1 SUMMARY

Measure limitation in architectural design

1.1.1 Framework and research questions

The visual quality of an architectural design is defined as a variation, as a balance between recognition and surprise. As Birkhoff and Bense noted, too much recognition leads to boredom, and an excess of surprise to chaos. When it comes to visual quality, this dissertation’s focus is limited to the size (quantity) of buildings, i.e. to measure, framed to: a variation of sizes that produces tension, while also remaining readable, without falling into chaos or monotony. Readability requires size limitation, tension requires variety in sizes.

The question in this study is whether it is possible to establish measurable criteria for an optimum between the two requirements. In addition to all kinds of solutions for the practical limitations of measuring, such as the use of integers, number and proportion systems were invented, which were seen as the ideal and later (in the 19th century) considered to produce visually attractive measures. The specific question is: do these numbers and systems contribute to a measurable balance and if so, in which way?

1.1.2 Classifying plan descriptions using operating themes

This dissertation uses a limited number of actually existing study objects, buildings in their environment and the reconstruction of an urban area. Actual buildings and urban projects were chosen because architecture cannot be seen separately from its surroundings and a real building programme. These objects let us determine the measures of a building’s aesthetic value, of how people experience a building and its surroundings. To find out what these measures are, the study objects are described systematically.

When describing the spatial effect of the various study objects several themes, surprisingly, kept cropping up. Systematizing these so-called operating themes, i.e. environment, enclosure, skeleton, visor, scale stick, and composition, subsequently gives the descriptions of the study objects greater impact. Where the language fails, due to its linear nature, drawings play a necessary and complementary role. One example of such an operating theme, the scale stick (chanted count), is derived from the well-known yardstick (Fig.1). If it were to only have millimetre markers, a yardstick would be totally unreadable, but by making every fifth marker a little longer, and every tenth marker even longer than that, a yardstick produces a readable scale. In a similar vein, major repetitions in several of the studied buildings make these buildings readable.

1.1.3 Analysis of measures and gradations of perception

Only De Jong’s global scale levels (Emo, Urban extension) were initially taken into account in the analysis of the measures referred to above. Aside from that, a closer look

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1 Jong T M de (2012) Diversifying environments through design TUDelft p.52
2 Birkhoff (1933) Aesthetic Measure (Cambridge, Mass.) Harvard University Press
3 Bense (1954) Aesthetica (Stuttgart) Deutsche Verlags-Anstalt
4 Jong T M de (2012) Diversifying environments through design TUDelft p.52
was taken at the presence of possible systems of measurement such as the Giorgi sequence, Golden Ratio, and Plastic Number. However, by replacing the nominal absolute designations (scale levels of well over factor 3) by dimensionless consecutive limit values (orders of size of well over factor 3), three correlated gradations of perception come about, enabling the establishment of correlations between the analyses and results from this thesis. Systems of measurement seem to address memorable difference and quantity within an order of size. The limitations of the consecutive scale levels with factor 3 can best be combined with a sequence based on the Plastic Number\(^5\) with an ample order of size of nine sizes\(^6\) (Fig.3, to the right).

Based on this combination, three gradations of perception seem pertinent:

- measures are visually equal (< Visual tolerance +/-2%)
- measure difference is visible, but too small to be named or to be remembered (< +/-14% memorable tolerance), 1\(^{st}\) gradation
- measure difference is visible and memorable (+/-14% - 50% memorable tolerance), 2\(^{nd}\) gradation
- measure difference leads to difference in character (> +/-50%), 3\(^{rd}\) gradation
- measures are so unequal that they can only be assessed based on mutual coherence of orders of size.

How gradations of perception work can be demonstrated using basic rectangular shapes. Such a shape is considered a block when the difference between measures stays below 50% (i.e. the ratio between the exterior measures is under 1:3). If the height measure is larger (over 1:3), the shape is considered a bar. If the width measure and the depth measure are larger, we perceive a slab. The turning points of 1:3 and 1:9, which form the neutral centre of a spectrum of basic shapes, play an important role in the abovementioned operating themes.

1.1.4 Systems of measurement arrange measures into orders of size

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\(^5\) Laan H van der (1960) *Le Nombre Plastique* (Leiden) Brill

\(^6\) Ample Order of size (1-9.5), compare, eight measures: Laan H van der (1983) *de architectonische ruimte* (Leiden) Brill p.86
The study objects were selected with a focus on obtaining a set of objects that show varied application (or the exact opposite) of visually-driven systems of measurement. Rather than to provide evidence, for which the number of study objects is simply too small, the idea was to unearth an appropriate analytical method. The analyses show the position of systems of measurement such as the Golden Ratio and the Plastic Number. These systems provide more precise specification of the memorable level, using three and seven measures per order of size respectively. The mutual differences between the ratios of the systems turn out to be small, which in a number of study objects leads to multi-interpretability. The drawings (Fig.3) also show some of the roles of systems of measurement. Between measures 1 and 9, there is only one unit between 1 and 3, while there are five between 3 and 9. And yet, the distance between 1 and 3 (1:3) is visually equal to that between 3 and 9 (1:3). Usually, you then halve the lower numbers and/or use decimals. Systems of measurement based on the Golden Ratio or the Plastic Number (example Fig.3) divide the measures more accurately along orders of size.

