more appropriate understanding of information system emerges. It appears that every information system in an organisation can appropriately be conceived as some implementation of some part of the organisation. This view emphasises the being intrinsically intertwined of informations systems and their supported organisations. It also clarifies why information system engineers should first of all study the construction and operation of the organisation before designing the information system. Basically, the information system is already there, because it is an intrinsic part of the organisation. Consequently, the functional requirements are also already there. The main task of the information system engineer is to find a new way of implementing a particular part of the organisation, in particular by applying ICT.

Although conceiving organisations as networks of actors who carry out transactions, is indifferent to a particular management style or approach, it certainly matches very well with a high degree of self-management, as discussed in [11]. Making decisions at the lowest hierarchical level that is possible, implies that one grants a high degree of autonomy to the employees on that level.

4.3 Overview of the EE Theories

Paraphrasing Einstein's quote above, the EE theories are the mental glasses through which enterprise engineers observe and understand enterprises, and seek to make sense of them. In addition, the EE theories are the roots of the methods for improving enterprises, as illustrated in Fig. 4.1.

Table 4.1 The current EE theories

Φ-theory	FI theory	EE information theory
M-theory	MU theory	EE model theory
T-theory	TAO theory	EE function-construction theory
Ψ-theory	PSI theory	EE organisational operation theory
Δ-theory	DELTA theory	EE system theory
Ω-theory	OMEGA theory	EE organisational construction theory
A-theory	ALPHA theory	EE organisational essence theory
B-theory	BETA theory	EE organisational design theory
I-theory	IOTA theory	EE organisational implementation theory
N-theory	NU theory	EE normalisation theory
Σ-theory	SIGMA theory	EE governance & management theory

The presently identified EE theories are listed in Table 4.1. Next to the Greek letter that serves as the primary identifier, their alternative names and EE references are mentioned. All theories are classified in the EE Framework of Theories (Fig. 4.5), which is an adapted version of the framework that was introduced in [1]. Four categories are distinguished: philosophical, ontological, technological, and ideological. The structure of Fig. 4.5 must be understood as follows. The philosophical theories underlie all other theories. On top of that, the ontological theories underlie both the technological theories and the ideological ones. The latter two categories do not have specific interrelationships. The classification of the theories in the framework is, to some extent, disputable, because they do not always fit in exactly one category. However, the presented classification seems to do justice to their main character.

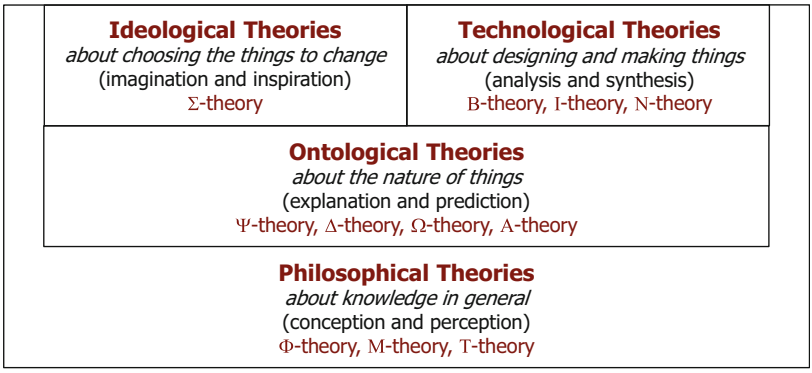

Fig. 4.5 The EE theories in the EE framework of theories

Philosophical theories concern the most fundamental ways in which people perceive and conceive the surrounding world, make sense of it, study it, etc. They are about knowledge in general, and therefore include, for example, epistemology, phenomenology, and logic. Philosophical theories are justified by their *truthfulness*. The truthfulness of a theory is established by reasoning or by judging its tenability in the face of reality.

Ontological theories are about the nature of things. They serve to explain their construction and operation, and predict the consequences of changing them, while completely abstracting from implementation. In EE, the things are organisations. Ontological theories are justified by their *soundness* and *appropriateness*. The soundness of an ontological theory is established by its being rooted in sound philosophical theories. The appropriateness of an ontological theory is established by the evaluation of its practical application, for example, through expert judgements.

Technological[6] theories are about designing and building things, and about putting them into operation. Generally spoken, they assist in analysing and synthesising things. Technological theories are justified by their *rigor* and *relevance*. The rigor of a technological theory is established by its being rooted in sound ontological and ideological theories. The relevance of a technological theory is established by the evaluation of its practical application, e.g., through measurements, evaluative comparisons, and adoption studies.

Ideological theories are not about things themselves, but about the context in which one decides on whether to make or change them. In EE, they serve to feed the imagination of people and to assist them in inspiring other people to adopt new, better ideas for running enterprises. Ideological theories cannot a priori be predicated as truthful or as sound and appropriate, nor as rigorous and relevant, even if they are rooted in rigorous and relevant other theories. One can only speak of their societal *significance*. The significance of an ideological theory boils down to the usefulness that is assigned to it by its supporters.

The summaries of the EE theories in Sect. 4.4 are presented in an order that seems to be most logical; one can read them from the first to the last without having to jump forward for explanations.

