3. LOGIC SUPPOSES A LINEAR LANGUAGE

This chapter takes some distance from logic considered as *the* a priori basis of our rational thinking. Logic can be understood as an experiential science. After millions of years hunting and gathering we have got some experience with sets. Words name sets and logic detaches their overlaps.

You can summarize similar actions, actors and objects in sets. You can imagine something inbetween or beyond. The human ability to gather more than two objects in one image brings a summarizing or intermediate third within reach. You can imagine, represent and combine them in an intermediate language in order to coordinate actions.

Logic formalizes the art of combining sets with conjunctions, but our capacity for co-action (thinking) includes more. The one-sided fixation on logical *truth* within a linear language limits the view on *possibilities* that are not (yet) true. The ability to design requires more space than the logical space.

§ 10 LOGIC IS LINEAR, LANGUAGE- AND TRUTH BOUND

THE LOGICAL SPACE IS LIMITED TO VERBAL LANGUAGE

If you point to something or someone, and you say a word (eg 'administrator'), then bystanders can nod or shake 'no'. The first means 'true', the other 'not true' ('false'). Each word, referring to an actual object, has such a positive or negative 'truth value' (true or false) in the 'logical space'. The usual logic excludes a third possibility (someway true *and* false) as a 'contradiction'. It is an administrator or it is not an administrator, not both as in 'multivalent logic' (disregarded here).

Symbolic logic uses the symbol '¬' for 'not' and '∧' for 'and'. Words ('variables') or assertions ('propositions') are abbreviated to letters (eg 'a' for 'administrator'). So, a∧¬a ('a and not a') is an inadmissible contradiction. This logical prohibition shows the *linear* limitation of a verbal language such as logic. A perpendicular view on a straight line 'b', may show a point, so b∧¬b. A 2D perpendicular symbol ('⊥') could make that contradiction allowable: b∧⊥¬b.

If you pronounce a second word (for example 'charming') before 'administrator', then that combination (charming administrator) becomes a 'judgment'. The bystanders can agree in one way and not agree in three ways. The logical space then consists of four 'cases': A administrator and charming, B administrator and not charming, C not administrator and charming, D not administrator and not charming. With every new qualification ('predicate') that number of cases doubles.

In the upper left corner of ***Fig. 39*** the logical space of 'a' (for example 'administrator') and 'c' (for example 'charming') is displayed and subdivided into 'a', '¬a', and 'c', '¬c'. They can be true (white) or not true (gray). The expressions $a=f_1(x)$ and $c=f_2(x)$ below mean that the words a and c here are a different name, attribute, or 'operation' f of the *same* object x (the object x that you have designated).[a]

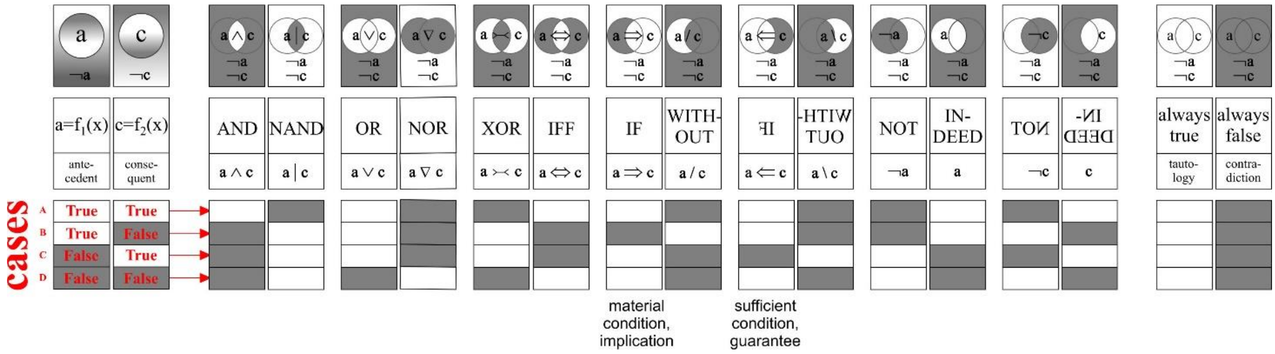


Fig. 39 Truth table

As soon as a and c are linked with conjunctions, their sequence as antecedent (a) and consequent (c) is important. Below, I will further specify the options A, B, C and D that may be 'the case'. Peirce (1883) was the first to design a table of truth values for conjunctions, but Wittgenstein (1918) made it popular.[b] Wittgensteind began with the famous phrase: "The world is all that is the case." The logical space then contains all *possible* cases, even if they are not 'the case'.

If you now put a conjunction between a and c, that *combination* will have its own 'truth value', shown in the top row of ***Fig. 39*** as white (true) and gray (not true) subsets with every combination in their logical space. In the bottom rows they are specified for each case A-D from both a and c true until both false. That creates some surprises.

For example, if a and c are both *false* (case D), a combination such as 'a∇c' ('neither a nor c') still can be *true*. This applies to more conjunctions (the white cells in the bottom row), for example 'if a then c' ('a⇒c'). ***Fig. 39*** thus combines a and c in each of those four cases A, B, C and D with the conjunctions coded in the middle row: 'a and c', 'not a and c', 'a or c', 'a neither c', 'either a, or c', 'a then and only if c', 'if a then c', 'than a if c' and so on.

