Where, how and why to intensify the city

Applying regression modelling to estimate intensification potentials

Dr. Meta Y. Berghauser PONT[1]; Bardia MASHHOODI[2]; Dena KASRAIAN MOGHADDAM[3]

[1] Assistant professor
Dep. of Urbanism, Faculty of Architecture
Delft University of Technology
P.O.Box 5043, 2600 CR Delft, The Netherlands
+31 15 2789020, m.y.berghauserpont@tudelft.nl (correspondent author)
[2] PhD student
Dep. of Urbanism, Faculty of Architecture
Delft University of Technology
P.O.Box 5043, 2600 CR Delft, The Netherlands
+31 15 2781996, b.mashhoodi@tudelft.nl
[3] Researcher
Dep. of Urbanism, Faculty of Architecture
Delft University of Technology
P.O.Box 5043, 2600 CR Delft, The Netherlands
+31 15 2781996, dkasraian@gmail.com

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Introduction

There is among many researchers and professionals a consensus that compact settlements are more sustainable than sprawl, and that – in the light of the fast growth of megalopolises – denser cities will somehow halt an unsustainable increase of consumption of transport, energy and resources [1] [2]. As a means of reaching this objective, the intensification of new urban development is high on the agenda in urban planning reports [3]. A major part of these strategies for intensification focus on a better use of the existing built-up areas or in other words to 'build the city inwards'.

The suitability and feasibility of intensification within existing urban areas can be studied from various points of view. Most research focuses on the question why and where to intensify from a macro scale perspective [5] [6] [7]. However, the question how to intensify on the micro scale (urban block or parcel) is hardly studied. It is in most cases a practical process of trial and error or a presentation of best practices [8].

The lack of systematic knowledge on micro scale intensification causes a mismatch between the goals set on the macro scale and the accidental design solutions on the micro scale [9]. The decision making thus takes place at two separated scales, often without studying compatibility. Critics posit that to deal with this, instruments are needed to be able to link systematic knowledge on micro scale intensification to the performance of the city or city region as a whole [10] [11] [12]. This paper presents the beginning of the building of such an instrument. The hypothesis is that the effects of urban rules on intensification, can be evaluated by a small set of generic and easily calculable parameters which are describing urban form. Based on that the intensification potential for small areas, but also for a city as a whole can be estimated.

Measurement of urban form and urban rules

To verify the hypothesis and develop a systematic understanding of micro scale intensification, firstly a method is needed to measure urban form from the perspective of density and in such a way that it can make a distinction between various developments with equal building bulk, such as i) high and spacious developments versus ii) low and compact developments. Secondly a set of commonly applied urban rules is needed to measure the intensification potential.

Berghauser Pont and Haupt [13] have shown that only by expressing urban density through a composite of parameters, one can distinction urban form. Spacematrix takes into account three different urban density measures: ground space index (GSI[1]), floor space index (FSI[2]), and road network density (N)[3]. Based on the work of Berghauser Pont and Haupt, five parameters are chosen to measure urban form in this research: FSI, footprint (m^2), block area (m^2), the weighted average width of the streets surrounding an urban block[4], and the geometry of the blocks, expressed with the parameter *narrowness*. This is the ratio of length to width of the *equivalent rectangle*[5] of a block.

To understand the limits of intensification within borders of urban rules, a set of commonly applied regulations in urban design practice is needed. According to Lehnerer [14] the list of rules should be kept as simple and as limited as possible. The rules used for this research are listed in Table 1 and are limited to rules concerning (i) access to sunlight, (ii) privacy, and (iii) construction.

