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USING BOUNDARY OBJECTS TO MAKE STUDENTS BROKERS ACROSS DISCIPLINES:

A DIALOGUE BETWEEN STUDENTS AND THEIR LECTURERS ON BERTOLINI'S NODE-PLACE MODEL

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Abstract

The competencies required for steering urban development sustainably are scattered amongst various disciplines. This is particularly relevant for planners working at the interface of different sub-disciplines, such as transport and land-use planning, exemplified by transit-oriented development (TOD). In this paper, we use Bertolini's node-place model (NPM) example for TOD to test whether it enables interdisciplinary work to be undertaken in planning education. We tested our hypothesis in two design studios by challenging urban design students to develop their own design brief based on an NPM. The paper is of a dialogic, discursive nature. Students discuss whether or not the NPM enables them to better understand the relationship between transit and urban development and to develop spatial strategies based upon an integrative approach. Our discussion reveals that the NPM cannot necessarily bridge disciplinary boundaries successfully. However, both lecturers and students see value in the model as a didactic instrument.

Keywords

Planning education, interdisciplinarity, transit-oriented development, node-place model.

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1. Introduction

Steering urban development sustainably requires knowledge and skills from various disciplines. Cities, with their multitude and complexity of actors, structures, and processes cannot be conceived as being the domain of one particular discipline. Rather, they are shaped and (re-)produced by the overlapping, converging, and sometimes conflicting outcomes of a range of disciplines. A number of them are explicitly connected to understanding, and in some cases ultimately influencing urban environments. Among these are architecture, civil and transport engineering, human geography, urban economics, or urban sociology, to name just a few. Public administration follows the same disciplinary logic by subdividing its institutions into different sectoral departments and agencies. Urban planning has already laid claim to interdisciplinarity with respect to urban space. However, it has conformed to the same idea of vertical separation between disciplinary domains. This vertical separation is evidenced in the distribution of responsibility and power among various stakeholders. While politicians and citizens expect planners to effectively steer urban development, planning departments have to act as brokers between various public and private actors.

Despite the multidisciplinary nature of urban planning, teaching approaches combining different sub-disciplinary knowledge are still relatively rare (Rooij and Frank, 2016). Establishing planning degrees with homogeneous groups of students has led to the formation of unique ways of thinking and doing within such programmes. However, scholars and practitioners alike are confronted with the challenge of understanding and incorporating different disciplinary backgrounds in group work. As a result, programme administrators and lecturers are looking for new ways to bridge potential incomprehensibilities between students, for example in graduate programmes of urbanism which admit students who have had a range of different undergraduate experiences (Bertolini, 2012).

Interdisciplinarity has been discussed as being both an encouraging and underdeveloped avenue for future research and teaching for a range of subjects over the last few decades. One case where this becomes clear is integrated transport and land-use planning. Sectoral technical planning and comprehensive land-use planning both exert a strong influence on our built environment and these are not always aligned. Planning practice and academia has long acknowledged the deficits that can arise for our urban environment if one of the disciplines involved in its formation becomes dominant over the others (Jacobs, 1961; Mitscherlich, 1965; UN Habitat, 2009). The dominance of the private car in Western cities can partly be attributed to the supremacy of traffic engineering in the post-war urban development of the 1950s and 1960s. This is strongly connected to the modernist ideal of the functionally segregated city and its adoption has, in many cases, been to the detriment of the quality of public space. It was only in the 1970s and 1980s that other disciplines, such as heritage protection and urban design, reasserted their claim to be considered equally in urban development. This example shows that it is necessary to find methods and tasks that enable disciplinary experts to introduce their knowledge into the urban development process.

Today, integrated transport and land-use planning is still an area that yields potentials for interdisciplinary student group work. Often, students with a civil or transport engineering background view urban development challenges more in terms of quasi-mathematical optimisation problems, while students with a background in the social sciences emphasise the specific place-based qualities that are in need of protection or strengthening. The planning vision of transport-oriented development (TOD), which suggests a joint analysis and alignment of settlement densities and (public) transport quality, creates space for a common discourse to take place between these disciplinary approaches (Kinigadner et al., 2016). The emergence of interdisciplinary discourses in urban planning and developments is summarised under the title of urbanism (Wolfrum and Schöbel-Rutschmann, 2011; Olsson and Haas, 2014; Gilliard and Thierstein, 2016).

2. Methodology

This paper presents two studio courses that took place over the last two years and employed the node-place model (NPM) which was developed in the 1990s by Luca Bertolini (Bertolini and Spit, 1998) to acquaint students with the challenges of integrating land-use and public transport planning.

