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COMBINATION OF SPACE SYNTAX WITH SPACEMATRIX AND THE MIXED USE INDEX. The Rotterdam South test case

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Abstract

At present, there are several spatial analyses tools available for analyzing the spatial properties of the built environment. Spacematrix' focus is on various types of density on the urban block such as FSI, GSI, OSR (or spaciousness), network density (N) and the number of floors (L). The Space Syntax method is dealing with the degree of integration of the mobility network between urban blocks in terms of topological and geometrical distance, combined with metrical radiuses. The Function Mix model's scope is on the degree of mix of functions in terms of dwellings, work places and amenities. The results from these various spatial analyses tools can be correlated with one another and with social-economical data through GIS.

The above-described methods were applied in the southern part of Rotterdam where the municipality wanted to test out various proposals for new bridges to the city's northern (more successful) part. As the analyses from the existing situation show, there is a correlation between the degree of mix of functions, density and integration. The higher local as well as global angular integration on the street net, the higher density in terms of a high degree of FSI as well as GSI at adjacent buildings and the higher mix of functions inside these buildings. As the planners from the municipality acknowledge, these tools contributes to a much more fine-grained strategic planning for the area than current Dutch planning practice does.

1. INTRODUCTION

At present, there are several spatial analyses tools available for analyzing the spatial properties of the built environment. During the last year, a group of researchers at the Urbanism-Lab (U-Lab), Faculty of Architecture, Delft University of Technology (TU-Delft) have combined Space syntax analyses with new methods to measure density (Spacematrix) and function mix (The MXI model). As it turned out, these methods complement each other and contribute to a more comprehensive understanding of the role of the spatial parameters on socio-economic processes in a city. An opportunity was provided through the municipality of Rotterdam for applying these different spatial analyses tools in the southern part of the city. This paper will present the results of the analysis in Rotterdam South.

Rotterdam city is the second largest city in the Netherlands and has the largest port in Europe. It has a population of 611.000 inhabitants, consisting of 169 nationalities. It is known to be a multi-cultural harbour city. The city is divided in a northern and a southern part by the river Nieuwe Maas. The economic centre with new offices and shopping centres are located in the city's northern part, while the southern part consists of several deteriorated neighbourhoods and urban centres.

The city's southern part is lagging behind in terms of investment. Many neighbourhoods have a poor reputation. The unemployment rate in whole Rotterdam is 8.5%, which is twice the national average. Rotterdam South has even higher numbers. Further, some neighbourhoods in Rotterdam South consist of 95% immigrants. The municipality's strategies for Rotterdam South are much in line with the existing national policy documents focussing on supporting the necessary spatial conditions for a sustainable economical development. The aim is to concentrate new development in existing urban areas, and to protect agricultural landscapes from urban sprawl (Nota Ruimte 2006). High diversity of various kinds of functions and cultural activities will contribute to vital lively urban areas and economic growth. This will further support existing public transport systems, make new public transport lines feasible and decrease the growth of car mobility. In the case of Rotterdam South the idea is further that a new bridge between the southern and the northern part (including a new public transport line) will help to upgrade the whole area.

The main questions we tried to answer through the use of Space Syntax, Spacematrix and the MXI model, were:

1. What are the spatial conditions for the most attractive locations for lively and vital urban areas with a balanced mixture of functions? Which areas are more suitable than others to develop into quiet residential neighbourhoods?

2. What are the spatial and functional effects of a new bridge (including public transport) connecting Rotterdam South to North in relation to the first question? How can it affect the functional and spatial potentials for Rotterdam South?

To what extent urban form influences the degree of function mix is one of the core questions in this inquiry. Seemingly, the area's position in the city plays a significant role. Therefore it is worth to investigate how the street and road network plays a role in aggregating function mix in adjacent buildings.

In the next section the three tools used for the analysis are introduced: Spacematrix, Space Syntax, and the MXI model. In the third section the results of the analysis of the current situation in Rotterdam South are presented. This includes a diagnosis of the city based on the spatial and socio-economic analyses. Through the combination of the tools, potentials for different types of interventions are indicated. In section 4 the effects of a new connection between Rotterdam North and South are discussed. In the last section the implications of the use of the tools for strategic planning in general and Rotterdam South in particular are discussed.

2. THE VARIOUS SPATIAL METHODS

2.1 Spacematrix

In Spacematrix, density is defined as a multi-variable phenomenon to be able to relate density and urban form. Most researchers such as Alexander and Forsyth claim that measured density and other physical factors are independent from each other (Alexander 1993, Forsyth 2003). Forsyth even warns for mixing up density and building types (Forsyth 2003). However, density is still a pragmatic necessity in the daily practice of urbanists. The use of a concept with such a large "warning disclaimer" is disturbing. However, it did not prevent urbanists using it in planning practice. During the last 60 years, density has played a significant role in the urban design and planning, but its definition has varied a lot. Unwin used the number of dwellings per acre (or hectare). In Germany the term *Weitraumigkeit* (spaciousness) was introduced in relation to built up density. Le Corbusier introduced high density in terms of high and spacious buildings to give sufficient open green spaces for recreations (Berghauser Pont and Haupt 2010).

The Spacematrix method has contributed to a clarification of the existing Babel-like confusion in the terminology currently being used by urban planners working with urban density. The most important contribution of the Spacematrix method is, besides a clear definition of density, that density can be related to urban form and other performances.

Spacematrix defines density as a multi variable phenomenon and makes a correlation between density and the built mass (urban form). *Spacematrix* uses the following measures: floor space index (FSI), ground space index (GSI), and network density (N). These three measures are represented in a three-dimensional diagram, the Spacematrix. Measures such as open space radio (OSR) or spaciousness, the average number of floors or layers (L) and the size of the urban blocks (w) can be derived from that.

For the purpose of this research Network density is not taken into consideration (but will be added in a forthcoming publication) and we thus work with only one of the three planes in the Spacematrix diagram (see Figure 1). Here FSI on the y-axis gives an indication of the built intensity in an area and GSI on the x-axis reflects the coverage, or compactness, of the development. The OSR and L are gradients that fan out over the diagram. OSR describes the spaciousness (or pressure on the non-built space), and L represents the average number of storeys.

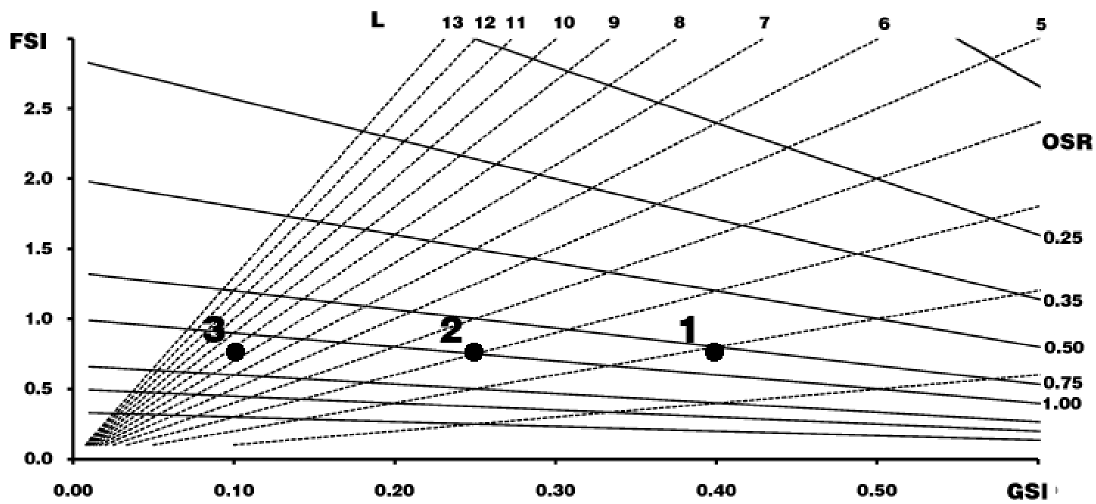

Figure 1 The relationship between GSI, FSI, OSR and L in Spacematrix (positions 1-3 refer to Figure 2) (Berghauser Pont and Haupt 2010).

Figure 2 shows a demonstration of three examples on how different an area can look like with one and the same density of 75 dwelling per hectare. When applying Spacematrix for describing the density of these three examples we get a more accurate description. In all cases the FSI is the same (based on mono-functional areas and 100 m2 per dwelling), but the GSI in the left case is relatively high. In the middle case, GSI is medium, whereas in the right case the GSI is low (Berghauser Pont, Haupt 2008). Figure 1 shows the position of the three examples in the Spacematrix diagram. Although the examples have one and the same FSI, their position in the Spacematrix is different due to the differences in GSI, OSR and L.

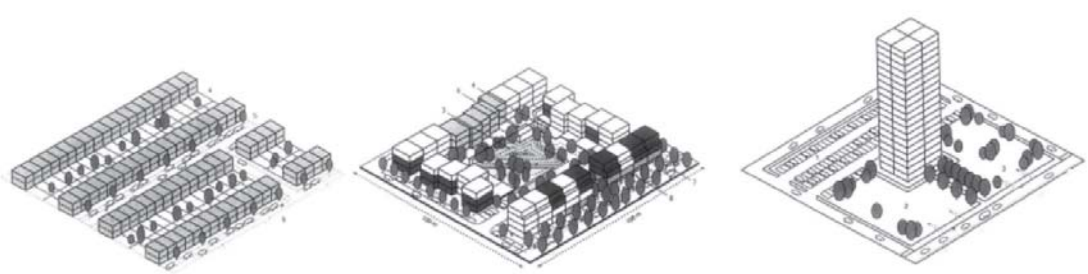

Figure 2 Three different types of urban areas with 75 dwellings per hectare (from left to right, 1-3, see position in Spacematrix in Figure 1).

The variables of Spacematrix used for this research are defined and calculated as follows (on urban fabric level and thus including public streets; for more details see Berghasuer Pont and Haupt 2010):

(1) Floor Space Index (FSI) is calculated as follows:

$FSI_f=F/A_f$

Where F is gross floor area in m2, and A_f is the area of the urban fabric in m2.