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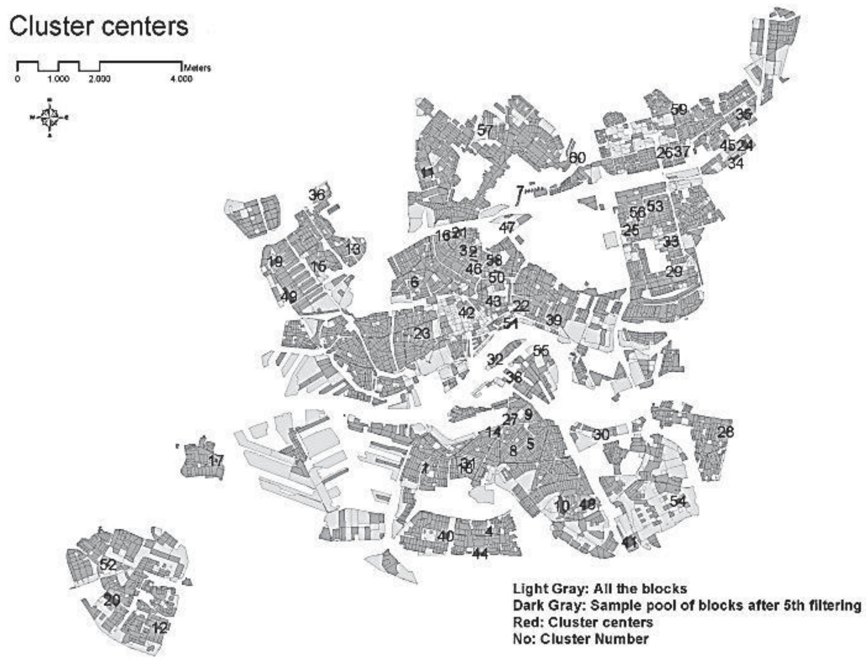
[1] GSI is equal to the sum of footprints in a block divided through the area of that block.
[2] FSI is equal to GSI multiplied by a weighted average of the amount of floors.
[3] For a detailed explanation of Spacematrix and the definition of the various measures, see Berghauser Pont and Haupt [13].
[4] Width is weighted by the length of adjacent side of block.
[5] An equivalent rectangle of a shape is a rectangle with the same area and perimeter as the original shape.

Intensification rules	Adding to the existing	New development
General	Access to sunlight: Angle of obstruction of 45 degrees should be respected at the borders of the block (i.e. maximum height of the building is width of the adjacent street) and also for development inside it.	Access to sunlight: Added new volumes must have access to sunlight from at least two sides, they should be added in a way that the existing volumes keep their access to sunlight from at least two sides as well.
Absolute	Annexation limit: Added width to the existing buildings in form of an offset is at most 5 meters and only possible from one side of the building.	Privacy: Minimum distance between new development and existing is 10 m (This rule is applied incase after the application of 45 degree rule the outcome allows for distances less than 10 m). Access to sunlight: Maximum width of new development is 20 m.
Relative	Construction limit: for buildings with 3 and less layers only one layer could be added on top. For buildings with 4 layers and more 2 layers could be added on top.	–

Table 1: Urban rules

Methodology

The methodology is based on linear regression modelling. The scale reference for this study is the urban block and the city of Rotterdam is used to test the method. To verify the hypothesis, firstly an appropriate sample of urban blocks is selected. In this case sampling is generally dealing with two conflicting ambitions. Firstly, the sample should describe the common types of blocks and not the exceptional ones. Secondly, the sample should represent the variety of common blocks within the city. To do so, a technique of sampling is developed which we call *finding diversity within normality*. In the first step, to guaranty normality, blocks with values of every urban form parameter (independent variables) within the range of 99% of normal values in the city ([Zscore] <= 2.58) are selected. By this 4,029 blocks out of 4,666 are selected. In the second step, to guaranty diversity, K-mean clustering technique is used to split this sample into 60 most distinctive clusters. The size of the sample is based on the amount of dependent variables and by the assumption of a large effect on the independent variable [15]. Finally, 60 urban blocks are selected that represent the cluster centres (Map 1).



Map 1: Sample of 60 urban blocks in Rotterdam

Secondly, the maximum possible intensification is calculated for the 60 sample blocks according to the proposed urban rules (see Figure 1).