We chose the NPM as an interdisciplinary approach because it reflects the relational turn in social and spatial sciences in a tangible and intuitive way (Graham and Healey, 1999; Jessop, 2008). A relational understanding conceptualises space in two complementary dimensions. The first dimension addresses physical space and localised qualities. The second dimension refers to the interlinkages of such places to other places and involves a network perspective on space. The NPM operationalises the two dimensions as node and place. Because of its restriction to two relatively simple and easy measurements, it is more suitable for the direct engagement of students, as opposed to the use of more abstract spatial frameworks such as the "space of flows" (Castells, 1989), even though the latter might be crucial for an advanced understanding of spatial processes.

The students had to familiarise themselves with the NPM and were asked to use it as an evidence base for identifying areas for development. The students had to understand the model, apply it as a calculation model, and interpret the results. Consequently, they developed design proposals on the scale of individual public transport stations and their surroundings as well as general strategies for an entire city. The learning goal was to familiarise students with an object that can span the boundaries of two disciplines: urban planning, and civil (transport) engineering.

The studio also fulfilled a second goal for us as teachers. Our MSc Urbanism programme is designed for graduates from various disciplines. Developing interdisciplinary methodologies that help students who arrive upon the course with different previous knowledge to communicate about urban space is crucial for their success upon the MSc degree programme. Our hypothesis for the studio course, as well as the paper, is that the NPM is a boundary object that allows experts from two fields of transportation and urban planning to jointly develop plans for the future. Wenger (2000) conceptualises boundary objects as processes, discourses or artefacts shared by multiple disciplines. They are designed 'to enable multiple practices to negotiate their relationship and connect their perspectives' (Wenger, 2000, p.236).

Students of both the MSc Urbanism and the MA Architecture programme joined our studio course. Ideally, students from the engineering department would have had the same opportunity to join the course, but different curricula and study regulations make this currently impossible. The MSc Urbanism programme is designed as an interdisciplinary course and admits students from various academic backgrounds. Participating students held bachelor degrees in architecture, civil engineering and geography. We tested our hypothesis on two scales: first for the city of Munich, and secondly for the metropolitan region of Munich. The hypothesis was assessed by a discursive, qualitative methodology. First, both student groups talked about their application of the NPM to an integrative land-use and transportation design project. Both groups then individually reflected on their experiences before developing a structured conclusion together. A positive outcome for us would be a more integrative understanding of the two disciplinary groups of participating students: transport develops a three-dimensional spatial realm beyond physical infrastructure, and spatial qualities are heavily influenced by non-visible changes in accessibility induced by stops of transport infrastructure. The last part summarises what we as educators learned from both projects and what we think the important implications of this are for planning education.

3. Node-Place Modelling as a Didactic Instrument

3.1. Bertolini's Node-Place Model

While the general, long-term impact of accessibility improvements on settlement patterns in the past is well documented (Wenner, 2017), the effect of land uses on transport infrastructure is not (Rietveld and Bruinsma, 2015). The node-place model (Figure 1) is an analytical tool that enables the formulation of planning guidelines. One of the major advantages of Bertolini's model is its combination of two basic concepts of space. First, space is formed by its geographical structure and refers to the dimension of place. Secondly, space also inheres a topological component that is addressed by the term 'node'. Regarding didactics, the NPM enables us to understand locations in a wider regional context and consider these from their position in transport networks as well as their physical qualities. The NPM suggests matching densities of activities, which generally corresponds to building densities, with the level of public transport services in order to achieve more sustainable urban development. The NPM essentially describes a normative relationship: areas of high density of activities ('places') should be served by more frequent and more diverse public transport, and accessible locations ('nodes') should be surrounded by dense and diverse urban development, while for sparsely used areas a lower accessibility level is acceptable, and vice versa (Bertolini, 1999). Locations where node- and place-quality are balanced are called 'accessible' (Bertolini, 1999). This serves two functions: on the one hand, high accessibility levels of public transport in low-density areas mean that there is an inefficient use of public resources which should be avoided (this would be an 'unsustainable node'), while high densities with low public transport accessibility gives rise to car-dependency, which is associated with negative social and environmental consequences ('unsustainable place').