4.4 Summaries of the EE Theories

4.4.1 The FI Theory

The FI theory or EE information theory (FI stands for *Factual Information*), clarifies how people acquire factual knowledge. Semiotics provides us with the *semiotic triangle* [12], which clarifies the dyadic character of information: it is the inseparable combination of *content* (the communicated thought) and *form* (the sign that signifies the thought). In addition, Semiotics provides us with the *semiotic ladder* [13], in which a distinction is made between the semantics and the pragmatics of thoughts, thereby clarifying that a thought consists of a *proposition* and an *intention*.

[6]Particularly in Information and Communication Technology, the term ‘technology’ has got the meaning of means. We prefer to stick to the original meaning of the word, which stems from its Greek origin: technè (meaning making) and logos (meaning knowing). So technology means knowing how to make.

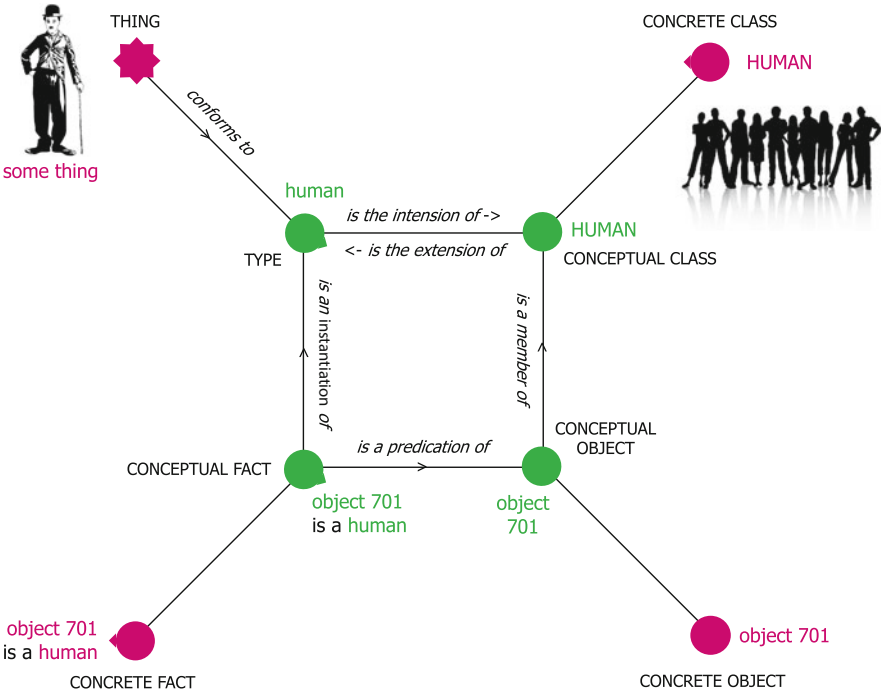

Fig. 4.6 The ontological mill

The core of the FI theory is the *semiotic mill*, refined into the *ontological mill*, which is a generic framework for understanding perception and conception, shown in Fig. 4.6. A *fact* becomes existent in the mind when a perceived concrete thing conforms to (the prescription of form of) a *type*. Therefore, a fact is an *instantiation* of a type. In logical terms, it is a predication of a conceptual object, with the type as the predicate. The conceptual object represents a concrete object that is considered to be the *identity* of a concrete thing. The first is a member of a conceptual class, and the second is a member of a concrete class. Type and class are dyadic notions: a class is the *extension* of a type; conversely, a type is the *intension* of a class.

Because the form of the thing with object 701 conforms to the type human, the conceptual fact is created in the mind that the thing is a human. In addition, factual knowledge can be acquired through communication.

Types can be *declared*, as original new types, but they can also be *derived* from existing types. Three ways of deriving are discussed: specialisation, generalisation, and aggregation. An example of *specialisation* is the definition of the type student as a specialisation of person: a student is a person for whom there is an admission in which the person is the admitted person. An example of *generalisation* is the (extensional) definition of the type vehicle: the class VEHICLE is the set-theoretic

union of the classes CAR, BIKE, SCOOTER, etc. An aggregation of a number of types is (extensionally) defined as the cartesian product of their classes. An example of *aggregation* is the definition of the price of an article as an attribute of the Cartesian product of article kind (e.g. apple), supplier (e.g. GreenShop), and day (e.g. today).

4.4.2 The MU Theory

The MU theory or EE model theory (MU stands for *Model Universe*), is a theory of models and modelling in general, and of conceptual modelling in particular. It adopts Apostel's definition of *model* [14]: Any subject using a system A to obtain knowledge of a system B, is using A as a model of B. This definition conveys the basic understanding of the concept of model as a role concept. The *model triangle*, which is based on the semiotic triangle (cf. Sect. 4.4.1), clarifies how complexes (systems and aggregates) of three major sorts (concrete, conceptual, and symbolic) can be viewed as models of each other. It is exhibited in Fig. 4.7.

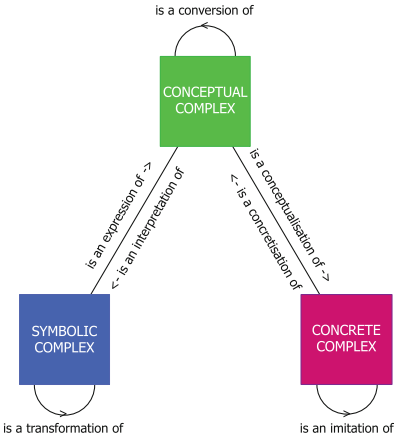

Fig. 4.7 The model triangle

By adding two levels of abstraction (the schema level and the meta level) on top of the conceptual complex or instance 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.

