The Memoirs of Faculty of Engineering
Fukuyama University
The 5th issue, March 1983

On A Measurement of Designing And Predicate Logic

by Okinori Taniguchi*

ABSTRACTS

The background of the study is that the ratio of the time spent in the verbal device in design process is 40% and it is indispensable to use a verbal device to fix the image of the form which a designer intends to build. I tried to measure design-thinking to do such activities for the science of design.

Under the hypothesis that we can trace back design-thinking through the form which satisfies requirements and the analysis of the form can be trace back through the analysis of requirements, we can get a certain measure which we may call the measure of synthesis. The means of synthesis is the logical one by Hintikka that if an predicate-logical argument step adds to the number of individuals we are considering in their relation to each other in the premisses, it is synthetic because we cannot be simply analyzing in the conclusion a complex of individuals (things, roughly speaking) which was already being considered in the premiss. This synthetic thinking is the kore of design-thinking, because by design-thinking certain things are introduced into design-situation and soon into the real world through certain activities in practice. So, it is justifiable to call it as the measure of design-thinking.

As the instanciation of this measure, I analyzed 33 requirements in "Community and Privacy (by S. Chermayeff & C. Alexander)" and obtained the magnitude 131. But how to use this measure is left unsaid.

* Department of Architecture

1. INTRODUCTION

If it is justified to say that the communications device itself imposes its inherent structure on what is being communicated, all this is of vital importance to the architect because he spends almost his entire working day in tasks which in general terms may be described under the heading of communications. According to motion studies about activities of architects in design offices, the percentage of time spent in drawings and associated activities is about 34% and that of otherwise activities except miscellaneous (12%) is 54%. The main activities of the latter is discussion and verbal communications (31%).[1] So the verbal communication takes great important part in design activities. Its ratio to non-verbal, namely, drawings activities is 1 to 1. If we take the view of thinking as self-communication, in drawings activities there may be contained much verbal activities because it is necessary to use words for us to fix one's concept and to operate such concepts. And the above ratio may increase in the former. As far as this is concerned it is significant to make close scrutiny about the function of verbal device in design situation and to make use of verbal device in designing.

On the other hand some risk of depending upon the verbal device in the creative work is pointed out. S. Chermayeff & C. Alexander suggested that the words are firmly anchored in the cultures of days gone by and that "Apartments," "row houses," "yard" and etc. are all heavily loaded words that make any number of irrelevant images spring to mind. Nevertheless, in order to get a clear view of the design problem, they say that we must break the problem down into its tiniest, most clearly visible parts and describe these with *words* that are emotionally neutral.[2] (italic is mine)

Broadbent pointed out that if one cannot change a word, then, conversely, one cannot change the concept to which it refers, and that that too is a matter of social contract — the relationship between signifier and signified. Without keeping this contract, it is not possible for a designer to communicate his messages to others.[3]

Furthermore the image which the designer has for the problem solution is fixed by the words and if we name it, we can mention it as if it were a concrete object. This point has been discussed somewhere.[4] And as far as an image is concerned, we have to deal with something possible, namely possible entity which is problematic from the ontological point of view. Here I want to say only one point about possible entity, especially the concept of possibility. According to Hintikka, one cannot usually distinguish effectively between what is 'really' a logically possible world and what merely 'appears' in the face of one's language (or thinking) to be a possibility.[5] This shows that a possibility has to depend upon the language with which we describe the thought, even if we try to purely think logically or that we cannot think of a possibility or possible things detached from the language which we use.

2. MEASUREMENT OF DESIGNING

One of the extreme ends at which the use of the verbal device attains is the measurement of design by various scales such as nominal, ordinal, interval and ratio. But we must be careful to specify the operations which are permissible in each scale in order not to perform 'illegal' operations which is possible only if the scale has the properties of a more rigorous one.[6] I propose the first step to constitute one of scales which measures "designing" or "design thinking". To do so I must make clear and define what is "designing" or "design thinking". This will be done at the next section. Before doing that, it is noticed that the scale must have such character as 1) the results which is obtained in measuring by such scale have some effect on what we design,[7) 2) the scale can apply to all field of architecture such as structural, functional (including the field of the environmental technology), and aesthetic. Of course the aspect of designing in these fields is at issue.