(2) Ground Space Index (GSI) is calculated as follows:

$FSI_f=B/A_f$

Where B is the built up surface or building footprint in m2, and A_f is the area of the urban fabric in m2.

The average number number of floors (L) and the open space ratio (OSR) are derived from the basic indicators FSI and GSI and can be calculated as follows:

(3) $L=FSI_f/GSI_f$

(4) $OSR_f=(1–GSI_f)/FSI_f$

The diagram in figure 3 shows, based on empirical samples from various locations in the Netherlands, Berlin (Germany) and Barcelona (Spain), where different types of urban areas are located in the FSI-GSI plane of the Spacematrix (Berghasuer Pont and Haupt 2010). It makes it possible to quantitatively describe the density for different types of urban areas. The areas with both high FSI and GSI are urban areas with mid-rise buildings dominated by perimeter blocks. These areas are marked as a circle with the letter “G”. Conversely, urban areas with both low FSI and GSI (marked as a circle named “A”) tend to consist of low rise single houses with large gardens. Areas with a high FSI but low GSI tend to be areas with high-rise buildings surrounded by large open spaces (marked as a circle named “H”). In particular post-War housing areas inspired by Le Corbusier’s La Ville Radieuse design principles belong under this category. Conversely, urban areas with a high GSI but low FSI (marked as a circle named “D”) tend to be low rise row houses with small gardens, but also industrial areas cluster here.

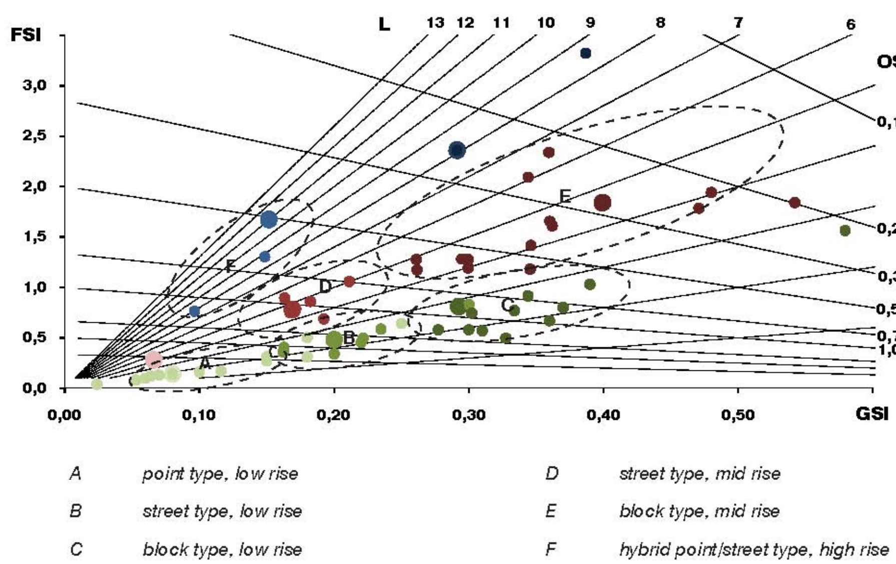

Figure 3 The various types of urban areas in the FSI-GSI plane of the Spacematrix (Berghauser Pont and Haupt 2010).

2.2 Space Syntax

The Space Syntax method is able to calculate the degree of integration of the mobility network between urban blocks in terms of topological and geometrical distance, combined with metrical radiuses. During the last ten years, the angular relationship between street segments has been applied in research. As research has shown, there is a stronger correlation between human movement and the spatial configuration of the street grid in the angular analyses (fewest angular deviations) than in the topological analyses (fewest turns) (Hillier et al 2007).

During the last five years, spatial integration with various metrical radii has been applied into the spatial analyses method. As the first tests shows, the main routes through and between urban areas are highlighted with a high metrical radius, whereas the various local centres in a built environment are highlighted with a low metrical radius. The historical centres in cities, towns and villages tend to be highlighted in the analyses with a low metrical radius (van Nes and Stolk 2011).

2.3 The Function Mix model

The Function Mix model (MXI) is developed by Joost van de Hoek with the purpose to measure various degrees of multi-functionality (Berghauser Pont et.al 2011). The MXI model is dealing with the degree of mix of functions in a quantitative way in terms of the percentage of dwellings, work places and amenities, measured in square metres. These three groups of functions are represented graphically in a triangle shaped diagram (see Figure 5). The three corners of the triangle correspond with the floor surfaces of one single function, which are either 100% amenities, 100% dwellings or 100% working places. When there is about 33% of each of these functions, the area is multi-functional consisting of both dwellings, amenities and working places.

Figure 4 shows where different types of urban areas are located in the MXI Model. As can be seen in the figure, historic city centres tend to be located in the middle of the triangle whereas post-War dwelling areas and office parks tend to be located at the mono-functional edges of the diagram.

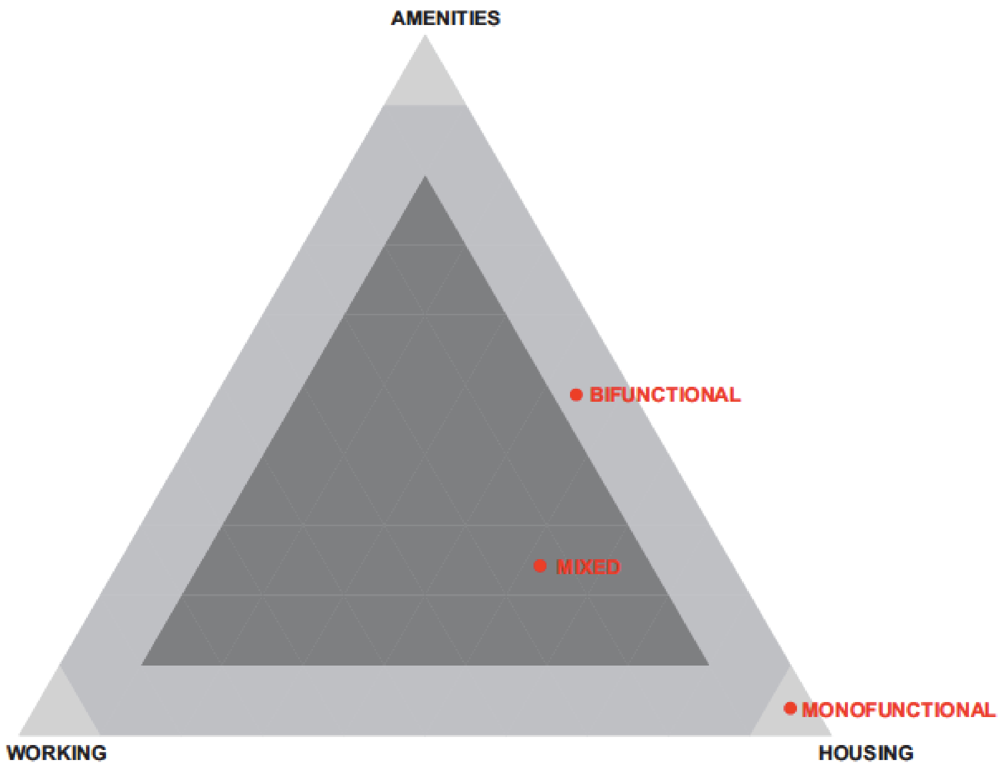

Figure 4: The function mix triangle (van den Hoek, 2010).

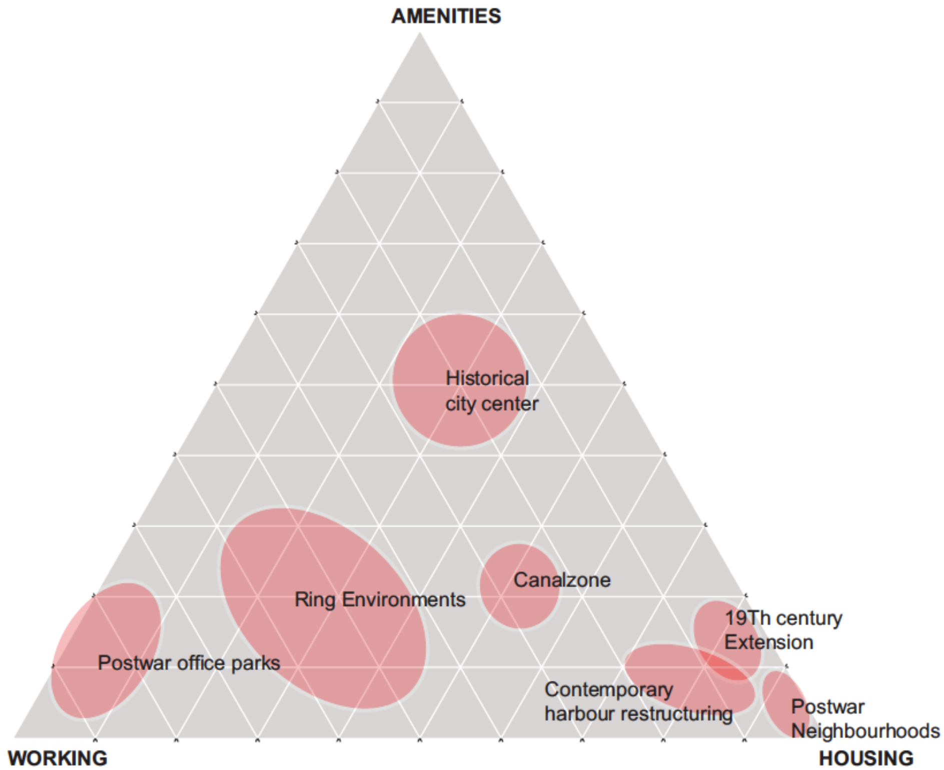

Figure 5: The function mix triangle and the distribution of 7 types of urban areas within the triangle (van den Hoek, 2010).

Van den Hoek's research has shown that there is a relation between FSI and degree of mixed-use. In areas with the lowest range of density (FSI lower than 0,50), no mixed-use areas were present as in areas with the highest range of density (FSI higher than 1,50) all areas were mixed. Mixed-use areas were here defined as having a minimum amount of 10% floor space for each of the basic functions dwelling, working and services. There is thus a clear relation between mono-functionality and low FSI, and multi-functionality and high FSI (van den Hoek, 2010).