It also makes clear that these notions are logical constructs, and that consequently any expression of them (in a suitable language) is directly transformable to first-order logic. The GCMF is exhibited in Fig. 4.8.

Because the form of the concrete complex conforms to the prescription of form that the conceptual schema represents, the corresponding conceptual complex is created in the mind. For communicating this 'thought', it is expressed in the symbolic formalism of the conceptual schema, yielding the symbolic complex.

In order to specify conceptual complexes, conceptual schemas and meta schemas, the *General Ontology Specification Language* (GOSL) is presented and discussed. The syntax of the language consists of graphical and textual symbols and constructs, as well as a textual part. The latter is an English-like formal language, which means that it is directly transformable to first-order logic, like the graphical part. The split between the two is a rather pragmatic one. Compared to common graphical languages for conceptual modelling, GOSL might be called minimal: it covers only the basic concepts and constructs. More complicated logical formulas can mostly be better expressed in formal textual sentences.

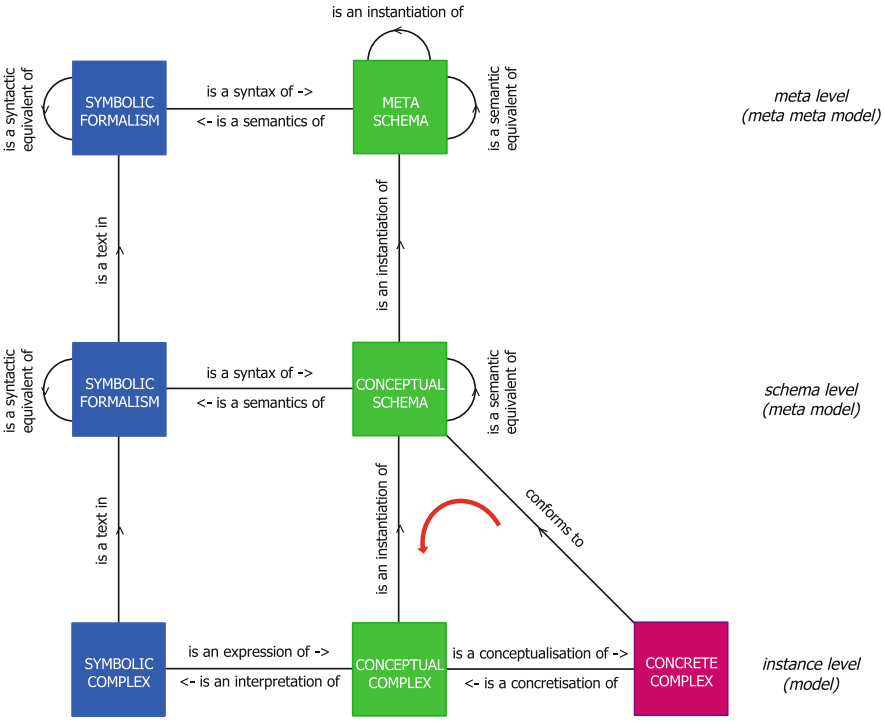

Fig. 4.8 The General Conceptual Modelling Framework

4.4.3 The TAO Theory

EE is an engineering approach to tackling problems in enterprises. By nature, engineers seek to understand the *construction* and *operation* of systems (where operation is defined as the manifestation of the construction in the course of time), in addition to their *functions* and *behaviours* (where a behaviour is defined as the manifestation of a function in the course of time). The TAO theory *(Teleology–Affordances–Ontology)* clarifies the distinction between function and construction. One of the clarifications is that the construction of a system is an inherent property of the system, whereas all of its functions are relationships between the system and stakeholders. Consequently, functions are not properties of systems. The TAO theory builds on Gibson's Theory of Affordances [15]. As Fig. 4.9 illustrates, *affordances* emerge from the perception by subjects (with needs or purposes) of concrete objects (with properties). As an example, if you walk in the woods and feel the need to sit, you may perceive that a tree trunk offers you the sit-on-ability affordance.

In addition to using the affordances that existing things offer, people also create things with particular affordances in mind. These things are commonly called *artefacts,* and their intended affordances *functions*. For example, chairs have the function to be sit-on-able. In addition, one can assign (new) functions to things. For example, one can assign the function of parking lot to a square, for particular days of the week.

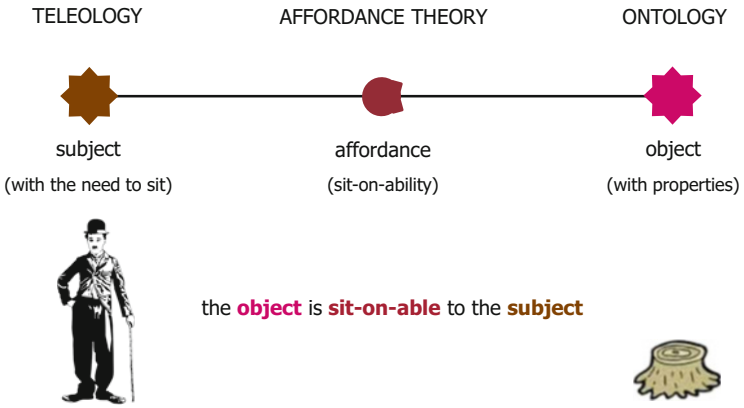

Fig. 4.9 Illustration of the TAO theory

Consequently, a strict distinction is made between the construction and the function perspective on things. In the *construction perspective*, one studies a thing in an objective way, that is, independent of the affordances it may offer. In the *function perspective*, one studies the affordances that a thing may offer to subjects,

while disregarding its construction. So, function (or affordance) is not a property of a thing, but a relationship between the thing and a stakeholder. For example, to people who know to drive, cars do offer relevant functions. This does probably not (directly) hold for the members of an isolated tribe in the jungle of Brazil.