In each case there are 16 combinations: 8 conjunctions and their denial. For example, 'a⇒c' ('if a, then c', 'a implies c') means the same as ¬a / c ('not a without c').

a Ryle(1949)The concept of mind(Chicago)University Press in his introduction calls it a violation of logical rules if you relate different 'logical types' in an assertion. However, he does not provide rules for that 'category discipline'. Here, I choose one object with different characteristics as an example, so that by definition I keep the same category or type for the object. However, the problem remains with its added attributes ('predicates'). You can not say that something is 'redder than round' (see further § 21 p52).

b Peirce editor(1883)Studies in Logic by the Members of the Johns Hopkins University(Boston)Little, Brown & Co
Wittgenstein(1918)Tractatus logico-philosophicus Logisch-philosophische Abhandlung(Frankfurt am Main 1963)Suhrkamp.
Except both are also called inventors: Dodgon in 1894 (the writer of Alice in Wonderland), Shosky, and Russell in 1912.

The negation of ⇒ is in the next column symbolized as /. Without c, a is not true, but *everything else* is true! That is 'counter-intuitive' (p102). This 'implication' limits a to a certain part of c ('a as far as c') and denies only 'a if not c'.

By contrast, the complete denial "not a" ("¬a") refers to an indefinite remainder (everything except a). 'Not' therefore shows an awareness that there are other possibilities. Designers need such awareness without limits.

PREDICATE LOGIC CORRECTS THE FALSE USE OF CONJUNCTIONS

Charming administrators are administrators *and* they are charming.
The overlapping of the set of all administrators with the set of all that is charming is delineated by the conjunction 'and' ('∧') from the rest (ie no gruff administrators or charming movie stars).

In common language the word 'and' is also used for both sets together (everything that is administrator and charming). A better conjunction is then 'or' ('∨'), if that at least does not have the meaning of exclusive *ór* ('either ... or' '>–<'): 'Do you want jam *ór* cheese on your bread?' (not both). The symbols distinuish them better than words.

Thus, conjunctions are not always used unequivocally, especially when a sentence has more conjunctions. For example: 'Do you want cheese and jam on your bread or cheese and hail and water or milk and if milk then cold or warm?'. With symbols, phrases with a large number of conjunctions can be handled correctly ('valid'). That is particularly important for algorithms with many operations.

If you assign properties ('predicates') to an object with a conjunction ('judgment'), then a contradiction can occur with an imprudent use of conjunctions. "Administrators are charming and not charming" (sentence 1) is such a contradiction, but it may be intended as: "There are charming and there are not charming administrators" (sentence 2).

In order to avoid the contradiction of sentence 1, the word 'and' could be replaced by an exclusive '*ór*' (>–<). That, however, changes the meaning into an assertion that is not precisely meant in sentence 2. Sentence 1 contains a hidden generalizing supposition: 'For all administrators applies: ...'.

Sentence 2 does explicitly *not* generalize by the phrase 'There are…'. That makes it a safe statement. In logic, this distinction is provided by 'quantifier symbols' $\forall x$ ('For all x') and $\exists x$ ('There are x' or 'There is an x'), followed by ':' ('for which applies'). Sentence 1 in symbols now reads: $\forall a: c \land \neg c$ (contradiction) and sentence 2: $(\exists a: c) \land (\exists a: \neg c)$.

PROPOSITION LOGIC COMBINES JUDGEMENTS, PROPOSITIONS

From more separate true statements (propositions) you can sometimes deduce another statement as a conclusion. The 'propositional logic' distinguishes different distractions, such as induction, deduction and abduction (***Fig. 40***).

Induction	Deduction modus ponens	Deduction modus tollens	Abduction
Aadorp, Aagtdorp, … and Zwolle are places in the Netherlands. (∃)	If I am in Delft, then I am in the Netherlands. (D⇒N), well, I am in Delft. (D)	If I am in Delft, then I am in the Netherlands. (D⇒N), well, I am *not* in the Netherlands. (¬N)	If I am in Delft, I am in the Netherlands. (D⇒N), well, I am in the Netherlands. (N)
So: All places are in the Netherlands. (∀)	So: I am in the Netherlands. (N)	So: I am not in Delft. (¬D)	So: I am in Delft. (D)

Fig. 40 Some kinds of reasoning

Induction can not yield a definitive *truth*, but at most a *probability*, how ever many observations you do. The example of ***Fig. 40*** counts 4000 places from Aadorp until Zwolle in The Netherlands, but one observation elsewhere, such as 'London is a place in England' may prove that the conclusion is false.
According to Popper[a], you always have to formulate a scientific conclusion so that everyone can refute it with a counter-example ('falsification'). Any inductive generalizing conclusion is then basically provisional (a 'guess').

The inductive conclusion of ***Fig. 40*** out of the more than 4000 cases proven true ('verifications') shows how a short-sighted generalizing assumption can lead to a wrong conclusion. Nevertheless, induction is generally accepted as a scientific method, albeit under Popper's condition of falsifiability, with sufficient examples for a statistically substantiated conclusion ('reliability') and (except this induction) furthermore a logically sound reasoning ('validity').

Deduction logically leads to a true conclusion when both first statements (the premisses 'major' and 'minor') are true. The most important scientific application of deduction is mathematics with its axioms and definitions as suppositions ('premisses').

Here only two examples of deduction are given: 'modus ponens' and 'modus tollens', but there are more logically valid modes. In this examples, the major takes the form of

a Popper(1934)The logic of Scientific Discovery(London 1983)Hutchinson

'In all cases ... ($\forall$)', the minor 'There is a case for which ... ($\exists$) applies'.
Induction only has observations 'There are cases for which applies ...' ($\exists$).