2.4 Research method: the application of GIS

As mentioned in the introduction, the hypothesis is that urban form (density and network integration) influences the degree of function mix. Therefore a technique was explored to bring both measurements (Spacematrix and Space Syntax) within one frame. As a result, a combined way of categorizing urban areas is introduced, which is suitable for assessment of interventions based on both methods. On one axis density (FSI) is set out as the other axis represents integration. In other words, we try to define the characteristics of an urban area based on a combination of various spatial attributes giving different potential for mixed-use development.

Since Space Syntax deals with the street network and the Spacematrix and MXI model deal with the urban blocks, there is a challenge to bring these methods together in one model.

GIS offers the tools for combining the various abovementioned methods. There are two approaches. One approach is to impose a grid with cells of 200 x 200 meter covering the whole city in the GIS file. The advantage for using such a grid is that more variables with different origins can be used and analysed simultaneously. Vector based values can be connected to the cells. Likewise, an area based or point based data can be translated into cell values. The grid analysis can further easily be repeated on other scale levels and in other locations (ESRI, 2001 and Jacobs, 2000). The chosen size of the cells is dependent on the context, the goal of the analysis and the power of the computers used.

In general smaller cells contribute to more precise results. However, a too small cell-size can also disturb the correlation between different factors. The goal in Rotterdam South is to grasp the degree of integration of the street and road net as well as the degree of density of the urban blocks and their degree of function mix inside the various cells. A cell should therefore be at least of such a size that the results from both methods are represented. In other words, a cell should cover the largest building and its surrounding streets.

The other approach is to use the urban blocks as polygons and use the degree of spatial integration in the streets tangenting the urban blocks. For this inquiry the first approach was used. Table 1 shows an overview over what kinds of values that were used to aggregate the information of different layers inside each cell of the grid.

Layer	Agglomeration rule	Description
Spacematrix	Accumulation	Sum of gross floor area and footprint per area of cell
Space Syntax	Maximum	Maximum integration value of axis within a cell
MXI	Weighted average	Percentage of the three functions in each cell (measured in gross floor area)

Table 1: Various techniques for aggregation of information.

3. THE RESULTS OF THE ANALYSES OF THE EXISTING SITUATION

To make a diagnosis of the current situation in Rotterdam South, the following analyses are made:

- Spatial integration analysis using the Space Syntax method at various scale levels and in relationship with the whole city;
- Density analysis using Spacematrix;
- Analysis of the degree of mix using the MXI model;
- Analysis of the correlations between spatial integration, density and mix of use by overlaying the results from the Space Syntax, Spacematrix and MXI analyses in GIS;

3.1 Space Syntax analyses

Figure 6 shows a global analysis (left) and a local angular analysis (right) of Rotterdam. The upper maps shows the Space Syntax analyses from Depthmap, while the lower map shows the distribution of integration on the raster created in GIS. The axes with the highest integration values inside each cell influenced the colour of it. The ring road is the most globally integrated part of Rotterdam. Even through the city is through planned with urban motorways – some of them with two lanes in each direction - the ring road is the fastest way to travel from the north to the south of Rotterdam. It has the highest to-movement potential in Rotterdam. In the local angular analyses (Figure 6, right), the main routes network through and between urban areas is highlighted. Where the integration is highest, shops are located along the streets.

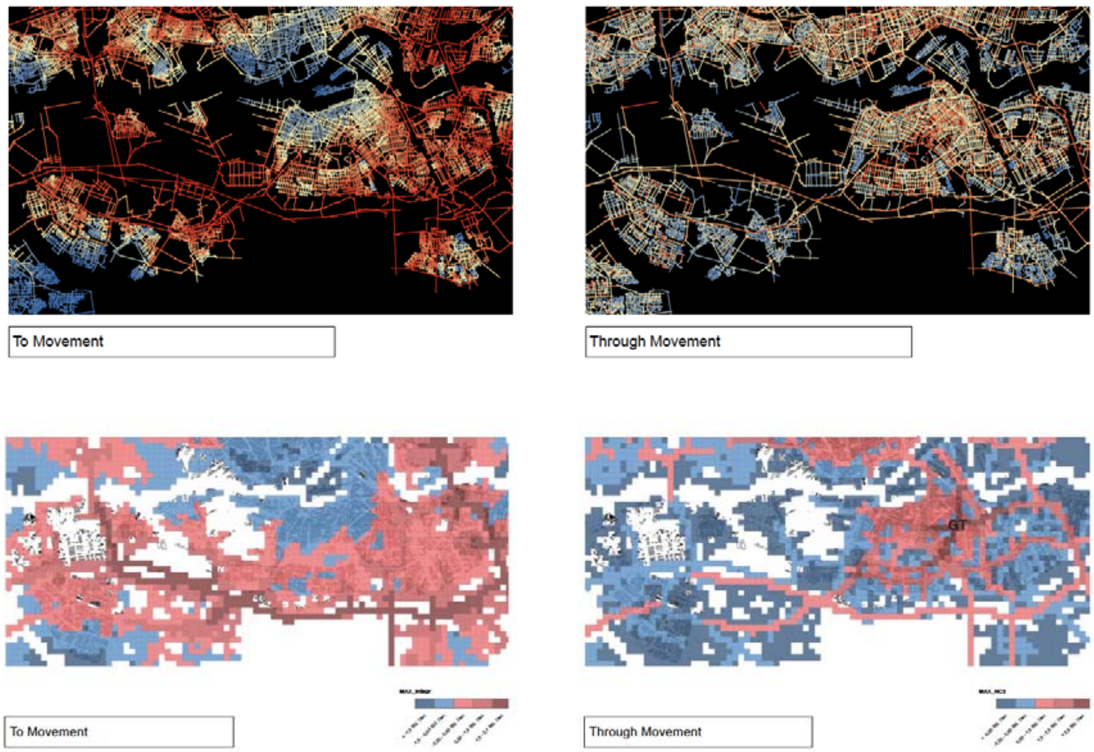

Figure 6: Global axial integration analyses (left) and local segment angular analysis with R3 (right) of Rotterdam.

When applying the metrical radiuses, the degree of vitality of the various local areas can be seen on a low metrical radius and the main route network is highlighted with a high metrical radius. Figure 7 shows an angular choice integration analyses with a low (left) and high (right) metrical radius. Streets with high integration values with a high metrical radius tend to be the potential routes for through movement. Conversely, streets with high integration values with a low metrical radius tend to be potential meeting places for the neighbourhood.

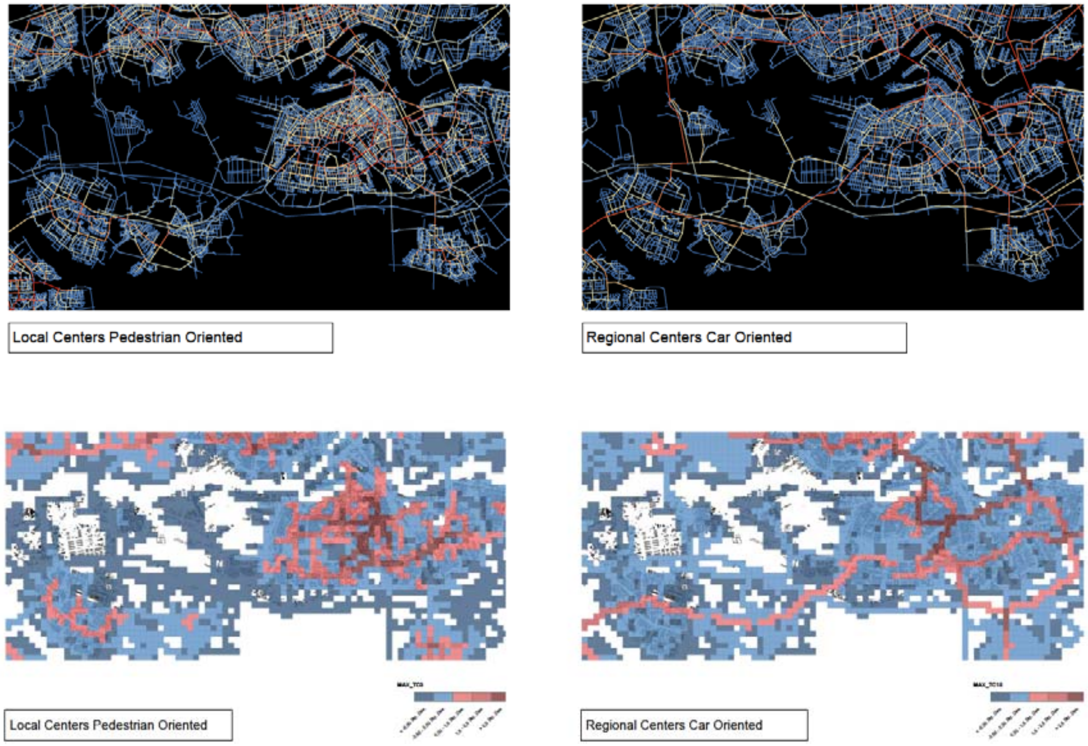

Figure 7: Angular choice analyses of Rotterdam with low (left) and high (right) metrical radius.

When comparing these two analyses with one another, the most vital urban areas tend to be where streets have high angular choice integration values with both high and low metrical radiuses. Often pre-War urban areas tend to have their vital urban local centres along the main route network. These areas tend to be visited by random trough travellers as well as locals. Many post-War neighbourhoods tend to have their local centres far away from the main route network. Even though the density of inhabitants sometimes is high in a post-War neighbourhood, the area only offers a local supermarket. The supermarket is mostly used by the dwellers in the neighbourhood, as visitors do not pass by. In pre-War neighbourhoods, the variation of shops tends to be much higher than in post-War areas, due to their strategic location in the mobility network. These streets can easily be reached from the main route net. Therefore, the variation of visitors and also shops in these shopping areas tends to be higher in old towns than in new towns.