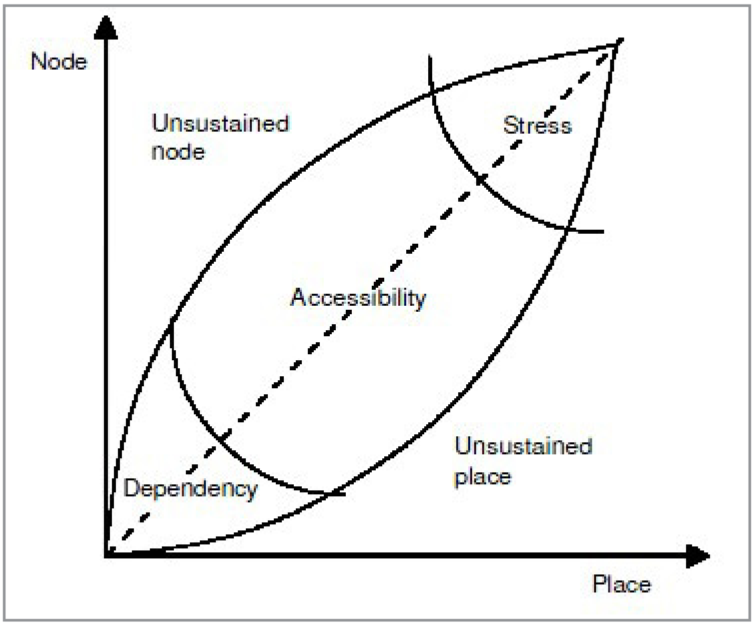


Figure 1: The Node-Place Model. Source: Bertolini (1999, p. 202)

There are, however, cases where node- and place- quality match which nevertheless can cause difficulties for urban development. First, there are situations of stress:

> 'Great concentrations of flows and activities mean that there is an equally great probability of conflicts between multiple, extensive claims on a limited space. The property development ideal of maximised intensity of land use and the transport development ideal of maximised flexibility for infrastructure adaptation and expansion have to find here a difficult synthesis' (Bertolini, 1999, pp. 201-202).

Secondly, there are dependent locations: here, factors other than accessibility are influential in maintaining the supply of both public transport and urban activities.

3.2. Experience of the First Studio

The studio included an analysis of the city of Munich, using Bertolini's NPM as a guideline, in order to identify places having potential for development and implementations of urban design projects. For the analysis, a node was defined as a rail-operated public transport station (suburban rail, underground or tram) and a place was defined by the characteristics of an area within a 700-metre radius around a node. Thereafter, calculable sub-values that comprised the final node and place values were defined.

The node value (Figure 2) was calculated from two sub-values: centrality and frequency. The centrality value represents the number of people who would travel through a certain station when going from point A to point B using the shortest path (between-ness centrality, as defined in Sevtsuk et al., 2016). The values were calculated using the 'Urban Network Analyst' tool developed at the Massachusetts Institute of Technology (MIT) as a plugin for ArcGIS. The frequency value represents the sum of the frequencies of all public transport lines that pass through a specific station. The frequency was calculated as the average of weekday and weekend frequencies at different times of the day (7am, 12pm, 9pm) and was given in trains per hour.

The place value (Figure 3) was also calculated from two sub-values: density and diversity. The density value comprised population density (municipal data from the City of Munich was available by neighbourhood and was recalculated for the 700-metre radius of each place), whilst built density was the percentage of the built area within the radius at ground floor levels (not considering the height of the buildings). The density of activities was defined by the number of businesses within the radius categorised by NACE as retail (G), gastronomy (I) or culture (R) and density of workers (which was taken from GIS firm data and modified to take into account small businesses as well as corporations). The diversity value was defined as the level of balance between the population density values, the number of workers, and the number of firms. The basic assumption was that ideal diversity exists when all three values are equal. Conversely, the bigger the difference between the three values, the lower the diversity value.

The final phase of the analysis required the node-place value for each station area to be entered into Bertolini's node-place diagram. This was done, as Figure 4 shows, in order to determine a classification for each station (unsustained node, unsustained place, stressed, dependent, or accessible). To calculate the node and place values, we used GIS data provided by the City of Munich, while frequency data was compiled using the online timetable of the municipal transit agency.

Figure 2: Node Values Overlaid on a Map of Munich. Larger circles indicate higher values.
Source: Authors' interpretation