Abduction is logically not valid, but is applied in practice, for example in case of law:

Major: "If you have raped her, then I can find your DNA on the spot." ($R \Rightarrow DNA$),
Minor: "Well, I found your DNA on the spot." (DNA)

Conclusion: '~~So you raped her~~.'

Fig. 41 An example of abduction

Abduction logically produces no truth, but it does offer a possibility (compare ***Fig. 40***: 'so I am in Delft'). This kind of reasoning may help designers in their search for possibilities ('heuristic value').[a] However, these possibilities are then limited only to the cases that are included in the Major-premise, and that is not an acceptable limitation of possibilities for designers.

AN IMAGE MAY CONTAIN CONTRADICTIONS

Now back to the predicates. 'True' in one direction can be 'false' in another direction. If you judge 'c' ('charming') while looking at an administrator 'a' from the side, then looking from the front I may judge '$\neg$c' ('*not* charming'). That way a line may appear as a point, *not* as a line. A cylinder is round, but from a different angle of view rectangular, *not* round. A bridge is closed and not closed at the same place and time, depending on the direction of approach by road or water.

In many judgements the direction tacitly plays a role. The verbal language supposes one direction by itself, one route in a spatial representation where many routes are possible. With verbal language alone you can not distinguish directions.
You may introduce a change of direction saying "Another approach is ...", but that does not determine the direction. You need an image to do so.

You can of course make a sentence such as 'The bridge is open, but closed perpendicular to the connection'. With 'perpendicular', however, you then forcefully refer to a spatial representation in which directions can be distinguished. I suspect that 'direction' (approach) is supposed in every word, and therefore *must* refer to an image. A verbal language refers; images show. That does not exclude that both can be misleading.

a Dorst (2013) Academic design (Eindhoven) TUE Inaugural speech p5, for example, interprets induction, deduction and abduction as forms of: what!+how?=Solution, what!+how!=Solution, and what?+how!=Solution. The exclamation marks and question marks here have the meaning '!=Determined' or '?=Undetermined'. According to Dorst, in the last form (abduction) the designers also lack the exclamation point for 'how' (what?+how?=Solution). Designing is then the art of questioning both 'what?' and how?' to be answered.
The question is, whether a reference to logical reasoning forms helps or restricts design. In § 12 p48 onwards I will summarize the restrictions.

'IF' SUPPOSES LIMITED ALTERNATIVES BY 'THEN'

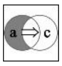
'Not' refers to an unlimited remainder ('*everything* except…'). 'If' refers to limited, determined cases next to or after eachother. The phrase 'If you pick up the other side of the beam, then we can carry it together', presumes the cases of picking up and carrying. The sentence 'If I grind this stone, then I can use it for cutting', presumes the cases of grinding and cutting.

It enables 'intermediate operations' such as making tools in a production process. This is seen in archeology as evidence of earlier human presence. The use of language as an intermediate act is also a 'tool', as well as laughing, looking angry or questioning.

With a series 'If a then b and if b then c', (a⇒b)∧(b⇒c), etc., you can weigh whole lines of argument on their consequences, but you can also weigh alternatives ('scenarios'). The logic immediately concludes a⇒c, but then you may forget a necessary intermediate step b. With (a⇒b)∧((b⇒c)∨(¬b⇒x)) you can create a branch in a tree structure of scenarios. Switches connected in series in a computer ('transistors') also do this, albeit binary ('on' or 'off').

If b='on' ('true'), then the road is open to the next switch c. A bifurcation arises when b 'out' ('false') triggers another switch x (in programming language: 'if b then c *else* x'). You then walk through another branch of the tree. Computer software is seen as an application of logic, but 'true' and 'false' do not play a part. They have been replaced by alternative *actions* c or x. You could call that 'action logic'.

§ 11 'IF' DIFFERS



A NECESSARY CONDITION ('IMPLICATION') IS NOT NECESSARY

The use of 'a⇒c' (in the sense 'as a, then necessarily also c' or 'a' only as a subset of 'c'), does not exclude that another condition x also implies c ('x⇒c'); 'a' does not only have to be a ('necessary') subset of 'c', but also of 'x' (for example if 'c' does not exist). If you take the car (a), you will definitely drive, but if you take the train (x) as well. Maybe there is still another possibility to drive, for example cycling (y).

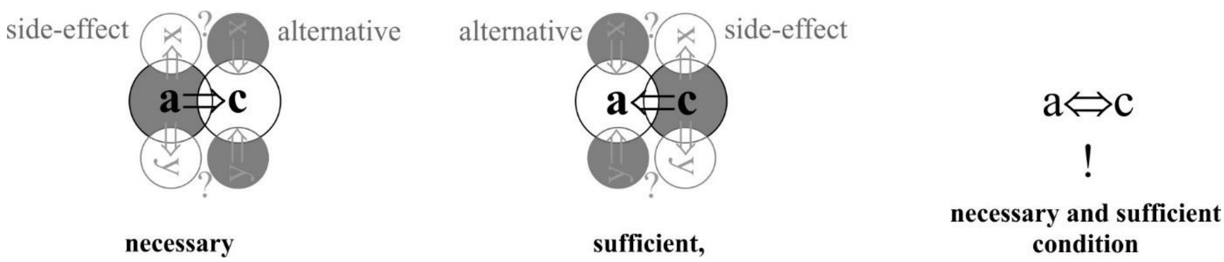
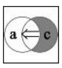


Fig. 42 Different conditions



A SUFFICIENT CONDITION IS NOT SUFFICIENT

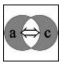
You only take the car 'a', if you have a driver's license 'c' ('a⇐c': then a if c). This does not mean, however, that you will also 'necessarily' will drive a car if you have your driving license ('a⇒c'). The logical arrow does turn around, but the logical sequence of antecedent 'a' from which follows consistently 'c' remains the same. The 'sufficient' condition is therefore not completely a 'reversed' necessary condition.