I imagine such a scale as autonomously to measure "designing" or "design thinking" in each field without referring to the value of other accidental field. For example, in practical phase we often takes the value of cost. It is said the smaller cost, the better design, but there must be a hidden criterion which implies the condition that only if the certain quality is equivalent. This certain quality must be made clear. I assume it comes from "designing". This leads to the thought that "designing" is to give some property to objects or put certain objects in certain relations. To explicate the thought in great detail we must make clear "property," "relation" and "object" without referring to the above other fields. This is why the view of predicate logic is introduced. But in order to make concrete the discussion, I refer to the functional field of architecture. This provides the model of the predicate logic to a logician who is interested in the application of logic.

3. METHOD OF ANALYSIS

Following the division of design situation into form and context like S. Chermayeff and C. Alexander, I adopt the devision of form and requirements. And I want to add to them "designing" as follows:

(1) $F = D'(R')$

where D' = designing, R' = requirements which compose contexts of form, F = form which fits to the context which is the set of requirements. Requirements compare to performance-specification by C. Jones.[8)] They imply so-called design conditions which correspond to the brief of Bruce Archer.[9)] The design situation implies all of three phases or stages — conception, realization, communication, or, analysis synthesis, evaluation — which were made clear in the Conference on Design Method in 1962.[10)]

Requirements are satisfied by the form which is the result of design thinking or, conversely, the form must satisfy requirements at issue. If we let mediate the designer, we can say that the designer is given complex of requirements and must consider complex of requirements or think many requirements at the same time. Even if the designer considered a requirements one by one, and made the form to satisfy all of requirements, we can say the designer considered requirements at the same time, or the form satisfies many requirements at the same time. As far as deisgn thinking is concerned, such process is reduced to certain more elementary design thinking. It does not matter whether the designer considers many requirement at the same time or not, but whether he considers many things at the same time. The form is composed of many things. The form is analysed into many things and their relations, and so-called requirements are temporary elements or intermediate units in the analysis of the context. If we want to get a scale to measure "design thinking", we must deal with more elementary units than requirements. This more elementary units is obtained by the logical analysis of requirements namely the conversion of a requirement to a logical formula. If we get such logical formula, then we can get a scale to measure "design thinking" by the function of form and requirements after converting to logical formulas. This is expressed as follows:

(2) $D = f(R, F)$

where D = degree of design thinking, R = requirements converted to a logical formula, F = a designed form which satisfies requirements, f = some function unknown yet.

The logical system which is used here is the predicate logic (or first order functional logic). By the predicate-logical analysis we can say how many individuals (roughly speaking, corresponding to things) are considered at the same time when we think about a requirement. This is detected by the number of nested quantifiers in the logical formula. There are two kinds of quantifier, namely existential quantifier ($\exists$) and universal quantifier ($\forall$). For example, we take the first basic requirement in "Community and Privacy (154p)":

(3) Efficient parking for owners and visitors; adequate maneuver space.

This is converted to the logical formula in the following:

(4) $\forall x \forall z \exists x\ (Ay \wedge Bz \wedge Cx \wedge Dxy \wedge Dxz \wedge \exists w\ (Dw \wedge Exw))$

or if we try to show more clearly nested quantifiers,

(5) $\forall y\ Ay \wedge \forall z Bz \wedge \forall y \forall z \exists x\ (Cx \wedge Dxy \wedge Dxz \wedge \exists w\ (Fw \wedge Exw))$

where small alphabets (x, y, z, w) correspond to individual variables, large alphabets (A, B, C, D, E, F) correspond to predicates — quality (A, B, C, F) and relation (D, E), $\wedge$ = and (in the interpreted systems),[11] (and) = making the division as usual. In (5) the maximal number of nested quantifiers is 4, namely $\forall y \forall z \exists x$ - - - - - $\exists w$. The properties which correspond to predicates are Ay=y is an owner, Bz=z is a visiter, Cx=x is efficient, Dxz=x is the parking for z, Exw=x has w, Fw=w is an adequate maneuver space. In the appendix there are all of 33 basic requirements and their logically converted formulas.