When using the affordances that things can offer them, subjects may have different *experiences*. For example, you may *value* the sit-on-ability of a chair higher than the same affordance offered by a tree trunk. Experiences are basically subjective impressions. However, they may be shared among stakeholders.

Corresponding with the function-construction distinction, two sorts of conceptual models (cf. Sect. 4.4.2) are distinguished: constructional models and functional models. A *constructional model* is a representation of the construction of concrete things, like cars. A *functional model* is a representation of the possible affordances or functions that a concrete thing may offer to someone, for example, the driving function of a car to a (potential) driver. Next, the constructional decomposition and functional decomposition of enterprises are discussed. To distinguish between the two, it is suggested that the term "organisation" be used when referring to the construction perspective, and the term "business" when referring to the function perspective. A decomposition of an enterprise's organisation is a *constructional decomposition*, and a decomposition of its business is a *functional decomposition*.

4.4.4 The PSI Theory

The PSI theory *(Performance in Social Interaction)* serves to study the operational essence of organisations. The word "organisation" indicates that one takes the construction perspective on enterprises. Organisations are systems in the category of social systems (cf. Sect. 4.4.3), which means that the system elements are social individuals, called actors. The operating principle is that actors enter into and comply with commitments towards each other.

An *actor* is defined as a subject (human being) in an actor role. The *actor role* determines the authority that the actor may exercise and the responsibility to do so. Commitments are raised in coordination acts, which are communicative acts in Habermas' category of regulativa (cf. Figs. 4.2 and 4.3). The result of performing a coordination act is the creation of the corresponding coordination fact. For example, performing a request act concerning some product results in the fact that the product is requested.

Coordination acts/facts are the atomic building blocks of organisational (but commonly called: business) processes. They always occur in particular patterns of interaction between subjects who play either the *initiator* role or the *executor* role in the transaction. These patterns are instances of one generic pattern, called the (business) *transaction*. The basic coordination acts in every transaction are the request (by the initiator), the promise (by the executor), the declare (by the executor), and the accept (by the initiator). The complete transaction pattern comprises in

addition, the decline (instead of promise), reject (instead of accept), and a revocation pattern for each of the basic steps. Every transaction (instance) is of a particular *transaction kind*. A transaction kind concerns one specific *product kind* and has one specific actor role as its executor role. The combination of a transaction kind and its executor role is called a *transactor role*. It is the (molecular) building block of organisations.

Based on the semiotic ladder (cf. Sect. 4.4.1), three human abilities are distinguished in performing coordination acts: *forma*, *informa*, and *performa* (cf. Fig. 4.4). This distinction gives rise to three levels of correspondence in the communication between subjects: the forma level (notational correspondence), the informa level (cognitive correspondence), and the performa level (social correspondence), as shown in Fig. 4.10. To be successful, all three conditions of correspondence must be satisfied, that is, the communication must be free of distortion. Below the forma level is the medium level, where forms are inscribed in physical substances and transported between subjects. Although evenly conditional for successful communication, this level is considered to be outside the field of EE, as is the 'inner self' upper level, where a person's wisdom and love reside, which constitute the basis for her/his decisions. He/she is basically autonomous in deciding how to respond to coordination events. At the same time, actors can always be held accountable, by other actors, for the acts that they decide to perform.

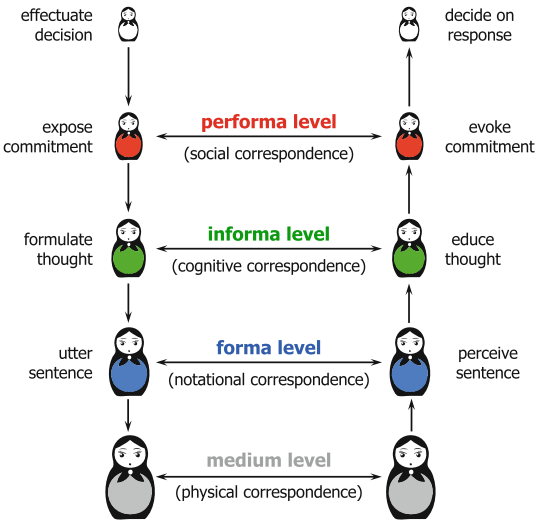

Fig. 4.10 The process of a communicative act

The structure of a coordination act/fact is shown in Fig. 4.2. Examples of intentions are: request, promise, declare, and accept. An example of a product (or production fact) is 'sale 1618 is completed'. As said, coordination acts occur in specific interaction patterns between two participants, called transactions. A transaction is successful if the (final) product is accepted. At that moment, the product starts to exist (comes into being). Figure 4.11 exhibits the complete transaction pattern, which is considered to be the universal pattern in all organisations. It consists of the standard pattern (middle part) and four revocations patterns.