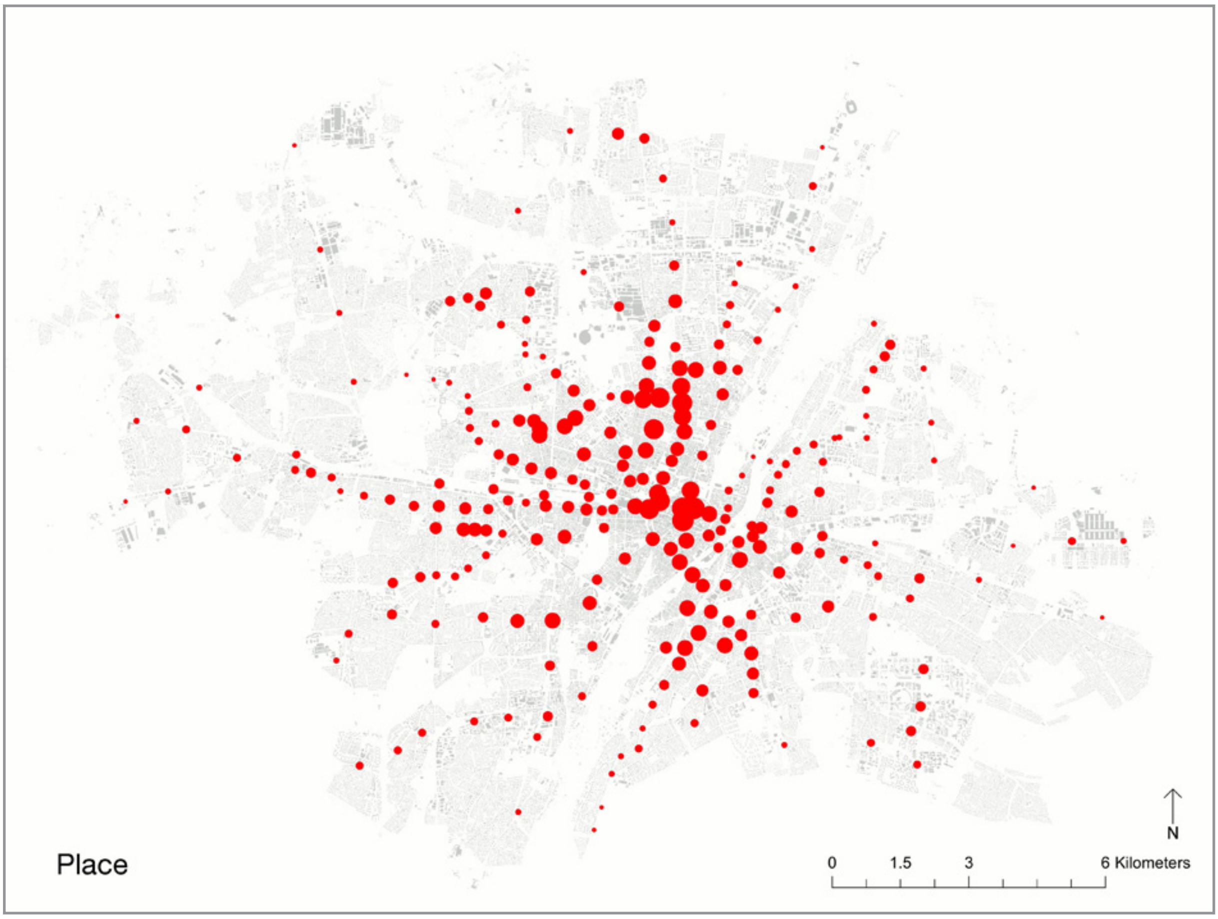


Figure 3: Place Values Overlaid on a Map of Munich. Larger circles indicate higher values.
Source: Authors' interpretation

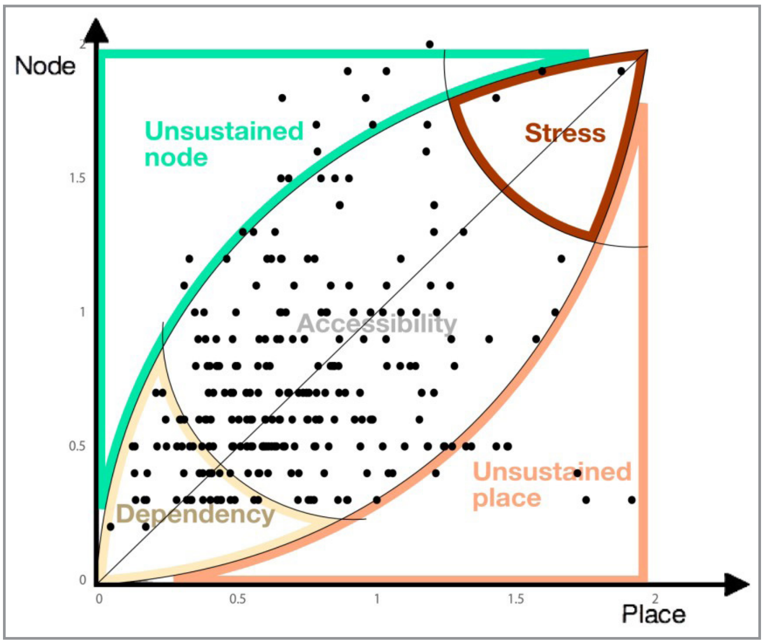


Figure 4: Node-Place Diagram Showing All Analysed Stations in Munich.
The abundance of accessible areas is clearly visible. Source: Authors' interpretation using Bertolini (1999, p.202)