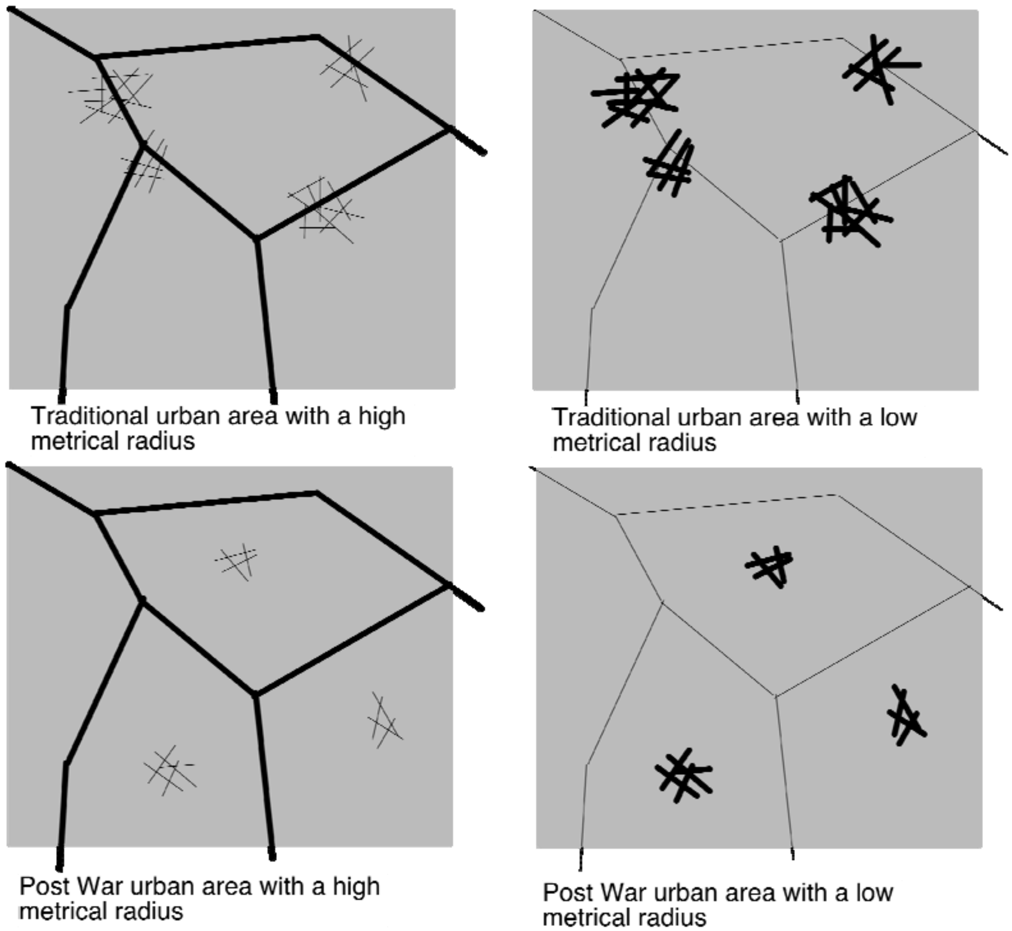

Figure 8 The principle of main route network in a new and old town.

Figure 8 shows the principles of the main route net on two scale levels in an old and a new town. In the top of the figure, the spatial principle of a traditional urban (pre-War) area is shown. The centres with a low radius are located either on or adjacent to the main routes. These centres are easily accessible by foot as well as by car and can thus be reached easily by locals and by visitors from further away. Below in the figure, the principle of urban centres in a post-War neighbourhood is shown. Here the centres with low metrical radius are located far away from the main route net on a high scale level.

To catch this duality, or lack of it, an aggregation was made of the two integration analyses (high and low metrical radii). A matrix with 3 x 3 cells was made on the relationship between high, medium and low integration and the analyses with high or low metrical radius. Figure 9 shows the raster analysis of Rotterdam South with these analyses. As can be seen from the map, the main routes through the various existing centres tend to have both high and medium integration values for the high metrical radius as well as for the low metrical radius. There is a dense network with highly integrated streets with both a high and low metrical radii in the centre of Rotterdam South. The next step is to reveal the FSI and GSI values in these areas through the use of Spacematrix.

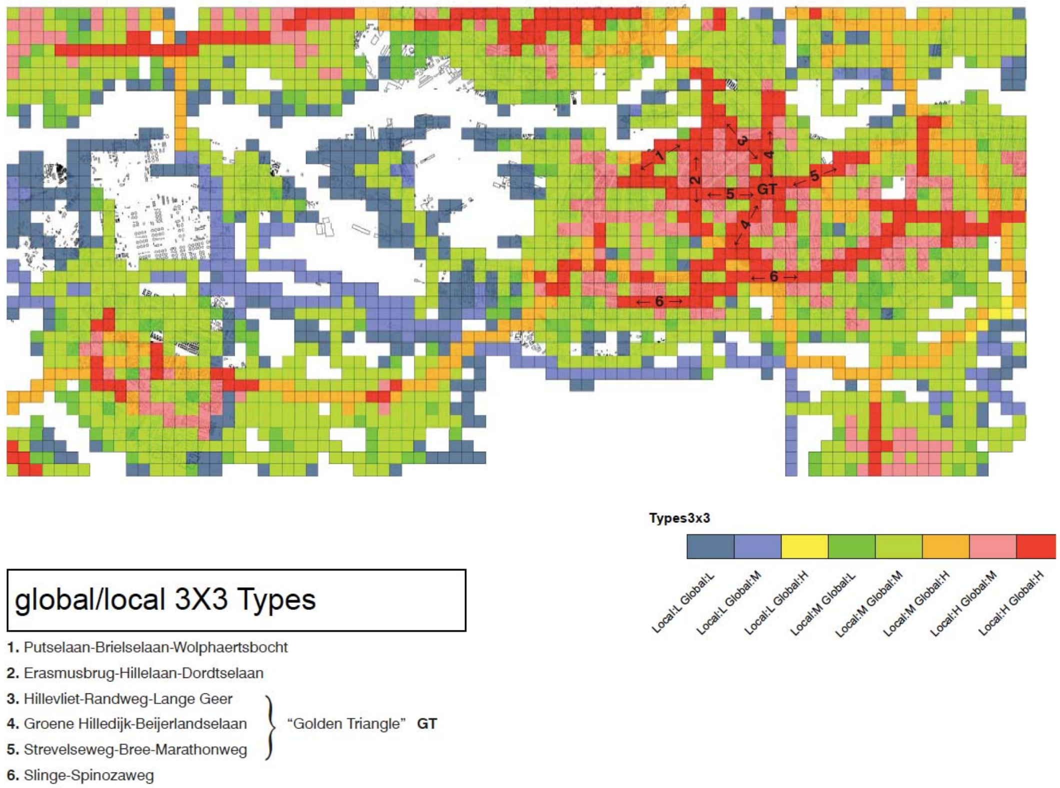

Figure 9: The combination of angular integration analyses with high and low metrical radiuses.

3.2 The density analyses with Spacematrix

Figure 10 shows the different density types in Rotterdam South. The city consists of a small number of high-rise developments, located close to the river and the Erasmus Bridge (the blue cells in the map). Further, the northern part of Rotterdam South consists of mostly mid-rise blocks with a relative high FSI and GSI (dark red cells). However, only a small part of the cells have these relative high densities.

In general the density of the built mass is low in Rotterdam South. Around 60% of the cells consist of low-rise buildings with lesser than 3 floors (yellow cells). More than 80% of the built mass has a FSI lesser than 1,0. Figure 11 shows the FSI-GSI plane of the Spacematrix with the percentage of the distribution of various types of density.

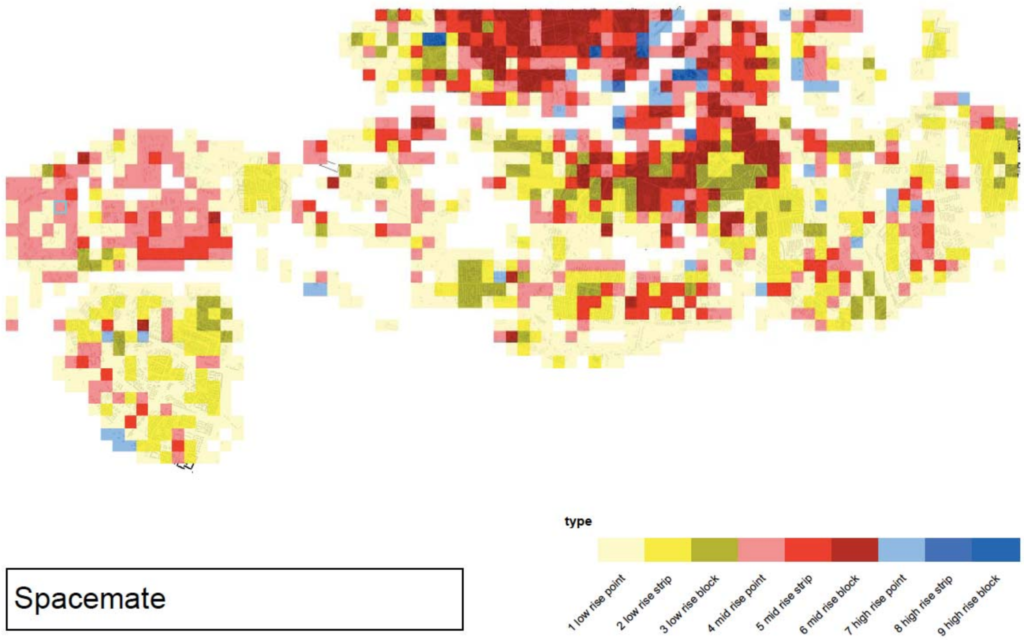

Figure 10 The location of the 9 different environmental types in Rottedam South as defined with Spacematrix.