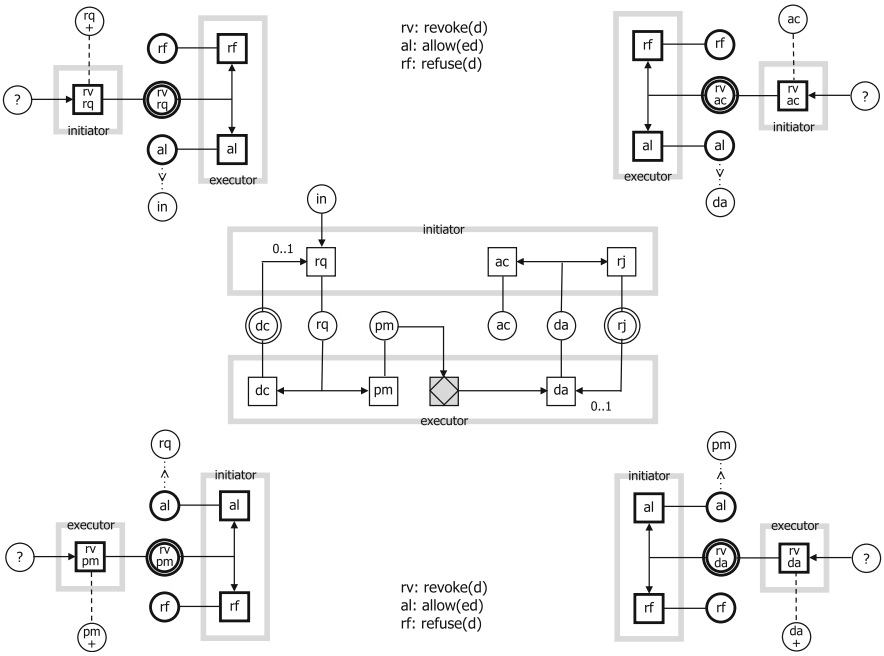

Fig. 4.11 The complete transaction pattern

4.4.5 The DELTA Theory

The DELTA theory or EE system theory (DELTA stands for *Discrete Event in Linear Time Automaton*) is a theory of discrete event systems, both from the construction and from the function perspective (cf. Sect. 4.4.1). According to Weinberg's division of the realm of systems [16], organisations fall in the category of organised complexity: they are too organised for statistics and too complex for (mathematical) analysis. Bunge's system definition [17] is adopted: a (homogeneous) *system* is a triple $(\mathbb{C}, \mathbb{E}, \mathbb{S})$, where $\mathbb{C}$ (composition) is a set of elements of some category, $\mathbb{E}$ (environment) is a set of elements of the same category as the elements in $\mathbb{C}$, and $\mathbb{S}$ (structure) is a set of influencing bonds among the elements in $\mathbb{C}$

and between them and the elements in $\mathbb{E}$. Examples of categories are: physical, biological, and social. Organisations fall in the category of social systems.

Two sorts of conceptual systems are distinguished that may serve as models (cf. Sect. 4.4.2) of concrete systems: the *black-box* system and the *white-box* system. White-box models are suited to study the construction and operation of systems (cf. Sect. 4.4.3). Black-box models are suited to study their functionality and behaviour. Because black-box systems don't have an internal state, the grey-box system is introduced as a black-box system with internal state. Well-known examples of grey-box systems are the finite automaton (or finite state machine) and the discrete event system. For a deep and formal study of grey-box and white-box models, the PRISMA model is introduced. Three ways of mutual influencing between (the elements of) systems are distinguished, called *activating*, *restricting*, and *impeding*. In the PRISMA *grey-box* model, all acts by the system, and their resulting facts, are divided in two kinds: *production acts/facts* and *coordination acts/facts* (cf. Sect. 4.4.4).

The PRISMA grey-box model is defined as a tuple (**P**, **R**, **I**, **S**, **M**, **A**), where:

P is a partial function, called the *performance function*
R is a set of C-fact types, called the *reaction base*
I is a set of C-fact types, called the *impediment base*
S is a set of P-fact types, called the *state base*
M is a set of P-fact types, called the *mutation base*
A is a set of C-fact types, called the *action base*

P is defined as: $\wp((\underline{\mathbf{A}} \cup \underline{\mathbf{I}}) * \mathbb{T}) * \wp(\underline{\mathbf{S}} * \mathbb{T}) \rightarrow \wp(\underline{\mathbf{M}} * \mathbb{D}) * \wp(\underline{\mathbf{R}} * \mathbb{D})$

where $\underline{\mathbf{X}}$ is the union of the extensions of $X \in \underline{\mathbf{X}}$ (X is A, I, M, R, or S); $\mathbb{T}$ is the discrete time scale and $\mathbb{D}$ is the set of (positive) time delays.