The results of the analysis showed that Munich is mostly a balanced city with a majority of accessible station areas (Figure 5). The stressed stations were, as expected, in the city centre, within close proximity to the main station and the historic centre. Most of the unsustained places were found in neighbourhoods close to the city centre where the population, business, and activity densities were highest. The majority of unsustained nodes were located along the main suburban rail line passing through the city from east to west. The stations categorised as dependent were mostly located in the city's periphery. The results of the analysis were mostly unsurprising, except for a few of the station classifications that stood out and required further attention. In Schwabing, a popular neighbourhood north of the city centre, three adjacent station areas with less than 500 metres between them received different classifications. Clemensstrasse Station was classified as an unsustained place, Karl-Theodor-Strasse as accessible, and Scheidplatz as an unsustained node. Scheidplatz Station also stood out as one of only three unsustained nodes not located on the main suburban line. A similar situation was found in Giesing, another central neighbourhood, with the two adjacent Tegernseer Landstrasse and Giesing Stations. Finally, it was very surprising to discover a cluster of mostly dependent stations right next to the city centre in the Altstadt-Lehel neighbourhood (Tivolistrasse Station, Bundesfinanzhof Station, and Paradiesstrasse Station).

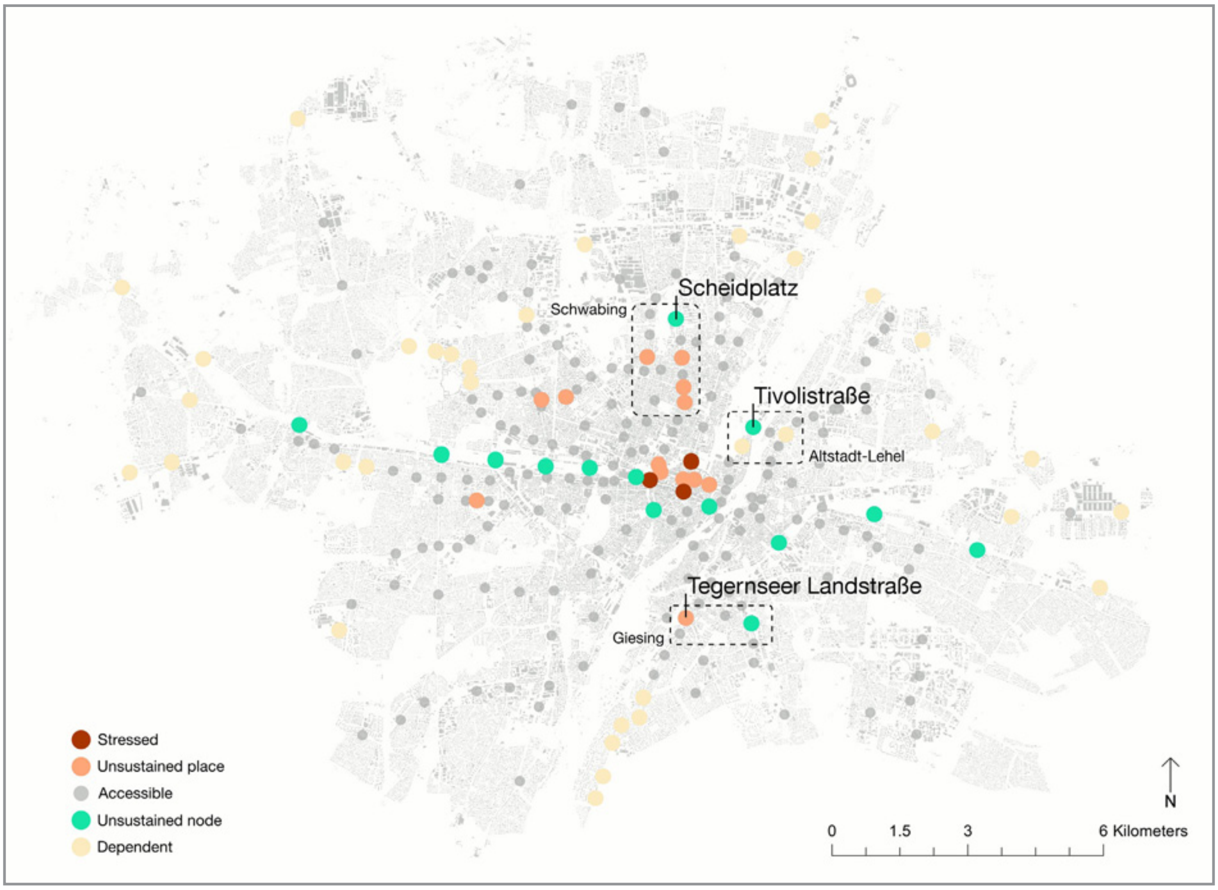


Figure 5: The Five Categories of the Node-Place Model: Accessible stations (grey), stressed areas (red), unsustained nodes (green), unsustained places (orange) and dependent areas (light brown). Source: Authors' interpretation

Limiting our analysis to rail-operated public transport stations meant that areas not covered by these networks were excluded. However, extensive coverage of the Munich suburban rail, underground, and tram networks made this a negligible problem as virtually all relevant areas of the city were found to be within reach of such stations.