That backward arrow is called 'sufficient condition', but that is confusing. It is not completely sufficient. If you are going to drive a car (a), you also have to bring your car papers with you (x). The driving license (c) is not 'sufficient'. Perhaps there is still another 'if' (y). For example, you do not have to drink too much alcohol.

'IF…THEN…' DISREGARDS POSSIBLE SIDE EFFECTS

In **Fig. 42** there are two other possibilities that deserve a question mark. Next to 'a⇒c' you can also 'a⇒x?' and 'a⇒y?' to sign unexpected or rare but possible side effects. For example, a driving license can also be used as an identity card.
It can have serious consequences if you do not take a warning triangle with you for the rare possibility of an accident.

You can miss positive opportunities if next to 'a⇐c', you not take also 'x⇐c?' and 'y⇐c?' in consideration. These are the extra possibilities (alternatives) that a designer can find when 'c' is decided once.



A 'NECESSARY AND SUFFICIENT CONDITION' EXPRESSES EQUIVALENCE

With '⇔' ('equivalence') you are rid of that asymmetry, but then 'a' and 'c' say the same 'in other words'. That is not entirely useless. In mathematics '=' is also very useful.

'IF' IN TIME DIFFERS FROM 'IF' IN SPACE

The use of '⇒' in the linear time (onedimensional) differs from the use in space (3D). The causal use of 'If a then c' in time (after a necessarily c)[a] is logically equivalent to the spatially sounding 'a not without c' ('No house without foundation')[b]. That is not causal, but (logically and practically) conditional.

The use in time is linear. It can therefore give a single immediately preceding antecedent 'a' ('monocausal') a consequence 'c', however composed 'a' and 'c' may be itself (for example, a composed 'a': 'A building connected by a street to the rest of the world and in which people live 'and a composed 'c':' a foundation, floors, walls, windows, doors and a roof '). What is the 'cause' of a house?

A temporal 'if…then…' hides a supposition of monocausality

Suppose we read in the newspaper: "The collision was caused by the driver losing control." That sounds very plausible, until an extraterrestrial descends next to us and says: 'Nonsense! A collision is caused by two objects moving towards each other on the same line! ' If he is right, the newspaper is wrong, because if that was not the case,

a Here only one or other sequence in the one-dimensional time is envisaged, regardless of whether you argue passively (causally) (scenario: 'If you let it go, then it falls') or active back (action plan:' As a house, then necessarily first a foundation'). Our ability to reason back is also an indication that we time spatially imagine, if desired, to choose a mirrored sequence for an action plan.

b For example, I like to defend: 'No change without difference' or 'No time without space'. After all, a process must 'take *place*'. I would like to change 'everything changes' (attributed to Herakleitos (-500?) by Plato as 'everything disappears', or 'everything flows',) into 'everything differs'.

there would have been no collision, even though one of the drivers had lost control of the wheel.

But there are other circumstances to think of where one of the drivers loses control over the steering wheel without causing a collision. If the cars had stopped, if the petrol had run out just before the collision, a breakdown in the engine occurred, a gust of wind had blown one of the cars off the course, an earthquake had opened a deep ravine between them, and so on.

If in that sense all conditions for a collision are met, then the last condition added (that the driver loses control over the steering wheel, does not pay attention or wants to commit suicide) is called the 'cause' of the collision. Every 'cause' is a condition that something can happen, but not every condition is also a 'cause'. A negative 'cause of failure', however, is easier to determine if one condition of the many falls away in a process you expected to function normally.

Design supposes more conditions than one cause

Every cause is surrounded by many other conditions that must be fulfilled in order to make something *possible*. The last added condition is often called 'cause' ('the roof made the house'). One 'if ... than' strain is not sufficient for use in the multidimensional space. There are 'vertically' all kinds of preceding roots (conditions) and subsequent branches (consequences): a 'tree of causality', or even a forest full of such trees together opening a rare possibility.

There are always many conditions (side-by-side, 'horizontally') at the same time, each with their own 'vertical' context of trunk and tree structure, in order to make something happen (or make it at least possible). That's what designers, managers and ecologists know about.

A linear language often ignores the other 'side-values' ('c' if 'a', 'p', 'q' and ...) as if they remain the same in all cases ('ceteris paribus'). They are all side streets that disrupt the line of argument. You can then add 'p ... z' as 'sufficient conditions' at 'a' in the logical formula, but how do you know whether this is actually 'sufficient'? Their number is basically infinite.

If you have enough seed, sun, water and minerals, you can grow a tree … if it is not eaten by animals or fungi, cut down, catches fire, and so on. These are all positive (if ... then) and negative (if not…then) conditions that do not yet result in a tree, but make it possible. What else is possible under these conditions? Which unnamed, but easy to realize conditions can I add? What is then possible more? Typical designer language.