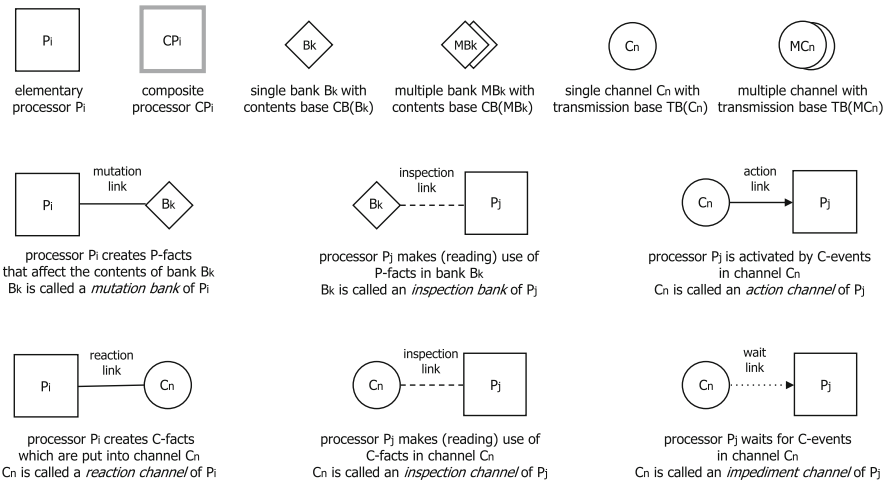

Fig. 4.12 Legend of the prismanet diagram

The PRISMA *white-box* model allows one to conceive systems as *prismanets*: networks of processors, channels, and banks. The complete prismanet model of a system is divided into the construction model and the operation model. The *construction model* of a system is the part that is expressed in the prismanet diagram, whose legend is shown in Fig. 4.12. The meanings of the various links between the basic shapes (box for processors, diamond for banks, and disk for channels) are expressed in an informal way. The *operation model* of a system consists of the action rules that constitute the performance function of the corresponding prisma. They reside in the processor that is the kernel of the prisma. The abstraction that is achieved through the notions of activating, restricting (constituted by inspection links), and impeding makes the prismanet comprehensive: no additional knowledge is needed to get a complete (ontological) understanding of the modelled system. That is why it is called the *essential model* of the system. In addition, prismanets are formalised systems; they can directly be implemented in software.

4.4.6 The OMEGA Theory

The OMEGA theory *(Organisational Modules Emerging from General Arrangements)* clarifies the coordination structures in which transactor roles are connected. Three basic structures are distinguished: interaction, interstriction, and interimpediment.

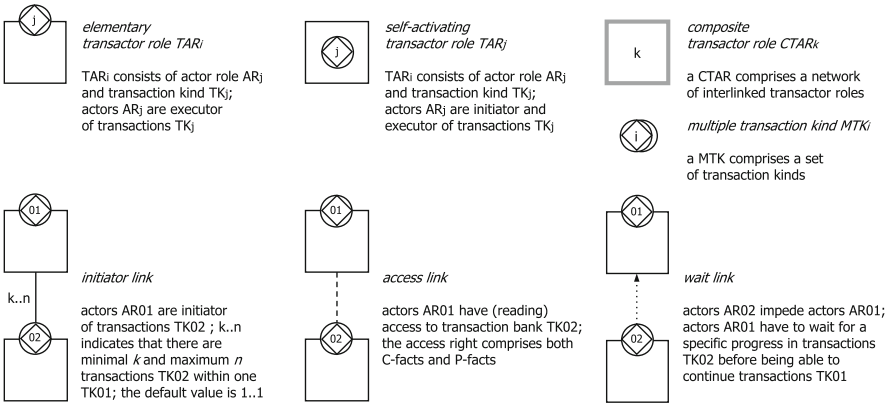

Fig. 4.13 Legend of the Coordination Structure Diagram

The *interaction structure* determines for every transactor role in the organisation which transactor roles are initiator in transactions of the corresponding transaction kind. It appears that the interaction structure of an organisation is always a set of tree structures. Consequently, the transaction kinds at any level of such a tree structure are enclosed in another transaction kind (except the 'root' of the tree) and do have enclosed transaction kinds (except the 'leaves' of the tree). The interaction structure

is the inherent fundamental structure of business processes (which are commonly envisioned as flows, that is, as sequences of events). In addition, it clarifies the responsibility ranges of actors in business processes, and thus notions like process ownership and data ownership.

The *interstriction structure* determines which transactor roles may inspect the history of the transactions of other transaction kinds. These other transaction kinds may be external to the organisation (or Scope of Interest). Actors do inspect the history of transaction processes because they need to take process facts into account when deciding on acts to perform. In this way, actors restrict each other's decision freedom.

The *interimpediment structure* determines whether actors in some actor role have to wait with performing specific acts until other transaction processes have reached a specific state. All three organisational structures are expressed in the *Coordination Structure Diagram* (CSD), of which Fig. 4.13 shows the legend. Figure 4.14 illustrates it, using the GloLog case (cf. Chap. 19) as an example enterprise. The red colour of the diamonds indicates that the transactor roles belong to the O-organisation of the modelled enterprise (cf. Sect. 4.4.7). There are four interaction trees, also called *business process kinds*. The top of the left one is a composite transactor role. The initiator link with TAR01 expresses that it contains a (unknown) transactor role that initiates transactions TK01. The top of the other three structures is a self-activating transactor role. The light-grey colour of some boxes indicates that they belong to the environment of the Scope of Interest (which comprises the white-coloured boxes). Each of the four processes has its own case kind: client order, supply order, ship content and container content, respectively. The evoked structural clashes [18] between them are resolved by the wait links. In addition, there are several inspection links. Figure 4.14 clearly shows the added value of product (tree) thinking in addition to flow thinking. There cannot be one 'seamless' process flow in GloLog. Instead, there are four autonomous processes, with their own process cycle, determined by their case kind. As alluded to in Sect. 4.4.5, no additional knowledge is needed to get a complete (ontological) understanding of the organisation, that is, of the collective business processes, provided that the action rules for the transactor roles are also known. Therefore, this model is called the *essential model* of the organisation.