As a way of checking our results, we calculated the model with a modified radius of 400 metres instead of the previously used 700 metres. This was meant to take into account the fact that 400m is, with regard to what people are actually willing to walk, a more realistic distance. Across the majority of stations, the relative place-value decreased. This produced a higher number of unsustained nodes. Although we could not, with absolute certainty, attribute a cause to this effect, we assume that it might be related to the often significant proportion of empty spaces that exist in the vicinity of stations such as street junctions, railway land, and so forth. A decrease in radius would render these areas proportionately more important. Another factor was that a decrease in radius would very often lead to a decrease in the diversity value on account of functions not being evenly spread out across the analysed area. This was an important find because it clearly illustrated the inaccuracies involved. As the NPM is relative, results can easily change depending on the dataset used. Thus, a station that is categorised as an unsustained node or place could, in another dataset, possibly be in an accessible range.

We also encountered several other shortcomings in the results of our node-place analysis. The analysis did not take the positive aspects of public open spaces (namely parks or the banks of the Isar River) into account. By virtue of being non-built-up areas, these areas had a negative impact on the place values of nearby stations. They do, however, especially during the summer months, generate significant footfall and contribute to a high quality of place.

We also found that the model could not realistically display situations where stations of different lines or modes were spaced closely together. This was especially true of many of the tram stops within the city centre which would consistently get low node values. However, many tram stops are within easy walking distance of a railway or underground station and interchange is therefore possible, but this is not accounted for in the model.

There have been many instances where the model could have been calculated in a much more detailed manner (e.g. by using actual walking distances instead of a predefined radius to define our areas of analysis). Since a strength of the model was its simplistic approach, we felt that the model would not necessarily be more powerful with such an increased level of complexity.

As the design phase of the studio did not seek to develop a coherent spatial strategy for the City of Munich, it was decided to pinpoint several localised improvements across the city which were taken forward by individual students. When choosing these locations, we selected a two-phased approach. First, a shortlist of stations was compiled from those that featured in the outer extremes of the node-place diagram. Secondly, the shortlisted stations were visited to enable an empirical analysis of the sites to be undertaken. During this stage it was decided only to interrogate the unsustained stations as we thought they would be more interesting to develop than stressed or dependent areas. It was also felt that this was appropriate because some of them were, as has been mentioned, among the more surprising results of our analysis. The stations that were selected were Scheidplatz and Tivolistrasse as unsustained nodes, and Tegernseer Landstrasse as an unsustained place.

Scheidplatz stood out as the sole unsustained node in the northern neighbourhoods of Maxvorstadt and Schwabing. Although the station is among the most important interchange nodes in the north of Munich, it is located between a quiet urban park and a primarily residential area. During the design process, an approach was taken to develop business and leisure in the area and to open up the park so as to increase its attractiveness and usage. By relocating large allotments within the park towards new buildings, diversity and density values could be raised to make the area more balanced (Figures 6 and 7).

The tram stop Tivolistrasse was found to have a similar urban setting. Located in a thin strip of urban fabric bordered by the green spaces of the English Gardens and the Isar River, the site is severely constrained in its development potential. A currently proposed tangential tram line across the north of Munich would pass through the station, further unbalancing its node-place values. This increase in connectivity would heighten the development potential of the area. An existing business park immediately to the north of the station was chosen as the most suitable location for an architectural intervention. Redeveloping this area through a mixed-use approach with high-rise elements enabled a significant increase in the density of both residential and office space units.

As the only unsustained place to be developed in our design studio, Tegernseer Landstrasse required an entirely different approach. Further analysis of the site showed the results of our node-place model to be somewhat misleading in this case. While the tram stop is situated next to a dense urban neighbourhood, the immediate vicinity is characterised by one of the most congested road junctions along the urban ring road called 'Mittlerer Ring'. This isolates the tram stop from its surrounding neighbourhood and there are also two underground stations located within only a few hundred metres of the site which have much better connections to the city centre. We felt that to propose an increase in services to the station was not an appropriate response. The chosen proposal for the site was a pedestrian-oriented redevelopment of the public open space. This included strengthening walking connections across the entire site and between the residential/commercial areas and nearby nodes as well as improving pedestrian crossing times at the road junctions.