But it is not necessarily possible that all of verbal expression (requirements) are converted to logical furmulae by predicate logic.

For example,

(6) I want to build a white house.

This verbal expression which contains a verb of "propositional attitude" — want — cannot be converted to a logical formula directly, because of its referential opaque character which is pointed out by W. V. Quine.[12] We need some conditions to do so,[13] but this deviates from the predicate logic and we need another kind of logic, for example modal logic. We do not go further in detail here, but at next section some remarks are given.

4. SYNTHESIS OF FORM

It is said that an argument step is analytic if and only if it does not introduce any new individuals into the discussion and/or if an argument step adds to the number of individuals we are considering in their relation to each other in the premisses, it is synthetic because then we cannot be simply analysing in the conclusion a complex of individuals which was already being considered in the premiss.[14] I correspond an argument step to designing or design thinking, the premisses to the first context of the first design situation. This means these two items are not fixed and move with design activities. If requirements are satisfied by the form which is composed by the designer taking into account of each requirement, then the step is synthetic in the logical sense if the maximal number of nested quantifiers in the logical formula of the requirement increases and is analytic, if it does not. But in the designing the matter is slightly different. The premisses are all of the requirements and the conclusion is the designed form which satisfies all of (or most of in practice) requirements. If a new form is designed, it is considered that the new individual is introduced in the design situation. (It may be not the introduction to the real world.) Which requirement is (or must be) first considered by a designer cannot be determined uniquely. So we cannot say each design step to be analytic or not according to the above definition. But as we can descriminate which requirement has the minimal nested quantifiers and which one has the maximal nested quantifiers, we can get the difference of the maximal from the minimal. This suggests that the concept of "synthesis" is adding to the things already existed something new. Of course this rough definition includes many points to be made clear, such as "things", "already existed" and "new". But I want to go ahead leaving these points in order to obtain the whole perspective.

In order to synthesize a form, Chermayeff & Alexander try to make a form (a constructive diagram) which satisfies a subset of requirements without getting a verbal expression which speaks of more individuals at the same time than individuals included in each requirement. I think such expression is the momentaum of synthesis. Without such expression of something taken part of such expression, it is very difficult to synthesize a form. In case of Alexander's figure at 118p.,[15] the lowest subsets (S1, S2), this difficulty does not seem clear, but when we try to construct the diagram for S3, it needs such expression which communicates an image of the form of S3. Speaking of the image is very easy because we are allowed to be indifferent toward the existence of things corresponding to the image. But we need a kind of a verb of propositional attitude in speaking of the image.

There is another case which we need to speak of the image of the whole. In case of codesign, codesigners who take part in the design situation share designing the part of the whole. We cannot design without knowing what we want to make as a whole and which part we are designing.[16] Even if the image of a whole is obscure, it gives the momentam to unify divided elements, I think. To make clear the discussion, I must give the logical concept of "the image" but remain only to suggest that it needs the logical analysis of the concept of possiblity, possible individual and possible world.

5. MEASURE OF DESIGN-THINKING

Here I try to formulate the measure of design thinking. I take as the example, 33 basic requirements in "Community and Privacy". There are various formulations considered. There are logical conversions of these requirements in the appendix. Table–1 shows the number of predicates, the number of maximal places of predicates, the number of different individuals which appear in each logically converted requirement and the maximal number of nested quantifiers in each logical formula.