LOGIC OVERLOOKS MULTIDIMENSIONAL CONDITIONS OF POSSIBILITY

'If a then c' (a⇒c), and 'then a if c' ('a⇐c') are assertions that can only be true or false. What is true must be possible, but what is possible still does not have to be true. It can be *made* true. True claims concern a small subset of a much larger set of possibilities. These possibilities are largely untrue or highly unlikely (***Fig. 3***, p11), but just that is the field of designers. By definition they are looking for possibilities that are not (yet) true or probable, otherwise they only make copies, reports or prognoses.

Before a possibility is 'made' (realized), you can not say: 'It is true that it is possible', because truth is a subset of possibility just as cows are a subset of animals, and you cannot say 'An animal is a cow' either. You can say, 'It is possible that it is (or becomes) true', just as you can say 'A cow is an animal'. This applies in general (∀ cows: cows⇒animals).

Not for all animals applies 'if animal than cow' (¬∀ animals: animals⇒cows).
In a special case you may still say: 'There is an animal for which applies: 'if this is an animal, then it is a cow' (∃ animal: animal⇒cow). The reverse '∃cow:cow⇒animal' is trivial, because our use of the word supposes itself tacitly '∀cows: cow⇒animal'. That is already decided in the meaning ('semantics') of 'cow'.

MODAL LOGIC MAKES POSSIBILITY SUBORDINATE TO TRUTH

If you are looking for conditions to make something possible, the 'modal logic' offers two new operators (□ and ◊). If a statement 'c' (for example, 'nothing goes faster than the light') must be true in all circumstances, then 'c' is necessarily true ('□c'). An assertion 'c' (for example 'it is freezing') being not true now and here (¬c), can be true in other seasons or parts of the world. It is 'not necessarily untrue' ('¬□¬c'), and therefore 'possibly' true ('◊c'). Possibly 'c' (◊c) is thus defined as ¬□¬c.[a] Impossible c (¬◊c) is therefore 'necessary not c': □¬c.

'In all circumstances' is replaced in modal logic by the even broader 'in all possible worlds[b]'. 'Necessary c' (□c) must then apply in all possible worlds and 'possibly c' (◊c) in some. Every assertion 'c' about an impossible world is itself impossible (¬◊c), and must therefore by definition necessarily not be 'c': '□¬c'. Thus it is possible to limit it by the necessary, everything that *must* be true in all possible worlds.

The modal verb 'must' (the operator □) is of course subject to a wide range of explanations[c], and there is a modal logic for every opinion. A common view is the 'alethic' vision. There are no worlds that do not meet the logic, our idea of 'being' ('metaphysical') and the generally applicable laws of nature. These conditions are also only 'descriptive' in our linear verbal language. In images perhaps there is more possible.

The modal logic includes different systems such as 'K', 'T' and 'D'. System 'K' includes all propositions of propositional logic plus □ and ◊. System 'T' adds that if p is

a Hughes(2005)A new introduction to modal logic(Abington)Routledge p17.

b Introduced by Leibniz(1710)Essais de Théodicée sur la Bonté de Dieu, la liberté de l'homme et l'origine du mal(Amsterdam)Changuio. In order to answer the always pressing question why an infinitely good and almighty Creator has allowed evil into the world (theodic), Leibniz argues that He has chosen the 'best of all possible worlds'. Leibniz also invented the infinitesimal calculus (integrating and differentiating), in other words, the useful handling of infinities in mathematics gave him a reassuring analogy in religion.

c Divers(2002)Possible worlds(Abington)Routledge p4. If possible worlds 'must' be logical (relatable), credible (doxastical), existable (metaphysical), nameable (analytical), knowable (epistemical) or tolerable (deontical), then this requires less or more logical suppositions about the possible in the modal logic. Divers does not mention the condition 'operating' that is presented here as 'practical'.

necessary, p is always true (□p⇒p). From this it can be proven that what is true is at least possible (p⇒◊p, that starts to look like ***Fig. 3*** p11). That is not yet fixed in 'K'. System 'D' adds to 'K' that what is necessary is also possible (□p⇒◊p).

A logical claim, however, can only be true or false. The statement a⇒◊c ('If a is true, then c is possible') then contradicts ***Fig. 3*** p11 (the view that truth is a subset of practical possibilities). If 'possibility' is a modality, then a part, and therefore 'truth', is also a modality. A modal logic that understands 'truth' itself as modality, can not take formal logic as a starting point and must look very different.

This is certainly not to say that logic is useless, but it has its limitations and it is not a priori innate.

§ 12 DESIGN HAS MORE DIMENSIONS THAN THE LOGIC SPACE

TRUTH IMPLIES POSSIBILITY

Modal logic makes possibility subordinate to truth, whereas what is true must surely be possible and that is more than word-bound 'not necessarily not'. Current logic is limited to 'truth values'. It is a linear language that does not involve 'perpendicular' relationships, so that the apparent contradiction (the perpendicularity paradox of ***Fig. 5*** p13) is considered to be inadmissible. Necessarily 'if a then b' also suggests that there is no alternative to b.

The common logic focuses on conjunctions and adjectives (predicates) instead of the central verb (or it had to concern the actionless 'is' that assumes a metaphysical 'being' in assertions, propositions). The 'being true' comes first, the 'making true' is left out of consideration. The assumption that computer programs are always based on this logic is not correct. The command 'if ... then ...' is an action choice without truth value.

Such reductions block design thinking. How to construct an action-oriented modal logic, in which 'truth' itself is a modality, I like to leave to others, but 'practically possible' I can define for the time being as 'what can be realized through action'. That requires a new operator. A non-language-bound, and therefore not assertion-bound, but action-related practical possibility condition, is definitely something else than a truth condition.