In the course of our design studio, we came to understand that first ideas for selecting areas for development can be taken from the node-place analysis. Following our basic assumption that a balanced and diverse place is best, we tried to take action across all three locations that would increase the lowest values so as to optimise results. However, in most cases the NPM only served as a starting point and further analysis was necessary to determine the best way forward. Nonetheless, we feel that the model did help our design process by offering an additional level of analysis and through bringing our attention to locations that we would not normally have looked at. While it is our belief that it cannot serve to define the qualities or shortcomings of a given site, it presented a different way of looking at a city and its functioning. Whereas the place values are more of a micro perspective of an area, the node values are a macro perspective, connecting a small area to the perspective of an entire city. The NPM helped to understand the immediate needs of an area in the city and made us appreciate that it is important to think about each small area and its particular functions, as well as how the city works as a whole.

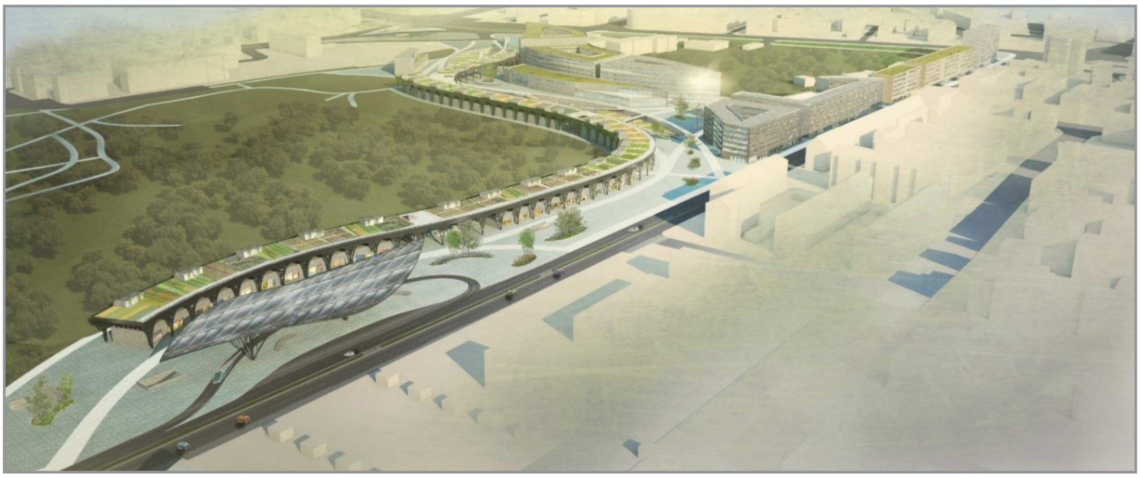


Figure 6: An Overview of the Urban Development Proposal in Scheidplatz Station, project by Gal Biran

Figure 7: Night Street View of New Business and Leisure Area in Scheidplatz, project by Gal Biran

3.3. Experiences of the Second Studio

The second studio started with the same task but for the entire metropolitan region of Munich. The project's first phase was to set up an NPM for the railway network of the metropolitan region of Munich (MMR). This network comprises regional and long-distance trains serving the more rural areas as well as the main city's additional underground and suburban rail services. Only trams were not included in our analysis for reasons of data complexity. For the calculation of node values, we used betweenness and gravity measures for every railway and underground station in the MMR. The gravity measure assumes 'that accessibility at [one specific station] is proportional to the attractiveness (weight) of [surrounding destinations] and inversely proportional to the distances between them' (Sevtsuk et al., 2016, p.12). In contrast 'the betweenness of a [station] is defined as the fraction of shortest paths between pairs of other [stations] in the network that pass by' (Sevtsuk et al., 2016, p.12).

With these two complex components, the calculation of the node-values could be quite standardised. To widen the node value's meaning we tried to add some extra information about the stations' inherent qualities. Therefore, we analysed the infrastructure and facilities of the stations such as Park & Ride areas and the possibility to charge electric vehicles. However, adding more criteria to our analysis did not make our analysis more accurate, so we decided to rely on the sum of gravity and betweenness.

Due to this extensive data analysis, it was simple to deduct the place values. In order to define it, we examined the number of inhabitants living in the stations' catchment areas to a radius of 600 metres, as well as the socio-economic services in the areas, which were classified by a ranking system including all enterprises, larger concerns and educational facilities. In addition, the cultural and leisure opportunities were considered. The first phase was concluded by the set-up of the node-place diagram and its interpretation.