The formulation of degree of design-thinking includes two steps. One is the formulation for each requirement and another is the formulation for a complex of requirements. Candidates of the first one are 1) the number of individual variables which are included in the logical formula of each requirement, 2) the maximal number of nested quantifiers included in each logical formula of requirement. Hintikka gives as the measure of how many things are considering in their relation to each other in a quantificational (or predicate-logical) sentence "the degree of the sentence H".[17] It is the sum of two numbers: i) the number of the free singular terms of H;

col. 0	col. 1	col. 2	col. 3	col. 4
1	7	2	4	4
2	5	2	3	3
3	18	2	9	3
4	22	3	11	3
5	7	3	3	3
6	9	2	3	2
7	11	2	6	4
8	20	2	11	6
9	11	2	6	6
10	5	2	4	2
11	2	2	2	2
12	6	2	3	2
13	3	2	3	2
14	4	3	3	3
15	8	3	3	3
16	2	2	2	2
17	9	3	6	3
18	3	3	3	3
19	5	2	2	2
20	5	2	2	2
21	4	2	3	2
22	3	3	3	3
23	4	2	3	2
24	4	3	3	3
25	6	3	4	3
26	2	1	2	1
27	12	2	7	6
28	5	3	3	3
29	5	2	2	2
30	6	1	2	1
31	5	2	3	3
32	4	2	3	3
33	4	3	4	3

Table–1 Requirement no. & predicates (col. 1), maximal places of predicates (col. 2), no. of individual variables (col. 3) and no. of nested quantifiers (col. 4)

ii) the maximal number of quantifiers whose scope have a common part in H. He calls the second of its addenda the depth of H and gives the recursive definition of the depth d (H) of H as follows: d (H) = 0 whenever H is atomic (or an identity); d (H1 ∧ H2) = d (H1 ∧ H2) = the greater of the numbers d (H1) and d (H2); d [(∃x) H (x/a)] = d [(∀x) H (x/a)] = d (H) + 1. I want to apply this concept of the "degree of the sentence H" to the measure of design-thinking, namely,

(7) $D(R) = d(R) + S(R)$

where D (R) = degree of design-thinking (of requirements R), d (R) = depth of R, S (R) = the number of singular terms of R. Then the recursive definition gives the measure of design-thinking in case of a complex of requirements, too. The calculation of magnitude of degree of design-thinking is as follows:

(8) $D(R2) = \max(d(R1), d(r2)) + S(r2)$

where $R2 = R1 \wedge r2$, D (R2) = degree of design-thinking of R2, d (R1) = depth of R1, d (r2) = depth of r2, S (r2) = the number of the free singular terms of r2, R2, R1, r2 = requirement-sentences respectively. For example, the degree of the logical formula 1* of the requirement 1 is as follows:

(9) $D(1^*) = d(1^*)$
$= 4$ (from Table–1 col. 4)

If the designer adds requirement 2 to the requirement 1 in considering, then he considers the $1 \wedge 2$. So the degree of such design-thinking is,

(10) $D(1^* \wedge 2^*) = d(1^* \wedge 2^*) + S(2^*)$
$= \max(d(1^*), d(2^*)) + 0$
$= \max(4, 3) + 0$
$= 4$

where $S(2^*) = 0$ because there is no singular terms in 2*. $d(2^*) = 3$ from Table–1. If we attain at the last requirement 33* like this procedure, we obtain as the degree of design-thinking which considers all of 33 requirements, namely,

(11) $D(1^* \wedge 2^* \wedge 3^* \wedge 4^* \wedge \cdots \wedge 33^*) = 6$ (maximum of Table–1 col. 4)

This is a queer result because it does not reflect the general intuition that the more requirement there are, the more difficult it is that the designer considers requirements in their relation to each other and gets a form to fit all of requirements. To improve this result, we must start from again requirements itself, but not their converted logical formula as follows:

(12) $D(C(1 \wedge 2)) = d(C(1 \wedge 2)) + S(C(1 \wedge 2))$

where $C(1 \wedge 2)$ = logical conversion of $1 \wedge 2$ to logical formula. It is noticed that $C(1 \wedge 2) \neq C(1) \wedge C(2)$. In the logical conversion we must take care of the above intuition and then it is reinterpreted that most of individual variables in logical formulae in the appendix comes from the certain logical formula by existential generalization. For example, 1* comes from the next logical formula of 1.[18]

(13) $G: \exists x (Cx \wedge Dxa \wedge Dxb \wedge Exf)$

where a (singular term) = the owner, b (singular term) = the visitor, f (singular term) = the maneuver space, x (individual variable), Cx (one-place predicate) = x is efficient, Dxa (two-places predicate) = x is parking for a, Dxb (two-places predicate) = x is efficient for b, Exf (two-places predicate = x has f. By three times application of existential generalization,

(14) $G1 = \forall w G(w/f) : \forall w \exists x (Cx \wedge Dxa \wedge Dxb \wedge Exw)$
$G2 = \forall z G1(z/b) : \forall z \forall w \exists x (Cx \wedge Dxa \wedge Dxz \wedge Exw)$
$G3 = \forall y G2(y/a) : \forall y \forall z \forall w \exists x (Cx \wedge Dxy \wedge Dxz \wedge Exw)$

Then, the degree of each case is as follows:

(17) $D(G) = d(G) + S(G)$
$= 1 + 3$

$= 4$

(18) $D(G1) = d(G1) + S(G1)$
$= d[(\forall w) G(w/f)] + 2$
$= d(G) + 1 + 2$
$= 1 + 1 + 2$
$= 4$

(19) $D(G2) = d(G2) + S(G2)$
$= d[(\forall z) G1(z/b)] + 1$
$= d(G1) + 1 + 1$
$= 2 + 1 + 1$
$= 4$

(20) $D(G3) = d(G3) + S(G3)$
$= d[(\forall y) G2(y/a) + 0$
$= d(G2) + 1 + 0$
$= 4$

Adding 2 to 1, C (1 ∧ 2) must be as follows:

(21) $H : \exists x (Cx \wedge Dxa \wedge Dxb \wedge Exf) \wedge \exists u (Aue \wedge Aug \wedge Bu)$

where *e* (singular term) = the service man, *g* (singular term) = the delivery man, u (individual variable), A*ue* (two-places predicates) = u is parking for *e*, A*ug* (two-places predicates) = u is parking for *g*, Bu (one-place predicates) = u is temporary. Then, the conversion proceeds as follows:

(22) $H1 = \forall w H(w/f)$

(23) $H2 = \forall z H1(z/b)$

(24) $H3 = \forall y H2(y/a)$

(25) $H4 = \forall v H3(v/e)$

(26) $H5 = \forall t H4(t/g) : \forall t (\forall v (\forall y (\forall z (\forall w (\exists x (Cx \wedge Dxy \wedge Dxz \wedge Exw) \wedge \exists u (Auv \wedge Aut \wedge Bu))))))$

Then the degree of each case is as follows:

(27) $D(H) = d(H) + S(H)$
$= 1 + 5$
$= 6$

(28) $D(H1) = d(H1) + S(H1)$
$= d(H) + 1 + 4$
$= 1 + 1 + 4$
$= 6$

(29) $D(H2) = d(H2) + S(H2)$
$= d(H1) + 1 + 3$
$= 2 + 1 + 3$
$= 6$

(30) $D(H3) = d(H3) + S(H3)$
$= d(H2) + 1 + 2$
$= 3 + 1 + 2$
$= 6$

(31) $D(H4) = d(H4) + S(H4)$

$= d(H3) + 1 + 1$
$= 4 + 1 + 1$
$= 6$

(32) $D(H5) = d(H5) + S(H5)$
$= d(H4) + 1 + 0$
$= 5 + 1 + 0$
$= 6$

If we convert $1 \wedge 2$ to slightly different form as follows:

(33) $H' : \exists u \exists x (Cx \wedge Dxa \wedge Dxb \wedge Exf \wedge Aue \wedge Aug \wedge Bu)$

then we obtain $D(H') = D(C'(1 \wedge 2)) = 7$.[19] If we proceed to all of requirements in the same way, we obtain at most,

(34) $D(C'(1 \wedge 2 \wedge 3 \text{----} \wedge 33)) = 131$

This is equal to the sum of the column 3 of Table–1. The "at most" means that there may be some overlapping individuals in the column. Now we can say that if we have a form which satisfies all of 33 requirements, the form has 131 synthetic degree or the degree of design-thinking of the form is 131 at most.

FINALLY

This study is a very tentative one. There are many things to be left unsaid. But I think the measure like this can describe or trace back the design process with more precision and objectivity. Especially in design education for school, it may be useful for the measure of student's design capability.

Reference

1) G. Broadbent "Design in Architecture" (pp. 205–6) John Wiley & Son, 1973. There is almost the same result in T. Oota "Architectural Design Method" in 'Special Report of Research Laboratory of Shimizu Construction Co., Ltd.' No. 4, 1970.
2) S. Chermayeff & C. Alexander "Community and Privacy" Penguin Books, 1963.
3) G. Broadbent op. cit. p. 273.
4) O. Taniguchi "Logical Study of Image Realization in Design Process" in 'The Memoirs of the Faculty of Engineering Fukuyama Univ.' the 1st issue, 1979.
5) J. Hintikka "Semantics for Propositional Attitude" (note 10) in 'Reference and Modality' ed. by L. Linsky, Oxford Un. Pr., 1971.
6) G. Broadbent op. cit. p. 292.
7) G. Broadbent op. cit. p. 118.
8) C. Jones "A Method of Systematic Design" (p. 63) in 'Conference on Design Method' ed. by J. C. Jones & D. G. Thornley, Pergamon Pr., 1963.
9) L. B. Archer "Systematic Method for Designers" (p. 54) in 'Design 176', 1963.
10) see 8).
11) A. Church "Mathematical Logic Part I" Princeton Univ. Pr., 1944, Rep. 1965.
12) W. V. Q. "Word and Object" (p. 30) M. I. T. Pr., 1960.
13) see 4).
14) J. Hintikka "An Analysis of Anlyticity" (p. 136, pp. 140–141) in 'Logic, Language-Games and Information' Oxford Un. Pr., 1973.
15) C. Alexander "Notes on the Synthesis of Form" Harvard Uni. Pr. 1964.

16) P. Laurentzen "Normative Logic and Ethics" (p. 102, p. 105, p. 143 in Japanese translation), 1968.
17) op. cit. p. 141.
18) There are many things to have to be said about, singular term, existential generalization and dispensing with singular term. For these points see W. V. Quine "Methods of Logic".
19) This magnitude corresponds to the old depth of C' $(1 \wedge 2)$ in note 33 of Hintikka op. cit., and the number of nested quantifiers in Table–1 col. 4 corresponds to the new depth.

The Appendix: The logical conversion of "Basic Requirements" by S. Chermayeff & C. Alexander