1.1.5 Study objects illustrates gradations of perception, orders of size and systems of measurement

Well-known study objects were chosen because their quality is not disputed and to enable the reader to visualise the objects to which the thesis refers. Study objects with above-average regularity are preferred, as these offer the clearest manifestation of the use of specific systems of measurement. The availability of reliable measurement data (including three existing studies by the author) also played a role in the selection of study objects.

| Stonehenge, Wiltshire in its current form (1600 BC) (Ch.3); | Van Nelle factory, Rotterdam (1926-1930) |
| Donjon Valkhof Nijmegen (1450-1500) (Ch.7) | Brinkman and Van der Vlugt (Ch.6) |
| Villa Emo di Fanzolo (1556) Andrea Palladio (Ch.4) | Unité d’Habitation, Marseille (1947-1952) |
| Nijmegen’s Stadsuitleg (1875-1910) (Ch.8) | Le Corbusier (Ch.5) |
| | Vaals Abbey (1961-1992) |
| | Dom Hans van der Laan (Ch.9) |
| | Nijmegen’s Benedenstad (1979-1981) B. Pouderoijen (Ch.10) |

Fig. 4 eight study objects in chronological order

<table>
<thead>
<tr>
<th>Measuring+material</th>
<th>Chanted Counting, Scale Stick</th>
<th>Comparison BI'2 GS PG</th>
<th>Neutral/centre</th>
<th>Uniform/proportional</th>
<th>Variation accord</th>
<th>Matrix of orders of size</th>
<th>Van Der Laan order of size</th>
<th>Gradations of perception</th>
<th>Basic shapes</th>
<th>Giorgi sequence</th>
<th>Models</th>
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Fig. 5 study subjects related to study objects
STONEHENGE was taken as the first study object because it reflects all aspects of measure limitation addressed in this study. The different gradations of perception can be recognised by the different extents to which the stones have been worked. The stones’ position within the whole arrangement is also taken into account, and is considered, by each of the operating themes, sufficiently defined to be able to consider the group of stones architecture. Practical dimensions (int-ext) turn out to be multiples of the same unit (yard), and can be captured in whole numbers (Giorgi). Visually relevant measures (centre-to-centre distances and average basic shapes) turn out to be interpretable using the Van Der Laan sequence. The suitability of Van Der Laan's Plastic Number model is down to low Giorgi numbers 1, 2, 3, 4, 6 corresponding to the PG without margins, as well as to the reduction of rough stones to straight basic shapes.

VILLA EMO The Giorgi sequence divides the measures into identical numbers (= roughly geometrically) across the orders of size, but the number of measures turns out to be too small in practice. Until he gets to the measures of spaces, Palladio uses the Giorgi sequence, albeit that he uses more measures by switching the base. The measures of the entire complex are defined by a constructive pattern (chanted counting), with some optical corrections.

The Golden Ratio proportions in the main building postulated by Fletcher turn out also to be present when using a larger scale (<VT), but these shapes do not make up a consecutive sequence, and the visual relevance of overlapping measures is doubtful. The Plastic Number enables accommodation of all relevant measurements according to their operating themes, but the main measures are tight - also in an optical sense.

STEIN UNITÉ Le Corbusier presents the Modulor as a continuous system of measurement – remarkably, he does so by referring to the octave – but in practice his Modulor series is limited to one set of dwellings, the separate prefab elements and the dimensions of roof structures. He incorporates material thickness and conduit areas by choosing a slightly bigger structure measure (also Golden Ratio). The composition of his vertical city is furthermore based on chanted counting as per the scale stick operating theme. And some main measures are in proportion again as per the Golden Ratio.

VAN NELLE The metric system employed here turns out to produce, due to the multi-stage rounding, roughly the same number of measures per order of size in practice, as in cases where a system of measurement is used. The thresholds repeatedly turn out to be a considerable order of size apart, possibly due to consistently sparing use of one material, i.e. concrete. The outer walls have been designed using chanted counting with windows and parapets.

When comparing the relevant measures using the three systems, a consecutive number of measures match the square root 2 sequence, the Fibonacci sequence, and the Van Der Laan sequence. In the case of the Van Der Laan sequence, the probability of a match is largest with low numbers. For part of the measures, the higher probability of a match is down to whole units (0.5m) plus material.

DONJON Proposed gradations of perception – the visual tolerance and the memorable tolerance - enable assessment of visual relevance of reconstructions: to what extent these must match the disappeared prototype for the difference not to be noticeable. Four models show that differences that exceed the visual tolerance will indeed stand out when placed.