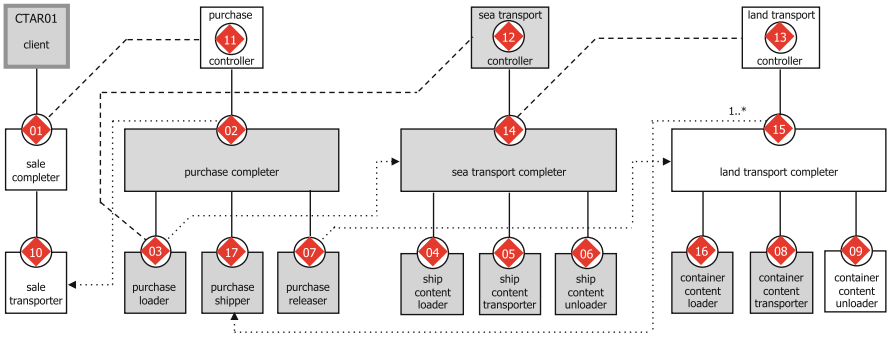

Fig. 4.14 CSD of the GloLog enterprise

There is a second kind of general arrangements, in addition to the ones above. It appears that every organisational structure is composed of a limited number of *reference patterns*, which often resemble legal patterns of action, like the transfer of property and the granting/obtaining of usufructuary rights.

4.4.7 The ALPHA Theory

The ALPHA theory *(Abstraction Layers in Production for Holistic Analysis)* is a theory about tree structures of (trans)actors, in addition to the compositional trees from the OMEGA theory (cf. Sect. 4.4.6). These tree structures occur in three transactor layers, which are based on the distinction of three sorts of production acts: original, informational (or infological), and documental (or datalogical).

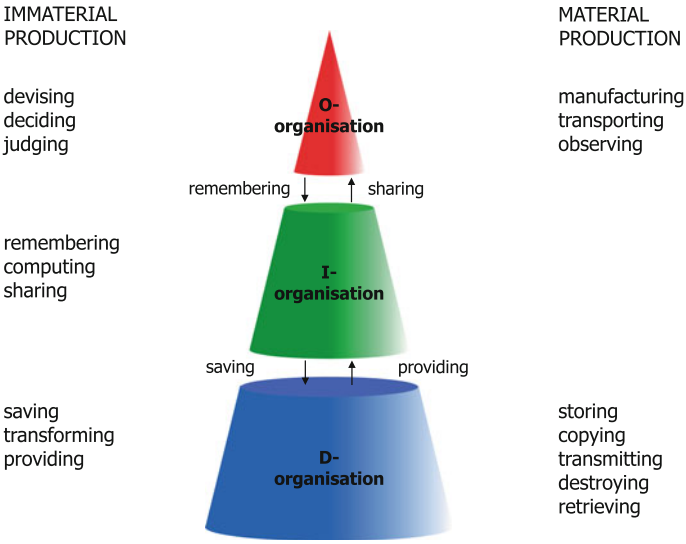

Fig. 4.15 Organisational layers and sorts of production

Original production acts bring about original, new, production facts. Examples are devising things, deciding and judging (all of them having intangible results), as well as manufacturing, transporting, and observing (all of them having tangible results).

Informational production acts comprise remembering facts (in the state of the production or coordination world of an organisation), recalling (remembered) facts, and computing or deriving facts. Computing does not change the state of a world; it only leads to presenting the state in new, possibly more intelligible ways.

Documental production acts concern the signs (or data) that contain facts, as well as the files that carry the data (cf. Sect. 4.4.1). They comprise saving, providing and

transforming (documents or data), and storing, retrieving, copying, transmitting, and destroying (files). Because original acts are the only acts that change the state of the production world of an organisation, they need to be performed by authorised and responsible actors, thus subjects in actor roles. Both informational and documental acts may be taken over by artefacts, notably ICT systems. However, as pointed out in Sect. 4.4.4, human actors are ultimately responsible and accountable.

Corresponding with the distinct sorts of production, the actors in an organisation can be partitioned in three layers: the *O-organisation* (O from original), the *I-organisation* (I from informational), and the *D-organisation* (D from documental). The I-organisation supports the O-organisation by means of informational services (remembering and sharing facts), and the D-organisation supports the I-organisation by means of documental services (saving and providing documents). By the *realisation* of an organisation is understood the devising of the I-organisation and the D-organisation, given its O-organisation (cf. Fig. 4.15). Conversely, abstracting from realisation yields the O-organisation of an enterprise. The additional abstracting from implementation yields the ontological model of the O-organisation, also called the *essential model* of the (total) enterprise (cf. Sect. 4.4.5).

The 'pie chart' in Fig. 4.16 illustrates the difference between material and immaterial production in the O- and the D-organisation (the production in the I-organisation is by definition only immaterial). The adjacency of material original production and material documental production expresses that the exact sort of an act/fact may depend on the point of view taken: sending a letter by postal mail is clearly a material documental act for the sender. Postal mail companies, however, may consider the distinction between original and documental production less interesting. Their business is to transport packages, including envelops, without much regard to their contents.