I write that 'practical condition' for the time being as c ⇓ a ('c supposes a'). For example ('transitive'): Culture ⇓ Biotics ⇓ Abiotics. 'Makes possible' or 'enables' then gets the symbol ⇑. These operators include the truth-valued implications 'c ⇒ a' or 'a ⇐ c' as 'possibly true', but according to ***Fig. 42*** p39 there are explicitly other alternatives x, y ... instead of 'a' to make 'c' *possible*. Three exercises in the next section should prove the usefulness of ⇓ and ⇑.

That 'c ⇒ a' is the only (or strictly necessary) possibility for c or a is premature. Such a linear 'necessarily true' is frustrating for designers in their search for nonlinear 'perpendicular' possibilities. Unfortunately, this 'necessity' is often assumed as self-evident by 'scientifically trained' advisers and experts.

If a designer wants to present a possibility as feasible, the assertion '∃ possibility: possibility ⇒ truth' is not a solution, because then the truth of that statement should already *include* the possibility (***Fig. 39*** p35). '∃ possibility: possibility ⇐ truth' is also not possible, because that possibility is not (yet) true (realized).

I am here on the slippery path of a 'meta language'. I am talking about the language use of truth and possibility, but in the same language and logic with an appeal to the same words 'truth' or 'necessity'. According to Russell, that can lead to contradictions. However, according to the perpendicular paradox (***Fig. 5*** p13), a meta-language is conceivable as 'perpendicular' to the language discussed. That logical contradiction ('⊥') then only *seems* a contradiction ('paradox').

The common logic does not apply to images or representations that are not covered with words. This is important for designers. 'If ... then ...' is assumed in every design, but the logical implication has a meaning that is inadequate for designers. It is discussed below with three 'exercises'.

The modality of common logic is not desirability or possibility, but 'truth'. What is 'true' is certainly possible, but not everything that is possible is also true. Truth is thus a part of possibility in ***Fig. 3*** p11. Because you can not speak of "truth" without an *assertion* that can be true or false, it is bound to a verbal language. However, words generalise (§ 42 p250). So different images are covered by one word and a word evokes different images in different people.

An assertion is 'true' if this claim corresponds to a reality that can be confirmed or repeated by others. This correspondence passes a considerable number of barriers deserving doubt about verbal communication (p100). If truth can only be expressed in words, then a photograph is not logically 'true'. The claim 'This picture covers reality' may be 'true', but that is a half-truth, because a picture never completely covers reality.

LAYERS OF CONTEXT DO NOT IMPLY (⇒), BUT SUPPOSE (⇓) EACH OTHER

Before there is a design, before there is an *object* to think about (afterwards), there is a *context* making a design possible. I distinguish the following layers of context (with primitive definitions in brackets):

management (administration, steering organizations),
culture (a set of common assumptions and provisions),
economy (livelihood through transport and exchange of goods and services),
technology (development of improbable opportunities),
biotics (a set of cells with local entropy-lowering metabolism) and
physics (abiotic matter with increasing entropy).

They seem to have some conditional stacking (**Fig. 46** p51). Which kind of conditionality is applicable here?

The necessary condition cuts off possibilities

Suppose first: 'management ⇒ culture ⇒ economy ⇒ technology ⇒ biotics ⇒ physics'. This means: 'if management then culture, if culture then economy' and so on. In the first glance I indeed can hardly imagine management without a shared culture ('not without' is the same as '⇒', see **Fig. 39** p35). Management implies after all a collection of shared self-evident assumptions: a language, agreements, a division of tasks, availability of facilities and their rules.

However, a dictatorial management or governance with coercion or death threat does not presume all that. Also a management that withholds information does not share its concealed assumptions in a common culture. And what about the management of robots? So I still can imagine a management without culture.

After that, I can hardly imagine a culture without economy: 'livelihood through transport and exchange of goods and services'. Without that, every culture will go under. Culture is then according to **Fig. 39** necessarily a subset of each economy (culture ⇒ economy).

However, a culture whose livelihood falls away, may fall back in hunting and collecting (perhaps even robbery) with direct individual consumption and thus without economy, but still with a (slightly changed) culture (keeping language, religion, etc). Children also do not have to be part of the exchange of goods and services (labor) by transport for many years. The elderly do so on the scale of the family, for the time being.

This also applies to sick people and families who can not provide for their livelihood. It may be provided outside of them by an economy and a care system on a larger scale keeping a family culture intact. The scale on which you give 'economy' and 'culture' a meaning therefore plays a role. Respecting the scale paradox (**Fig. 6** p14) you cannot change the level of scale in an argument. So I keep reasoning at one level of scale.

This way I can imagine a culture without economy on a family scale. The implication 'management ⇒ culture ⇒ economics' does not apply completely if you keep the same level of scale in the argument. For the following layers of context I can also come up with falsifying examples

The sufficient condition is not sufficient

Then take: 'management ⇐ culture ⇐ economy ⇐ technology ⇐ biotics ⇐ physics'. This means: 'management if culture', 'culture if economy', and so on. That is possible, but not necessarily true. The inverted implication ⇐ therefore is not practical if you want to leave unrealized (untrue) possibilities open to designers. Culture may make management possible, but not necessarily.

If you take 'bringing cups to the kitchen and do the dishes' as a part of 'living by transport and exchange of goods and services', then a family also has a family economy, but it does not necessarily produce a family culture. This applies entirely to hermits, but there are also examples from cultural anthropology, and the question is whether you can speak of 'culture' for example in an ant colony.