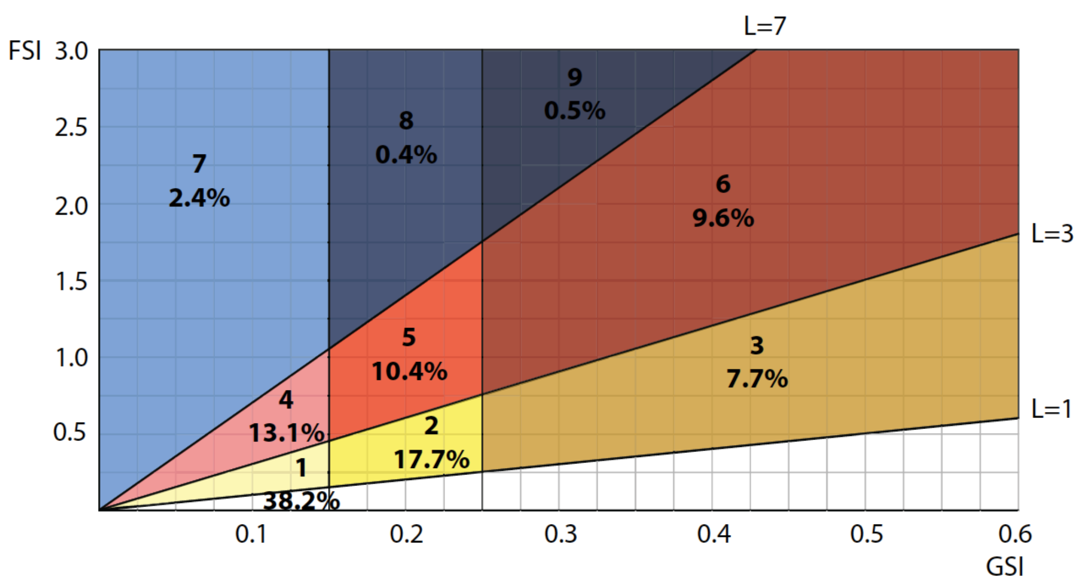

Figure 11 The FSI-GSI plane of the Spacematrix with 9 different environmental types.

3.3 The MXI analyses

Figure 12 shows the distribution of functions in Rotterdam South. As can be seen from the map, the Rotterdam South area tends to be rather mono-functional. The large red areas are housing, the yellow areas are amenities (shops and services), while the blue areas are working places – mostly dominated by harbour activities. The orange areas have a mix of housing and amenities and the grey cells represent a mix of all kinds of functions; the greyer the cell the more mixed the urban area inside this cell is. In the upper part of Figure 12 only one black cell can be seen within some grey areas. This is the centre of Rotterdam (located in North), which has a balance between amenities, dwellings and working places. In Rotterdam South only 7,4% of the cells has a mix of all three functions (see type 7-9 in Figure 13). Further, 46% of the cells are dominated by dwellings and 19% of the land is dominated by working places.

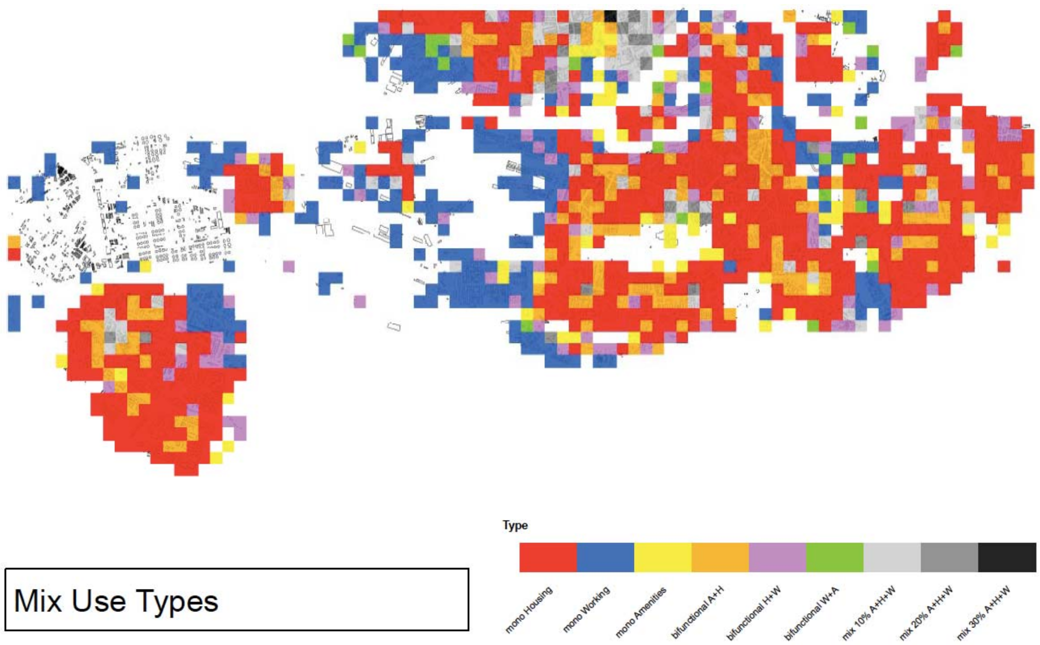

Figure 12 The degree of function mix in Rotterdam South.

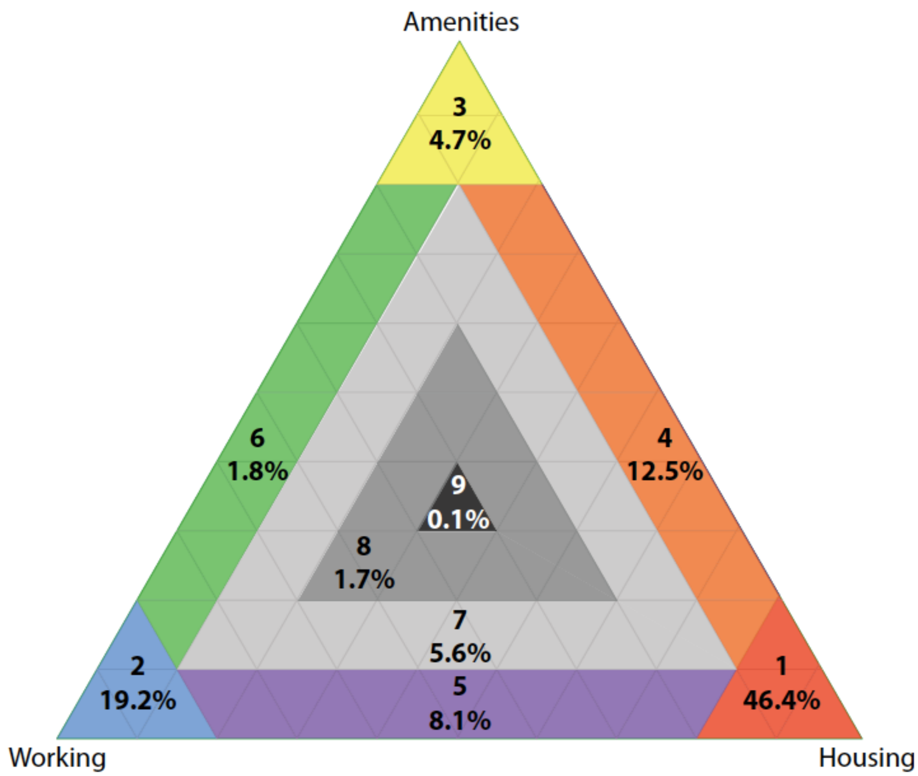

Figure 13 The distribution of functions in Rotterdam South.

3.4 The combination of Space Syntax, Spacematrix and the MXI Model

Through the use of GIS, it is possible to aggregate the data from the Space Syntax, Spacematrix and the MXI analyses.

The first outcomes from this inquiry show clearly that the multi-functional areas and especially those with a mix of dwellings and amenities (orange areas in Figure 12, section 3.3) tend to be along the highly spatially integrated main routes in the centre of Rotterdam South (compare with Figure 7 in section 3.1).

Moreover, correlations are found between the distribution of the types of densities and the different types of mixed-use areas. Figure 14 shows that in the mono-functional areas 65-75% of the cells are dominated by low-rise types of buildings. Especially the type with the lowest FSI and GSI are overrepresented. In the mixed areas this is reduced to only 30-40%. The mid-rise type starts to dominate here.

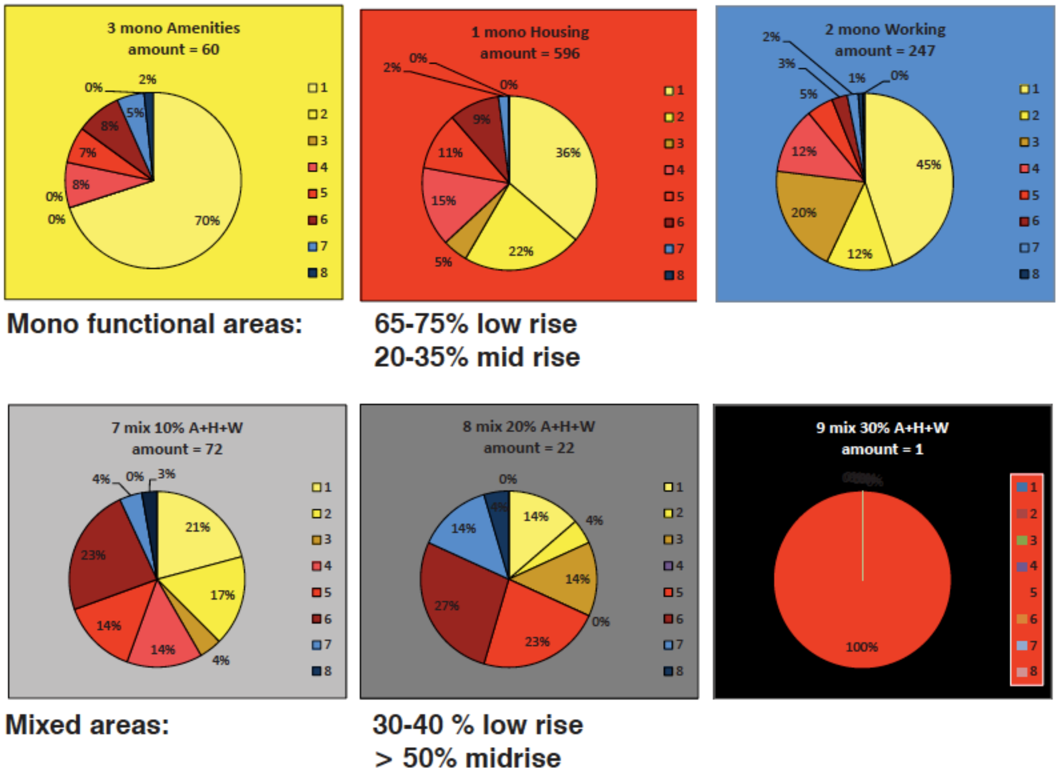

Figure 14 Pie charts of the distribution of functions in Rotterdam South.