1. Efficient parking for owners and visitors; adequate maneuver space.	1*	$\forall y \forall z \exists x (Ay \wedge Bz \wedge Cx \wedge Dxy \wedge Dxz \wedge \exists w (Fw \wedge Exw))$
2. Temporaty space for service and delivery vehicles.	2*	$\forall x \forall y \exists z (Ax \wedge By \wedge Dzx \wedge Dzy \wedge Cz)$
3. Reception point to group. Sheltered delivery and waiting. Provision for information; mail, parcel, and delivery boxes; and storage of parcel carts.	3*	$\exists x (Ax \wedge \exists y (By \wedge Dy \wedge Kxy) \wedge \exists z (Bz \wedge Ez \wedge Kxz) \wedge \exists w (Kxw \wedge \exists v (Gv \wedge Kwv) \wedge \exists t (Ht \wedge Kwt) \wedge \exists s (Is \wedge Kws) \wedge \exists p (Jp \wedge Kwp) \wedge \exists u (Lu \wedge Fwu)))$
4. Provision of space for maintenance and control of public utilities. Telephone, electricity, main water, sewerage, district heating, gas, air conditioning, incinerators.	4*	$\forall x (Ax \wedge \exists u (Eu \wedge Mxu) \wedge \exists v (Fv \wedge Mxv) \wedge \exists t (Gt \wedge Mxt) \wedge \exists s (Hs \wedge Mxs) \wedge \exists r (Ir \wedge Mxr) \wedge \exists p (Jp \wedge Mxp) \wedge \exists q (Kq \wedge Mxq) \wedge \exists z (Lz \wedge Mxz) \wedge \exists w (Ow \wedge Dw \wedge \exists y (Ny \wedge Byxw \wedge Cyxw)))$
5. Rest and conversation space. Children's play and supervision.	5*	$\forall x (Jx \wedge \exists y (Ky \wedge Dxy \wedge Cxy \wedge \exists z (Ix \wedge Ezy \wedge Fxzy)))$
6. Private entry to dwelling, protected arrival, sheltered standing space, filter against carried dirt.	6*	$\forall x (Ax \wedge Bx \wedge Cx \supset \exists y (Ey \wedge Dyx) \wedge \exists z (Fz \wedge Iz \wedge Gxz \wedge Hz))$
7. Congenial and ample private meeting space; washing facilities; storage for outdoor clothes and portable and wheeled objects.	7*	$\forall x (Dx \wedge Cx \supset Ax \wedge Bx) \wedge \exists y (Ey) \wedge \forall w \forall u \forall v (Hw \wedge Iu \wedge Jv \wedge \exists z (Gzw \wedge Gzu \wedge Gzv))$
8. Filters against smells, viruses, bacteris, dirt. Screens against flying insects, windblown dust, litter, soot, garbage.	8*	$\forall y (By \wedge Az (Cz \wedge \forall w (Dw \wedge \forall u (Eu \wedge \exists x (Mx \wedge Axy \wedge Axz \wedge Axw \wedge Axu))))) \wedge \forall t (Ft \wedge \forall s (Gs \wedge \forall r (Hr \wedge \forall q (Iq \wedge \forall p (Jp \wedge \exists v (Lv \wedge Kvt \wedge Kvs \wedge Kvr \wedge Kvq \wedge Kvp))))$
9. Stops against crawling and climbing insects vermin, reptiles, birds, mammals.	9*	$\forall y (Ay \wedge By \wedge \forall w (Cw \wedge \forall z \wedge Au (Eu \wedge \forall v (Fv \wedge \exists x (Gxy \wedge Gxw \wedge Gxz \wedge Gxu \wedge Gxv)))))$
10. A one-way view of arriving visitors; a one-way visible access space.	10*	$\forall y (Ay \wedge \exists x (Bxy)) \wedge \forall v (Dv \supset \exists w (Evw \wedge Cw))$
11. Access points that can be securely barred.	11*	$\forall x (Ax \wedge \exists y (Byx))$
12. Separation of children and pets from vehicles.	12.*	$\forall x (\forall y (Ax \wedge By \supset Dxy) \wedge \forall z (Az \wedge Cz \supset Dxz))$
13. Separation of moving pedestrians from moving vehicles.	13*	$\forall x (Ax \wedge \forall y (By) \supset \forall y (Cxy))$
14. Protection of drivers during their transition between fast-moving traffic and the pedestrian world.	14*	$\forall x (Bx \wedge \exists y \exists z (Exyz \wedge Cy \wedge Dz))$
15. Arrangements to keep access clear of weather interference: overheating, wind, puddles, ice and snow.	15*	$\forall y \forall z \exists x (Iy \wedge (Hz \wedge (Az \vee Bz \vee Cz \vee Dz \vee Ez)) \wedge Fxyz)$
16. Fire barriers.	16*	$\forall y \exists x (By \wedge Axy)$
17. Clear boundaries within the semi-private domain.	17*	$\forall y \; Az (Cy \wedge Cz \wedge Nyz \supset \exists x (Bx \wedge Axyz)) \wedge \forall u$