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8 Villa Emo (1556), unchanged
next to each other, while the character of the tower is retained. Differences beyond the minimum memorable tolerance do influence that.

STADSUITLEG The measure limitation of the studied area that results from a wide range of technical and functional requirements that this thesis will not go into, produces a sweeping uniform background, on which extensive variations are subsequently made. As far as its dimensions are concerned, the visual quality is produced not by correspondence to one system of measurement, but by correspondence to visually relevant alternation of measure repetition and measure difference, which is relevant because that alternation keeps in step with discernible orders of size (variation accord\(^{11}\)). A second quality concerns the length/width ratios of fronts and street profiles on the one hand, and vertical, often centre, *fields* and horizontal, often neutral, *fields*. Long *fields* and *strips* are still subdivided into centre or short *fields*.

VAALS This abbey is in fact the only study object that was designed entirely by adhering to one system of measurement (the Plastic Number). The irregularities in this design can be avoided by applying a different Plastic Number formula\(^ {12}\), but a model that uses the Golden Ratio also seems feasible, partly as a consequence of the selection of a multi-interpretable primary proportion (3:8), without affecting the quality of the design with its far-reaching uniformity and proportionality. Orders of size turn out to be slightly broader than the seven measures suggested by Van der Laan himself, consisting of eight measures that fit into the sequence of De Jong's scale levels (1 - 9.5 in 1 - 10).

BENEDENSTAD Despite the numerous practical and programmatic measure limitations, consistent application of the Plastic Number on parcel level still turns out to be possible. The author's project shows a combination of Plastic Number-based measures (Van der Laan sequence) for uniformity and proportionality with chanted counting (*scale stick*). When introducing this operating theme into the actual situation, we do, however, end up with Plastic Number-like margins. Models show that a reasonable approximation can only be made using the Golden Ratio (due to ratio of 6:7).

### 1.1.6 Results and conclusions

This study's central question regarding measurable criteria for visual quality and systems of measurement's contribution to measuring visual quality has produced several new insights.

The referenced gradations of perceptions introduce coherence into the analyses of the different forms of measure repetition and measure difference, roughly by orders of size (a) and more accurately through chanted counting (b) and systems of measurement (c).

a) Measure overviews that were made of most study objects (seven of the eight) show that consecutive orders of size correspond to the identifiable components. These make up a first rough basis for repetition and difference. In the case of the Van Nelle factory, wearers of threshold measures that demarcate the orders of size are defining elements of the composition. In the cases of Unité and Urban Extension that basis has been worked out into a variation accord: alternation of repetition and difference DRDRD… to the rhythm of orders of size. Both study objects won (inter)national acclaim. For the less regular Urban Extension, however, the question arises what maximum degree of alternation would be permitted with such a regular basis, without slipping into chaos. This concerns only one study object of this type. Further research into, among other things, study objects that are

\(^{11}\) Jong T M de (2012) *Diversifying environments through design* TUDelft p.21 p.220

\(^{12}\) Par. 9.4.1
b) In the case of six of the eight study objects, the measure difference is created by chanted counting (scale stick). Basic shapes and/or components are combined to form larger units by repeating them, within a limited order of size up to three basic shapes and/or components, and within a larger order of size up to eight basic shapes and/or components. Also without systems of measurement, these repeated (arithmetical) proportions turn out to be demonstrable in Stonehenge and Emo, and partly also in Unité. What is striking in these study objects is that limitation to eight. Further research into chanted counting will have to show whether this is a coincidence or a general characteristic of variation.

c) Owing to their geometrical properties, systems of measurement facilitate a specific balance between repetition and difference, i.e. uniformity and repetition of proportions. This way they boost recognisability and surprise. In the case of Emo, Unité and the Benedenstad, as well as of Vaals, uniformity and proportionality are directly produced by the system of measurement applied (Giorgi, Modulor, Van Der Laan sequence for part of it, and Van Der Laan sequence for all of it respectively).

Systems of measurement differ from each other in terms of measure difference and number of measures per order of size. In practice, mutual comparison of systems of measurement is hampered by multi-interpretation of common ratios. Aside from that, the most effective system – in the opinion of the author – stays close, according to the Plastic Number, to the Giorgi sequence (Emo) that was (widely) employed during the Renaissance, which often comes down to chanted counting plus material (five study objects), or practical rounding of the metric system (Van Nelle). A possible conclusion to draw from this is that selecting a measure as per or approximating the Plastic Number (maximum number of sizes, minimum memorable difference) is the obvious or desirable option.

Besides direct application of a system of measurement, knowledge thereof gives a designer a certain level of insight into the visually relevant options, and within which boundaries in which gradations of perception. That is how they advance not only the many conditions and requirements with which measures already have to comply in today's design practice, but also conscious handling of measures in a visual sense.