To bring measurements of Space Syntax and Spacematrix within a same frame, four types of density and four spatial integration values were combined in a matrix. The used integration values are combinations of both global and local integration values. Table 2 shows a way to categorise and combine these data. The statistical analysis supports the validity of this categorization. The combination of a high density and a high integration was categorised as highly urban, medium high density and medium high integration as urban, etc. All categories can be found in Figure 15.

Density Category (indicator = FSI)	Meaning
High	Belong to first 25%of data with lowest value of indicator
Medium high	Belong to second 25%of data with lowest value of indicator
Medium low	Belong to second 25% of data with highest value of indicator
Low	Belong to first 25% of data with highest value of indicator

Pedestrian-oriented integration's category (indicator = TMC3)	Car-oriented integration's category (indicator = TMC3)	Meaning
High	High	Belong to first 20%of data with lowest value of indicator
Medium	Medium	others
Low	Low	Belong to first 20% of data with highest value of indicator

	Pedestrian-oriented integration			
Car-oriented integration		High	Medium	Low
	High	High	Medium high	low
	Medium	Medium high	Medium low	low
	Low	low	low	low

Table 2: The combination of various data with purpose to produce categories of urban areas used in Figure 16.

The results show that the highly urban area type consists of a high degree of function mix. In areas where the spatial integration as well as the density on the built mass is high, the areas tend to be highly urban and having a high degree of function mix. Conversely, in areas with low density and low spatial integration, the areas are highly sub-urban and having a low degree of function mix. In other word, this combination of density and integration is a distinctive tool for evaluating the potentials of mixed-use development. Therefore it has been used for the assessment of urban interventions in the next section.

The next step is to reveal the areas where the spatial integration of the street and road net is low, but the density is high. These areas are coloured in a warm light blue (T1 in Figure 15) and have potential for a certain kind of transformation. The same accounts for the areas where the spatial integration is high and the density is low. These areas are coloured in darker blue (T2 in figure 15).

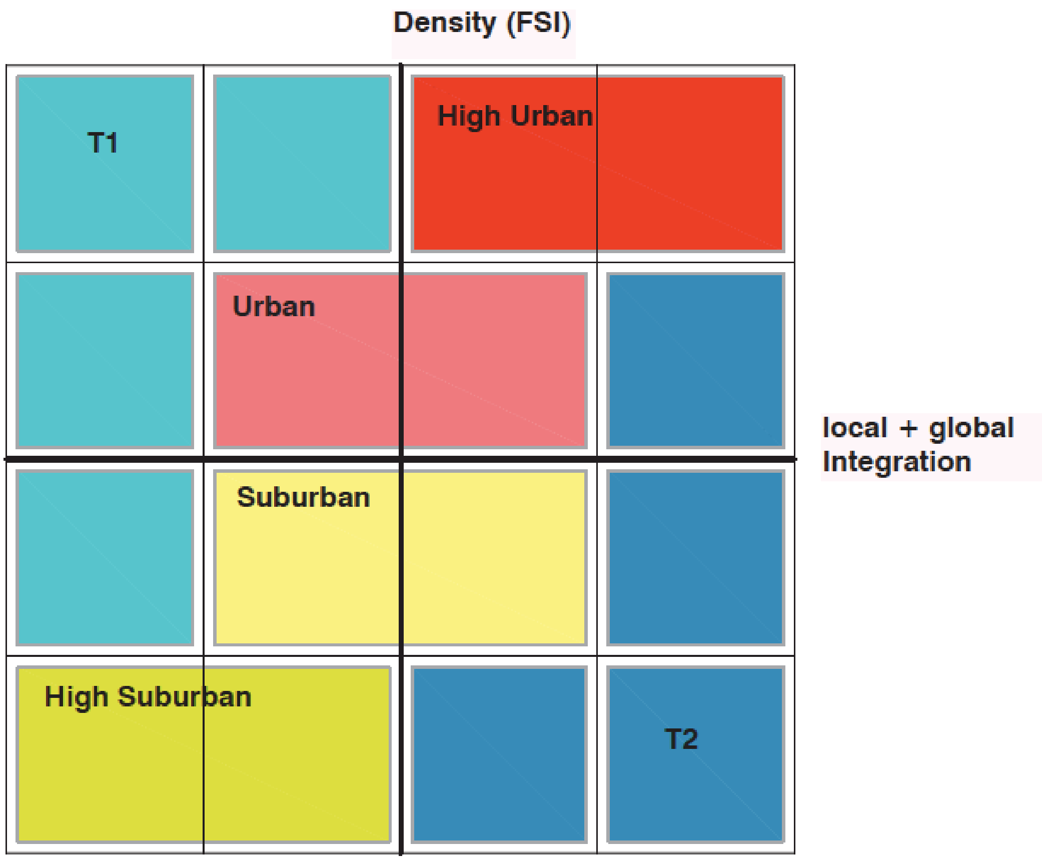

Figure 15 The Matrix with colour codes used for aggregating the Space Syntax and Spacematrix data in GIS.

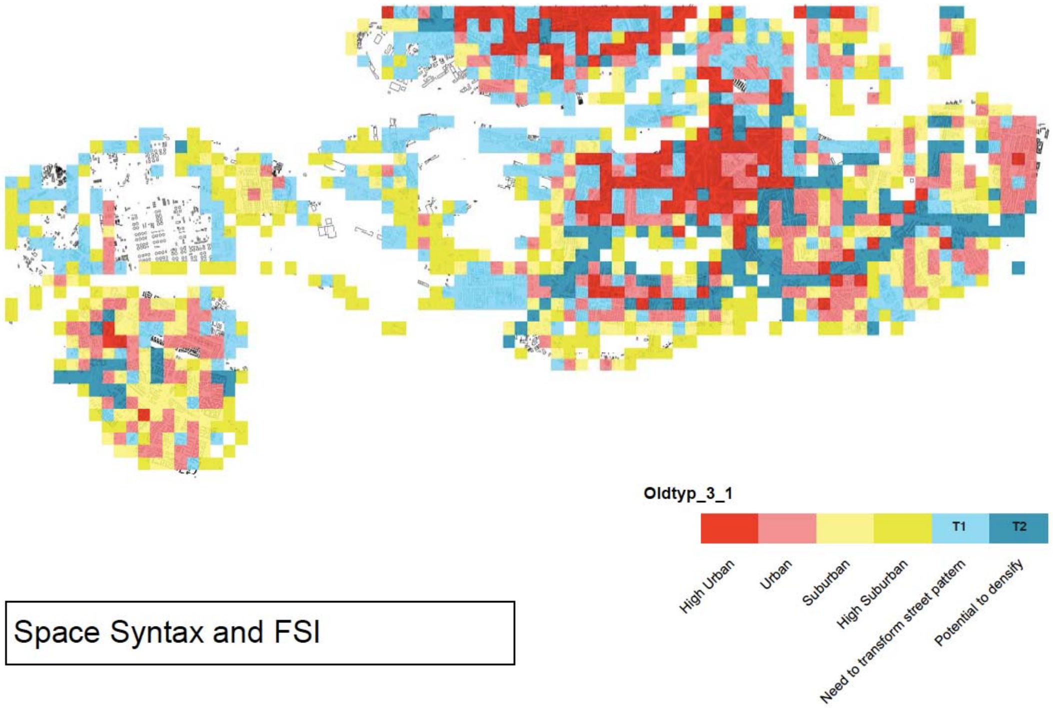

Figure 16 The combination of Space syntax and Spacematrix in Rotterdam South.

Figure 16 shows the distribution of the combination analyses of the density of the built mass and the degree of spatial integration of the street and road net in Rotterdam South. The highly urban areas (coloured in red) are in the centre of Rotterdam South. These areas are also mostly multi-functional. The highly sub-urban areas (coloured in yellow/green) are found in the edges of the city and in the through planned garden cities styled planned neighbourhoods. These areas tend to be more mono-functional, consisting of either dwellings or industrial areas.

The areas coloured in warm light blue (category T1) tend to be segregated industrial areas. Interesting enough, some rather central areas between Rotterdam North and South are of this type too. The integration of the street net is low here, and the FSI is relatively high. The areas coloured in darker blue (category T2) show areas that have the potential to be intensified as the integration is already high here. The lower the density is, the more potential these areas have for such a transformation. In particular the areas around the Feyenoord stadium have large potentials for intensification or densification of the built mass.

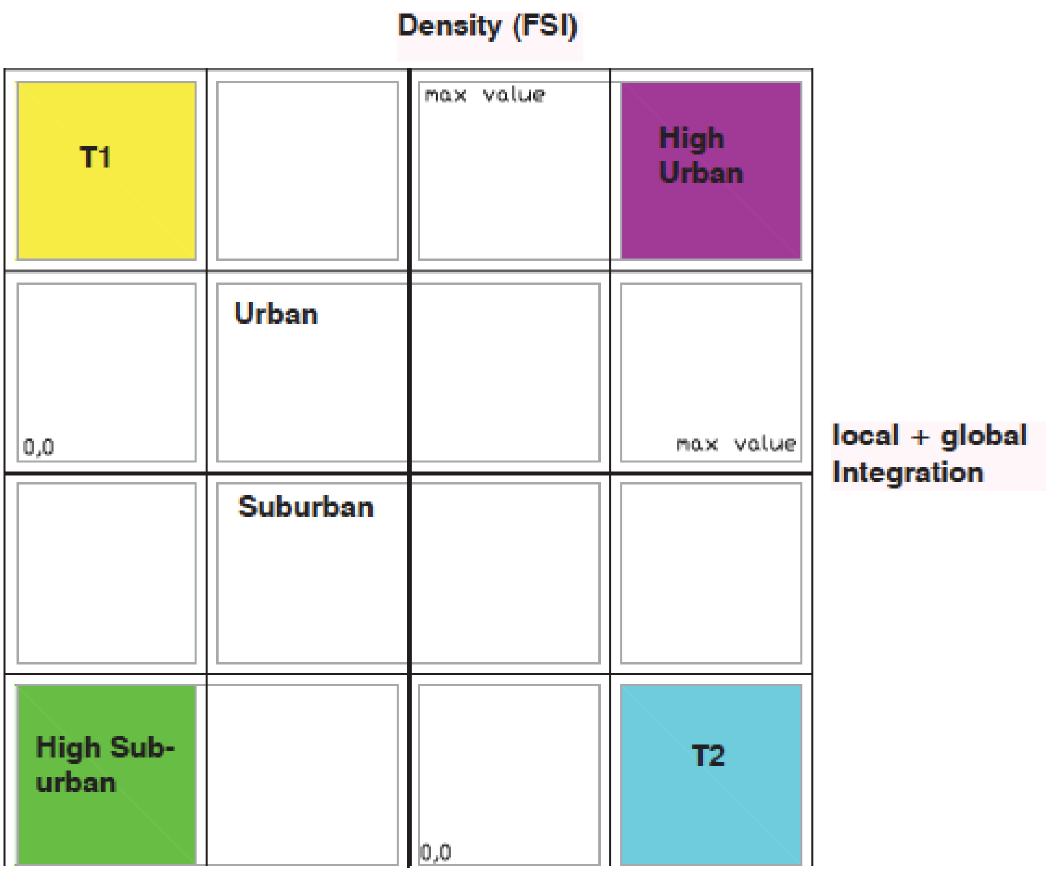

Figure 17 The extreme areas in Rotterdam South.