Neighbor to neighbor; tenant to management.

$\exists v\,(Du \land Ev \supset \exists x\,(Bx \land Axuv))$

18. Clear boundaries between the semi-private domain and the public domain.

18* $\forall y\, \forall z\, \exists x\,(By \land Cz \supset Axyz)$

19. Maintenance of adequate illumination, and absence of abrupt contrast.

19* $\forall x\,(Bx \supset Ax) \land \exists y\,(Dyx \land Cy \supset Ex))$

20. Control at source of noises produced by servicing trucks, cars, and machinery.

20* $\forall y\,(Dy \land (Ay \lor By \supset Cy) \supset \exists x\,(Exy))$

21. Control at source of noises generated in the communal domain.

21* $\forall y\,(Cy \land \forall z\,(Ayz \land Dz) \supset \exists x\,(Bxy))$

22. Arrangements to protect the dwelling from urban noise.

22* $\forall y\,(By \supset \forall z\,(Cz \land \exists x\,(Axyz)))$

23. Arrangements to reduce urban background noise in the communal pedestrian domain.

23* $\forall y\,(Cy \land \forall z\,(Dz \land Byz) \supset \exists x\,(Axy))$

24. Arrangements to protect the dwelling from local noise.

24* $\forall y\,(Ay \land \forall z\,(Dz \land \exists x\,(Cx \land Bxyz)))$

25. Arrangements to protect outdoor spaces from noise generated in nearby outdoor spaces.

25* $\forall y\,(Fy \land \forall w\,(Ayw \land Ew) \land \forall z\,(Dz \supset \exists x\,(Bxyz)))$

26. Provision for unimpeded vehicular access at peak hours.

26* $\exists x\,(Bx \supset Ax)$

27. Provision for emergency access and escape, fire, ambulance, reconstruction, and repairs.

27* $\forall x\, \forall z\, \forall u\, \forall v\, \forall w\,(\forall y\,(Ixy \land Jxy \land Gy) \land Cz \land Du \land Ev \land Fw \land \exists t\,(Atx \land Atz \land Atu \land Atv \land Atw))$

28. Pedestrian access from automobile to dwelling involving minimum possible distance and fatigue.

28* $\forall y\, \forall z\,(Ay \land Bz \supset \exists x\,(Exyz \land Dx \land Cx))$

29* $\forall x\, \forall y\,(Ax \land Cy \land Dy \land Ey \supset Bxy)$

29. Pedestrian circulation without dangerous or confusing discontinuities in level or direction.

29* $\forall x\, \forall y\,(Ax \land Cy \land Dy \land Ey \supset Bxy)$

30. Safe and pleasant walking and wheeling surfaces.

30* $\forall x\,(Cx \supset Ax \land Bx) \land \forall y\,(Dy \supset Ay \land By)$

31. Garbage collection point enclosed to prevent pollution of environment.

31* $\forall x\,(Bx \land \forall z\,(Dxz \supset \exists y\,(Fy \land Gxy \land Cyz)))$

32. Efficient organization of service intake and distribution.

32* $\forall y\, \forall z\,(Cy \land Dz \supset \exists x\,(Bxy \land Bxz))$

33. Partial weather control between automobile and dwelling.

33* $\forall y\, \forall z\, \forall u\,(Ay \land Bz \land Cuyz \supset \exists x\,(Dxu))$