An ant colony in any case clearly has a form of 'livelihood through transport and exchange of goods and services'.[a] So I can imagine an economy without culture. In this way I can also come up with 'However ...' examples for the other logical relations in the series (falsifications) where the 'sufficient condition ⇐' does not suffice.

Design requires a practical condition
I prefer 'Management ⇓ culture ⇓ economy ⇓ technology ⇓ biotics ⇓ physics': 'management possible by culture', 'culture possible by economy', and so on. You may exchange 'possible' by 'supposed' (litterally under-stood ⇓) if it concerns the possibility of imagination. In the opposite direction you can use ⇑ ('culture makes management possible'). In a special case (∃) you can still hold '*this* management necessarily implies a culture' (⇒).

These possibility conditionals ⇓ or ⇑ include ⇒ or ⇐, without becoming ⇔. Releasing the necessity from 'if ... then' is a liberation for a designer who seeks possibilities instead of truths or necessities. The tacit, but common assumption of truth and necessity, plays the leading role in every communication. A good designer questions current assumptions and only comes up with something new if some assumptions are omitted or replaced ('reframing').

The question 'can I imagine x without y, but with z?' increases the possibility of imagination.

LAYERS OF OBJECT DO NOT IMPLY (⇒), BUT SUPPOSE (⇓) EACH OTHER
The previous exercise concerned layered characteristics of the design *context*. This exercise involves several layers of the design-*object* (***Fig. 46*** p51).

Each design process gradually gives its design object a content (material which can take on form), a form (a durable and thus recognizable state of dispersion of that content), a structure (a set of separations and connections), functions (operations) and intentions. They suppose each other in this order in one way or another.

A *design process* does not have to follow that sequence itself. There are as many design methods as designers. One starts with the material or the form ('resource-oriented design'), the other with the function or intention ('goal-directed design') and each method then jumps back and forth between all these levels in order to constantly change them into a conditional a close connection (concept), for example: 'does the form meet the function?'. Which conditional connection is that?

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a An exchange of goods and services is not necessarily tied to a culture with valuation, money, agreements and so on. In nature you will find numerous examples where goods and services are exchanged without a trace of what you can call culture in the sense defined here.

The necessary condition is not necessary

Suppose again the logical implication first: content ⇒ form ⇒ structure ⇒ function ⇒ intention.
This is not right. Liquid or gas do not necessarily have a stable shape; there are structureless forms; and so on.

This also applies the more so for the content of our imaginations. They do not have a stable form, a structure, function or intention. In order to 'place' them in the midst of other imaginations, we can *give* them form, a dispersion in an imaginary space considering possible structures.

Cicero[a] sequentially 'placed' the parts of his argument as a memory support in different rooms of an imaginary palace, considered different routes, chose one for his speech and then could remember that walk during his speech.
A designer can even leave rooms empty for the time being, giving them a form without content, without choosing materials, structures, functions or intentions yet.

This may be characteristic of any design skill. A design object does not exist before it is designed. This also applies to its components. Considering different possible combinations of variable components, you can finally choose the best and make a proposal for realization. The realisation itself gets the sequence of necessary conditions indeed: the material must be collected first, then given form, structure and functionality in order to fulfill the original intention.

The sufficient condition misses opportunities

Suppose then the 'sufficient condition': content ⇐ form ⇐ structure ⇐ function ⇐ intention.
This means that a content necessarily exists in so far it has a form, and a form only if it has a structure and so on.
This can not be true for the imagination of a designer

A designer can draw a shape (contour), still without any idea about the structure keeping it in form.
A designer can describe a structure that still may have all kinds of external functions, and so on.
These representations exist only in thought, and that applies to every possibility that has not yet been realized, even if it is not realizable at all.

Truth logic *has* room for what is not true (an indefinite rest), but it is not a tool to explore that rest.
Only when that rest has taken shape, the truth logic offers the right conditional sequence to *realize* it or to determine that the design is not realizable in a given (true) context of conditions. To explore what is not (yet) true, requires a different kind of conditional.

a Cicero(-55)De oratore II 531(Cambridge Mass 1959)Harvard University Press Loeb.Heinemann p465

3 LOGIC SUPPOSES A LINEAR LANGUAGE

You can guess that my preference for design logic again comes down to the use of ⇓.

LEVELS OF SCALE DO NOT HAVE ONE CONDITIONAL SEQUENCE

In both previous exercises the meaning of concepts that I defined as layers and levels turned out to be scale sensitive.
I have already drawn attention to the scale sensitivity of the term 'function' in § 1 p 8.

In ***Fig. 6*** p 14 I demonstrated a reversal of meaning already with a factor 3 scale difference ('scale paradox').
For example, the meaning of 'diversity' at the level of buildings in a street (in a radius of about 30m) is very different from diversity between the streets (in about 100m radius).

In order to find conceptual changes in the layers and levels of what you mention as 'context' or 'object', you must carefully distinguish orders of magnitude that are at most approximately the factor of 3 linear (10 in surface).
For this reason I have used an order of magnitude in the global ('nominal', 'naming') radius R of the context or object in consideration.

With a factor of about 3, a semi-logarithmic series of size orders arises: R = {… 10cm, 30cm, 1m, 3m, 10m ...}.
A 'nominal radius' may be broadly interpreted as lying between the preceding and following value.
Each element from that series can then be added as an index to identical terms (for example function_{30m}, function_{100m}).
With such an index the meaning of every homonymous word is specified.