Figure 17 shows the four extreme types within the combined integration-density matrix and Figure 18 shows where these are located in Rotterdam South. For each of these areas different strategies are needed in spatial planning. The highly urban areas (purple) have all ingredients to become the liveliest parts of Rotterdam South. The highly integrated street net generates high local to-movement as well as through movement potentials in these areas and the density of the area itself is high. In cases where public transport is lacking, it could be an aim to improve it in these areas. These areas offer the spatial potentials or possibilities to a high degree of urban activities on streets as well as inside buildings. In cases where no mix of functions is present, rules that prevent this can/should be removed or function mix could be stimulated through subsidies from the municipality. Another strategy in these areas could be to facilitate the possibilities for constructing high quality dwellings for middle-income people to generate also a mix of different types of people (in case this is lacking). For the highly sub-urban areas, few strategies are needed in terms of spatial interventions. These mono-functional dwelling areas have a low density of the built mass and are rather segregated from the rest of the city. In other words, nothing should be expected here in terms of mixed-use developments.

The areas offering the highest priority for improvements are those with high spatial integration of the street and road net, but with low density (coloured in blue, T2) in figure 18. Since the street net is highly spatial integrated, the 'armature' for to-movement and through movement is already present. Many of these areas are located close to existing highly urban centres, so it can benefit from the existing infrastructure and services. Densification is a strategy to be used here. Conversely, the areas with low priority for improvements are those with low spatial integration of the street net and with high density of the built mass (coloured in yellow, T1). An upgrading of these areas requires changing the whole structure of the street and road net. Otherwise, an improvement of the built mass will have few effects.

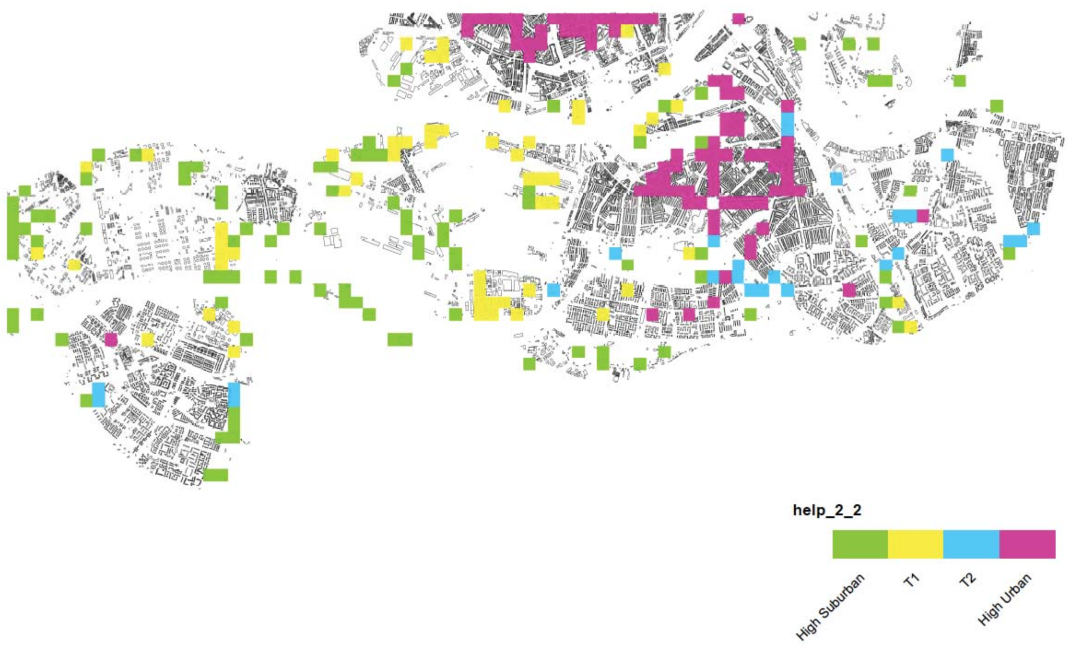

Figure 18 The extreme areas in Rotterdam South plotted on a map.

4.5 The aggregation of Space Syntax and Spacematrix data with social index data through GIS

The spatial integration and density data were also aggregated with the social index data provided by the municipality of Rotterdam. It is based on statistic data about the quality of the living environment, socio-economical capacities (factors such as level of income), social involvement (social and cultural activities) and social binding Based on this data, a priority map is made for the municipality relating the social index with the analysis from paragraph 4.4. Firstly, three categories of intervention are defined:

1. physical interventions in areas where the spatial conditions are not balanced;
2. socio-economic interventions in areas where the spatial conditions are balanced;
3. no intervention needed.

Within the first category (physical interventions), three sub-classes were defined:

1a. High priority – the area's social conditions are weak

1b. Medium priority – the area's social conditions are vulnerable

1c. Low priority – the social conditions are good

The same was done for the second category (social interventions):

2a. High priority – where the social conditions are weak

2b. Medium priority – where the social conditions are vulnerable

When aggregating all these six categories through GIS, a map with colour codes is given (figure 19). No intervention is needed in the greenish areas (category 1c and 3). In the dark red and yellow areas (category 1a and 2a), the need for improvement is highest. Both have to deal with social problems (a low score in terms of the social index), but in the first case (the dark red areas, category 1a) also a physical mismatch seems to be part of the problematic. Here a dual approach is needed including both physical as social interventions. An example of such an area is Feyenoord, which is located centrally between Rotterdam North and South.

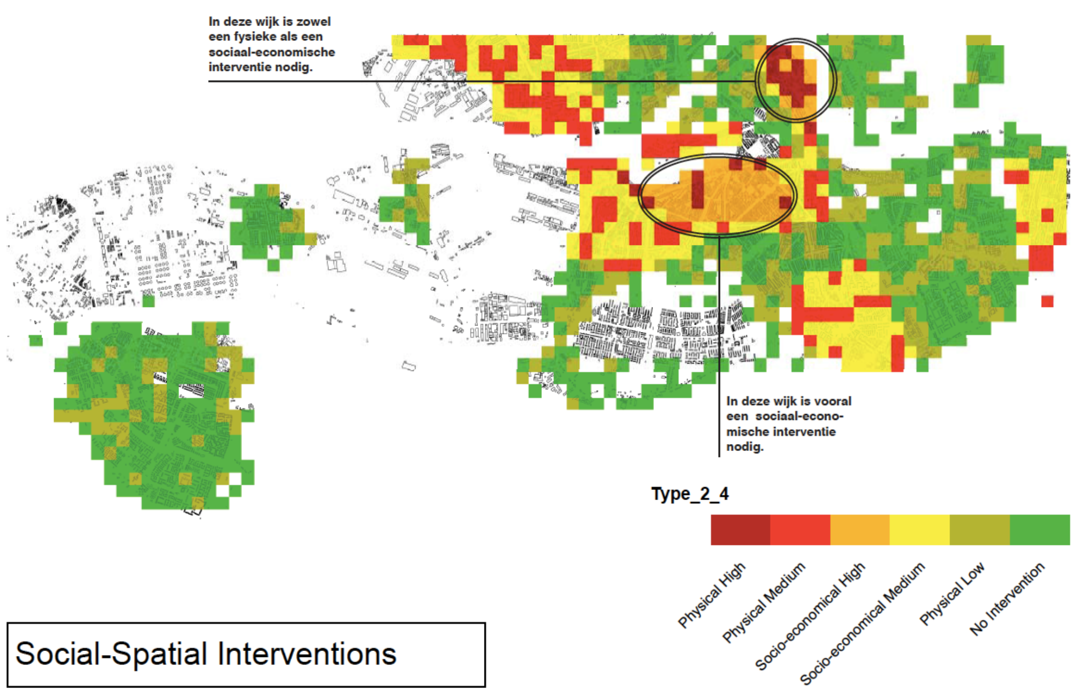

Figure 19 Proposal for socio and spatial interventions in Rotterdam South.

5. AN EXPERIMENT WITH A NEW BRIDGE

An experiment with a new bridge was tested out. Figure 20 shows the location of the bridge where it connects the western areas of Rotterdam North with the western areas of Rotterdam South. In the first instance, changes in the integration of the street and road net were calculated. Then the spatial integration for the new situation was aggregated with the density data for the existing situation.

Figure 20 The location of a new bridge.