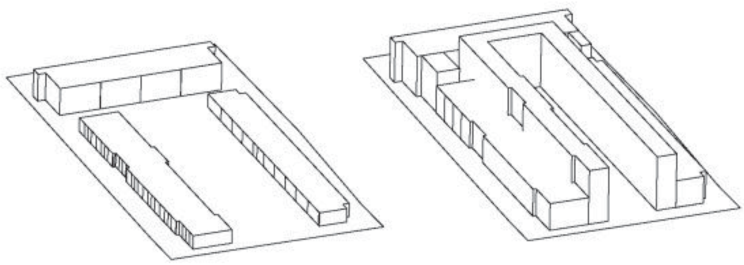


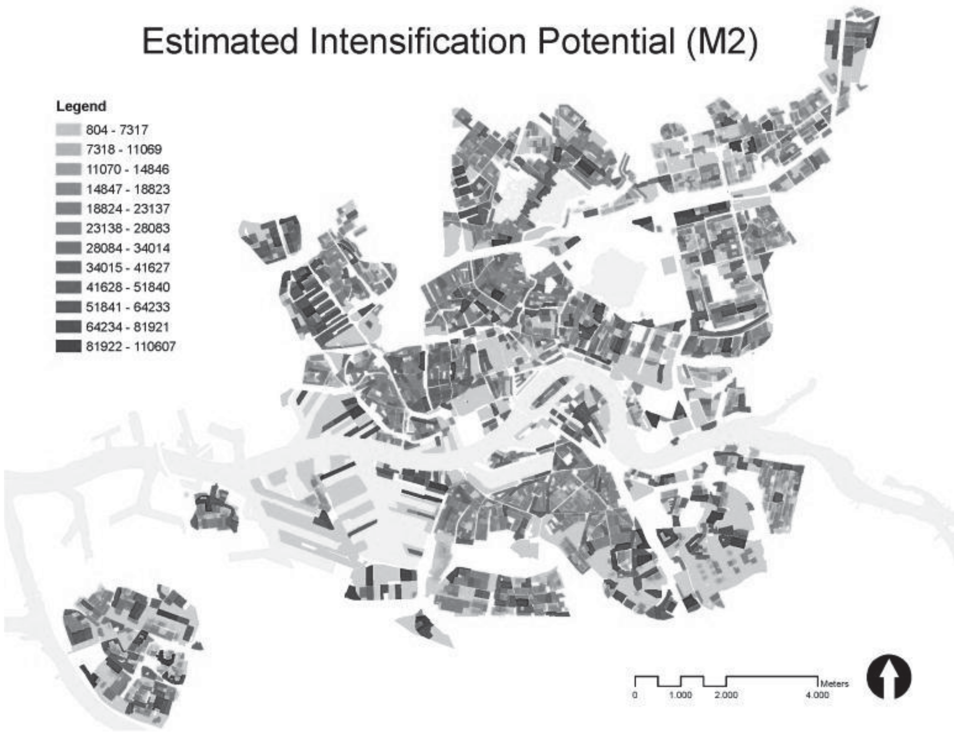
Figure 1: Example of maximum intensification potential (before and after intensification)

Thirdly, regression modelling is used to test the significance of the relation between the dependent variable (amount of intensification per block) and the independent variables (FSI, footprint, block area, weighted average of streets' width, and narrowness).

Conclusions and discussion

The regression model shows a significant relation between the independent variables and the dependent variable within the 60 sample blocks. In other word the five variables (FSI, footprint, block area, weighted average of streets' width, and narrowness) are capable and sufficient to estimate the effects of urban rules on the intensification potential of urban blocks. The regression model is explaining 88.5% of the intensification potential, which is a very high rate. Block area has a positive and most distinctive role, followed by FSI and footprint. Narrowness is the only predictor with negative effect, which can be explained by the limitations set by rules concerning daylight access. Weighted width of streets has a very low positive effect, which can be explained by the limitations set by the construction rules. So most of the time adding floors is limited by the urban rules and not by the width of streets surrounding the blocks.

Based on the results the intensification potential of the city of Rotterdam a s a whole can be estimated. The amount of gross floor area (today about 35 millions m^2) can increase with 140% within the limitation of the proposed urban rules (Map 2). However, this number doesn’t take into account positive effects such as available public transport or negative effects such as a lack of public space. Further research will focus on adjusting this micro-scale potential to such macro scale factors.



Map 2: Estimated intensification potential in Rotterdam

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