The question now is whether such a series of size orders also do have a conditional relationship.
In ***Fig. 39*** on p35 is a ⇒ c depicted as sets a and c for which applies 'a only where within c'.
Since 'a' should then be smaller than 'c', you could conclude small. Earlier I also wrote something like economics child ⇒ economy family ⇒ economy caring society.

This assertion only stood if the concept of 'economy' could be interpreted differently by different size orders (micro- meso and macro economics are also different disciplines). If there are fluctuations in the observation of the smallest particles or deviations in the orbit of planets and their moons, physicists also point to the influence of fluctuating fields in a wider environment. Small ⇒ large then leads to an infinitely large universe as a conclusion.
It is also correct with a ⇒ c in ***Fig. 39*** p35, where 'a' is a subset of 'c'.

Can you say for example that 30m does not exist without 100m (30m ⇒ 100m)? For designers, every object that still has to be designed always has a larger context (small ⇒ large), from which a program can be derived for the smaller object. Within this larger context, they also outline their object from large to small, from coarse to fine.

However, the desired effects on the larger context must be fulfilled by the smaller object (large ⇒ small).
Every conscious action reasoning back from the supposedly (if probably desirable) consequences for that larger context (small ⇐ large). The conscious action is then, as it were, at odds with the existing reality and leads to a reverse logic (perpendicular to paradox on p14).

Does that also apply to the 'if ... then' commands for action in a computer program? The computer logic is then a practical action logic. In any case, physics can not ignore the fact that the statistical macroscopic behavior of gases has microscopic mechanical conditions (small ⇐ large). On an even smaller scale (quantum theory), statistics are more effective and on a larger scale mechanics. So in physics the method also changes with the scale.

There is something to be said for both logical conditions (necessary and sufficient), but small and large are certainly not equivalent (⇔). Here too I like the possibility variant ⇓, although a designer has to alternate two directions, two methods: small ⇓ (supposes - but not necessarily -) large for empirical, probable possibilities and small ⇑ (is - although not necessarily - supposed in) large for unlikely possibilities.

LAYERS AND LEVELS SHOULD BE REPRESENTED SPATIALLY STACKED

The truth logic can be represented analogous to sets in the flat plane such as ***Fig. 39*** on p35. In c ⇒ a, 'c' is then only true as a subset of a more comprehensive 'a'. That means that 'c' is necessarily part of 'a'. If 'c' is *possible* by 'a', but not *necessarily* by 'a', then 'c supposes a' (c ⇓ a). It does not necessarily implicate 'a'. The necessity of 'a' decays, but c ⇓ a does not exclude that necessity either.

You may imagine a third dimension as a stacking.[a] In that case c is 'based' on a or it sup-poses 'a' as an action. With this, design gets more space than the necessity-bound inductive (empirical) and deductive science. In the case of the abiotic basis a, as a necessary condition for life phenomena b, which in turn are a necessary condition for culture c, c ⇒ b ⇒ a ('abc-model') certainly applies. They are subsets trapped in the flat plane. Layer b can not be replaced by x, y, etc. (***Fig. 42*** p39).
However, parts can be replaced by technology, design, making more possible than 'c'.

If 'c' is subdivided into management, culture (in the narrow sense), economy and technology (***Fig. 44***), then you can no longer propose them as subsets or necessary implications. After all, we were able to propose management in certain cases without culture, culture without economy and economy without technology. ***Fig. 44*** and ***Fig. 45*** therefore give a spatially constituent picture of the previous exercises in 'layers'.[b]

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a Stolk(2015)Een complex-cognitieve benadering van stedebouwkundig ontwerpen(Delft)Proefschrift TUBk Urbanism p176.
b Because collections in relation to truth conditions are always drawn with smooth lines, I have distinguished the conditions of their likelihood as rectangles, although this is unfortunately not consistent with the symbols for possible (◊) and necessary (□) in modal logic.

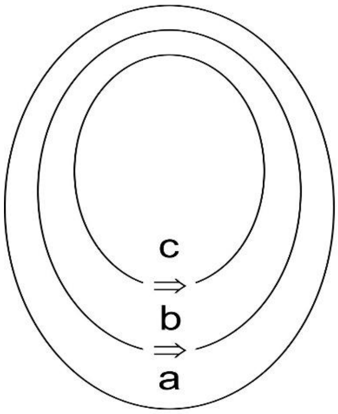

Fig. 43 Necessarily
$c \Rightarrow b \Rightarrow a$

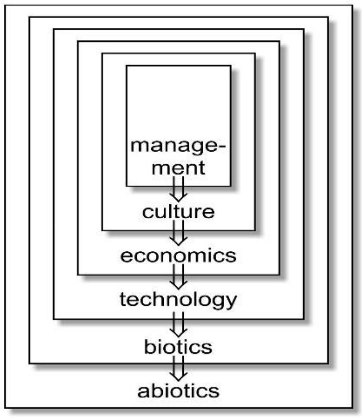

Fig. 44 Contextlayers ⇓

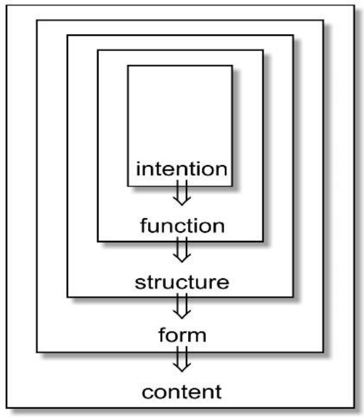

Fig. 45 Objectlayers ⇓