Fig. 4.16 Organisational layers and sorts of production

4.4.8 The BETA Theory

The BETA theory or EE design theory (BETA stands for *Building from Essence with Technology and Architecture*), is a theory about designing artefacts. Where the ALPHA theory tells one how to abstract from the concrete appearance of a system

(realisation and implementation), the BETA theory guides one in designing a system and in making it concrete. First, Simon's notion of *design* [19] is discussed, understood as devising a situation that is considered preferable to the current situation, as well as Alexander's notion of *design process* [20], understood as a sequence of alternate analysis (of the problem) and synthesis (of a solution) steps. Next, the *General System Development Process* (GSDP) is introduced. It is a general framework for understanding the development of an *object system* for the benefit of a *using system* (cf. Fig. 4.17).

With reference to the TAO theory (cf. Sect. 4.4.3), a clear and sharp distinction is made between the function and the construction of the object system, as well as between the function and the construction of the using system, thereby clarifying that the function of the object system supports the construction of the using system. The three main phases in a development process are function design, construction design, and implementation design. *Function design* starts from the ontological model of the using system, which is commonly arrived at by reverse engineering (cf. Sect. 4.4.7), and ends with the specification of the object system function. There are two inputs: *functional requirements* (determined by the using system construction) and *functional principles* (determined by the applicable architecture). *Construction design* starts from the object system function, and ends with the ontological model of the object system. There are two inputs: *constructional requirements* (determined by the using system construction) and *constructional principles* (determined by the applicable architecture). *Implementation design* (also called *engineering*) starts from the ontology of the object system and ends with the fully detailed specification of a possible implementation, which can subsequently be implemented with appropriate technology. The inputs are both the constructional requirements and the constructional principles.

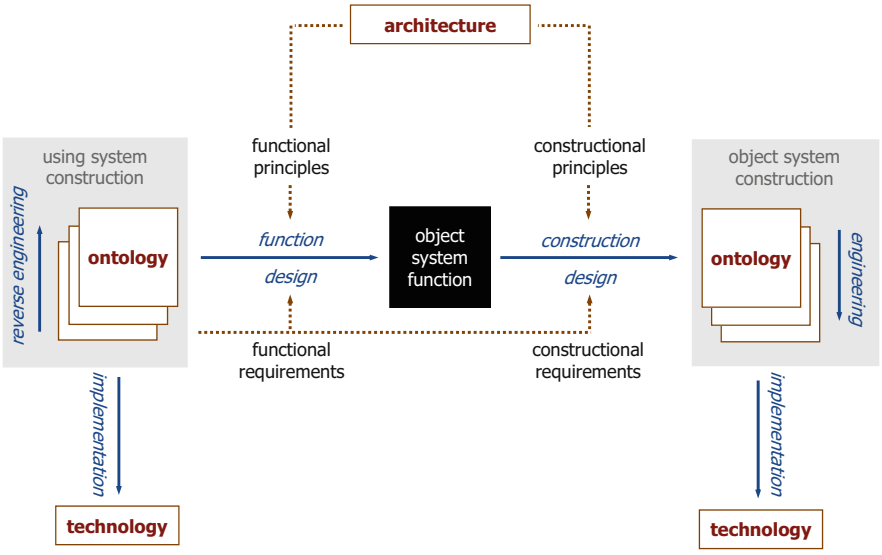

Fig. 4.17 The General System Development Process

A general problem in system development is the (too) large amount of design freedom that is left when all requirements are satisfied. Since time immemorial, the notion of *architecture* helps designers to use this freedom in a purposeful and systematic way. To exemplify this, the Metropolitan Opera in New York, the Sydney Opera House, and the Scala in Milan have the same basic function, namely to offer the facilities that are needed to perform operas. Yet, their appearances are very different. One only has to look at the photos of the respective buildings to see it. Thus, whereas the functional requirements for each of the opera houses are (for the largest part) the same, the applied architectures are quite different.

The *General Requirements and Architecture Framework* (GRAF) is introduced for expressing architecture in practicable design and implementation *principles*, which are basically understood as *generic requirements* that constrain system development in addition to the specific requirements.

4.4.9 The IOTA Theory

The IOTA theory or EE organisational implementation theory (IOTA stands for *Implementing Organisations with Technological Alternatives*), is theory about the implementation of organisations. With reference to Fig. 4.17 (right-hand side), the BETA theory covers the engineering (or implementation design) process, but not the implementation itself. It stops at the implementation model, thus the lowest level construction model of the OS. This is the point where the IOTA theory starts. It guides the enterprise engineer in determining the content of the implementation model, as well as in finding, justifying, and assigning technological alternatives for the actual implementation.

The IOTA theory has yet to be produced. The first steps are taken in [21].

4.4.10 The NU Theory

The NU theory or EE normalisation theory (NU stands for *Normalised Units*), is a theory about the construction of systems. It can best be considered as complementary to the DELTA theory (cf. Sect. 4.4.5). The NU theory is concerned with the evolution of systems. Applying the NU theory in the development (cf. Sect. 4.4.8) of a system results in a modular structure of the system that prevents unwanted side effects when the system undergoes changes.

The NU theory has yet to be produced. A candidate footing is the Normalised Systems Theory [22, 23].

4.4.11 The SIGMA Theory

The SIGMA theory or EE governance & management theory (SIGMA stands for *Socially Inspired Governance and Management Approach*), 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. 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. There is 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 interests with enterprise performance interests. This unitarist perspective rejects any supposedly 'natural' opposition between them. The SIGMA theory is made operational through the notion of meaningful work, which is seen as an affordance (cf. Sect. 4.4.3): 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 organisational 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 radiates. The SIGMA theory is extensively discussed in [24].

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