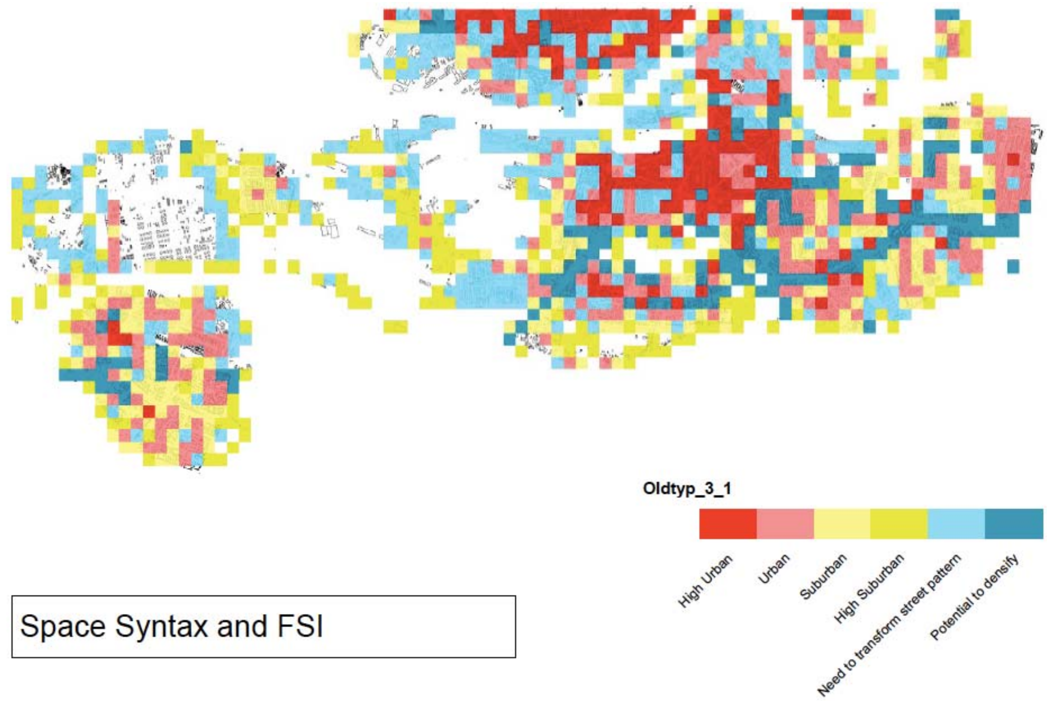

Figure 21 The combination of Space syntax and Spacematrix in Rotterdam South; existing situation.

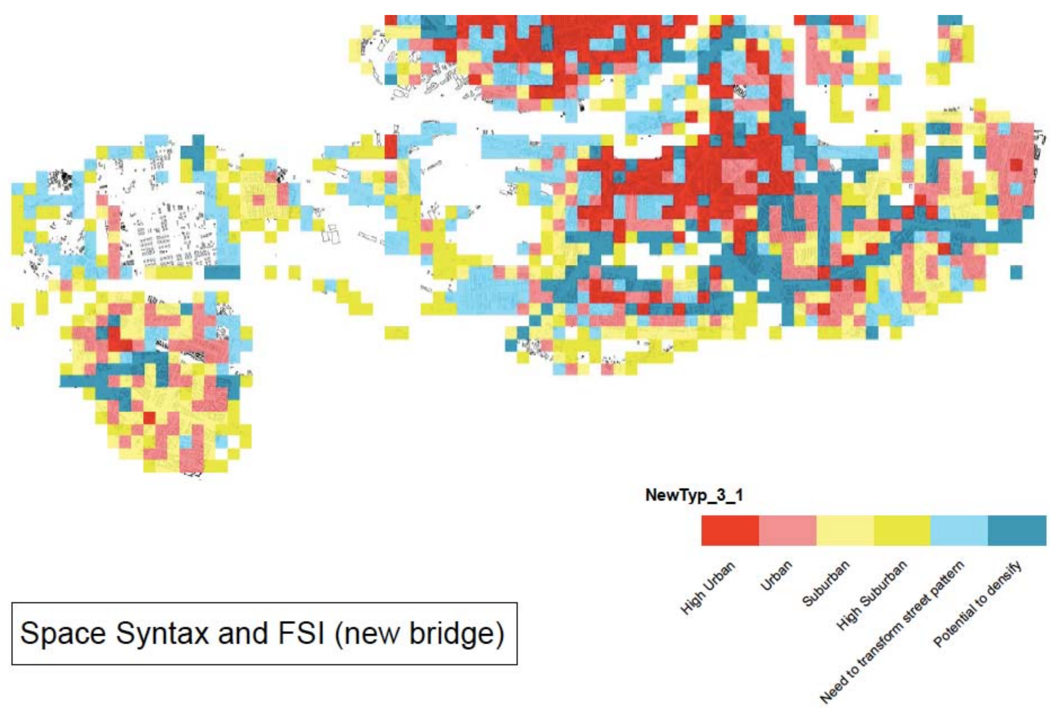

Figure 22 The combination of Space syntax and Spacematrix in Rotterdam South; new situation.

Figure 21 shows again the existing situation, where Figure 22 shows the new situation. In order to highlight the changes, Figure 23 shows where the changes as an effect of a new bridge will take place. As can be seen on the map, the changes of the various local areas do not only happen in the vicinity of the bridge's landing point, but also in the eastern parts of the centre area of Rotterdam South.

Two important changes can be seen. Firstly, there are areas that suddenly get a potential to intensify due to an increase of the spatial integration of the street and road net. These are the red areas in Figure 23 and are mostly found in the southern parts of Rotterdam. The areas along the north-south axis along the railway tracks in particular gain potential for densification. Secondly, some areas in Rotterdam North improve their balance between density and integration through an improved spatial integration on the street network as an effect of the bridge. In other words, these areas were poorly integrated and had a relative high density. Through the new bridge, the integration increased and therefore created a better balance between density and level of spatial integration. Another mix of functions can be expected here after the bridge is realized.

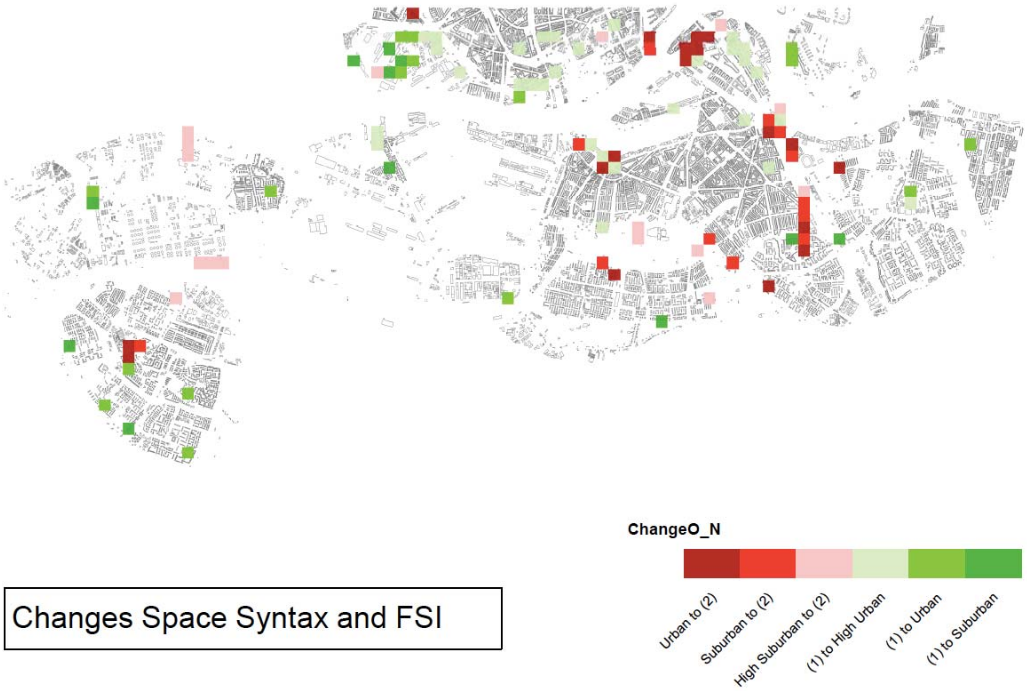

Figure 23 The bridge's impact on the Rotterdam South area.

What this test indicates is that when large urban road and street connections are made, its effect must be studied on a city level rather than only on a neighbourhood level. The purpose is to identify the eventual future potentials as an effect of these changes and to reduce the uncertainly of unforeseen effects. The used models in this research prove to be effective in doing so.

6. DISCUSSION OF THE RESULTS AND ITS CONTRIBUTION TO URBAN KNOWLEDGE

The result of this inquiry is a first step in the process of identifying the correlations between the various spatial and socio-economic parameters. As the maps and conclusions presented here are results of tests in only one city in the Netherlands, conclusions cannot be generalized. More empirical research in other cities is needed to arrive at more robust conclusions. Despite this warning disclaimer, the results can already be used to improve current planning practice.

First of all, current planning practice on a neighbourhood level is not always effective. In some cases a small local change on the street structure can have impact on large urban areas or even in a whole city. Improvement or implementing a main route can affect the vitality of several neighbourhoods. Sometimes this can be better than demolishing the built stock and replacing it with new buildings. At present practice in the Netherlands is to replace buildings in the hope to improve the so called “problem neighbourhoods” (*probleemwijken*). Nothing is done on the spatial structure of the street net. The effectiveness of this strategy is questionable.

Furthermore, this inquiry’s methods provided insights on the potentials and problems of various neighbourhoods on various levels, such as social, economical, densification levels and various spatial integration levels. The old urban areas in Rotterdam South have a good match between the network layout and density. The street grid is fine grained, and there is a balance between a relative high FSI and GSI giving potential for an interesting variation in the mixture of functions. However, the social composition of the dwellers is rather weak. Therefore it is more effective to intervene in the socio-economical situation in these kinds of urban areas than to transform the physical structure. The Feijenoord area has a weak spatial performance as well. Here a dual approach is needed, combining spatial interventions with strategies on a social level.

On a theoretical level, the following generalisation can be made. The higher local as well as global integration on the street and road net and the higher density, in terms of both FSI and GSI, the more multi-functional the areas tend to be. Conversely, the lower local and global integration and the lower density of the built mass, the more mono-functional the area is. To come up with real statistical proof, these first findings have to be further elaborated and more cities have to be analysed with the combination of Spacematrix, Space Syntax and the MXI model. However, given the area’s size in this inquiry, we can still firmly claim that the degree of spatial integration, the degree of density affects the degree of function mix in urban areas.

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