The results of the data output of the first calculation gave a consistent and argumentative overview of the railroad stations of the entire MMR. Locations with a high frequency, line quantity and population density as well as services yielded a high node and place value (each on a scale of 0 to 100), such as the Munich Central Station (MHBF in the chart below, with node =100, place=88) or Marienplatz München (MMAR in the chart below, with node=50, place=94). Besides their high importance for commuters and travellers, these places also offer a high range of facilities such as high retail, office or housing density. Furthermore, stations with high node values and low place values in comparison, including Ingolstadt Central Station (IHB in the chart below, with node=68, place=50), were identified (Figure 8).

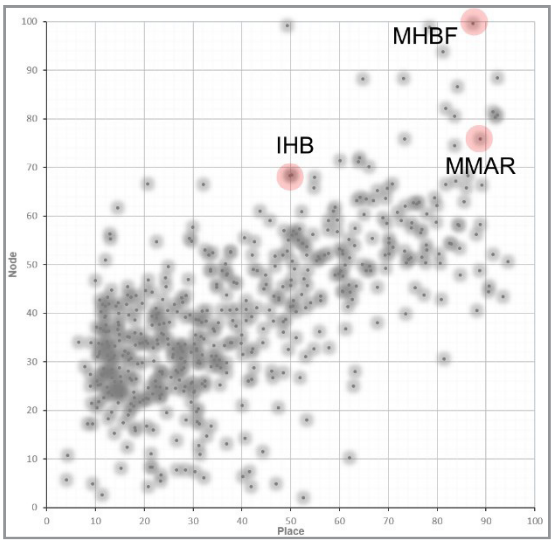
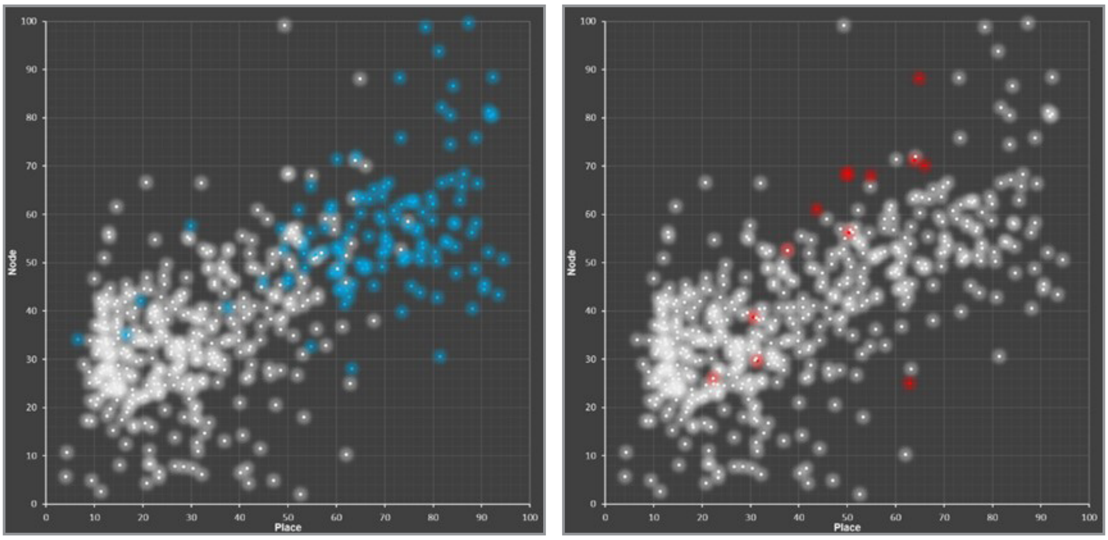


Figure 8: Node-Place-Diagram of the Metropolitan Region of Munich. Source: Authors' interpretation

After detailed consideration, we had a closer look at the nature of the investigated cities and locations. This reflected the results in a new way, as shown in Figures 9 and 10.



Figures 9 / 10: Node-Place-Diagram of the Metropolitan Region of Munich with Munich's stations highlighted blue, other smaller cities highlighted red.
Source: Authors' account

Some problems in understanding occurred with regard to the interpretation of the chart. Some stations are located in unexpected positions. Through closer examination we got concluded that Bertolini's calculation model is disputable. With the metropolitan region being a very diverse area consisting of dense city structures as well as extremely rural areas, it is questionable as to whether one can compare the same data for stations that are located in very different locations. Furthermore, in some areas the importance of the railway network is not as high as it is in other areas. For example, cities like Ingolstadt and Augsburg that are a lot smaller than the city of Munich are not covered by an urban railway system. This phenomenon is supported by our calculation of the inhabitants per railway station value. As shown in Figure 11, a city like Ingolstadt would need 14 additional stations in its railway network to reach a coverage similar to that enjoyed within Munich. Ingolstadt has fundamental problems with motorised individual traffic, but the essential information about the connection of public transport coverage and urban development could not be deduced from the previous model.

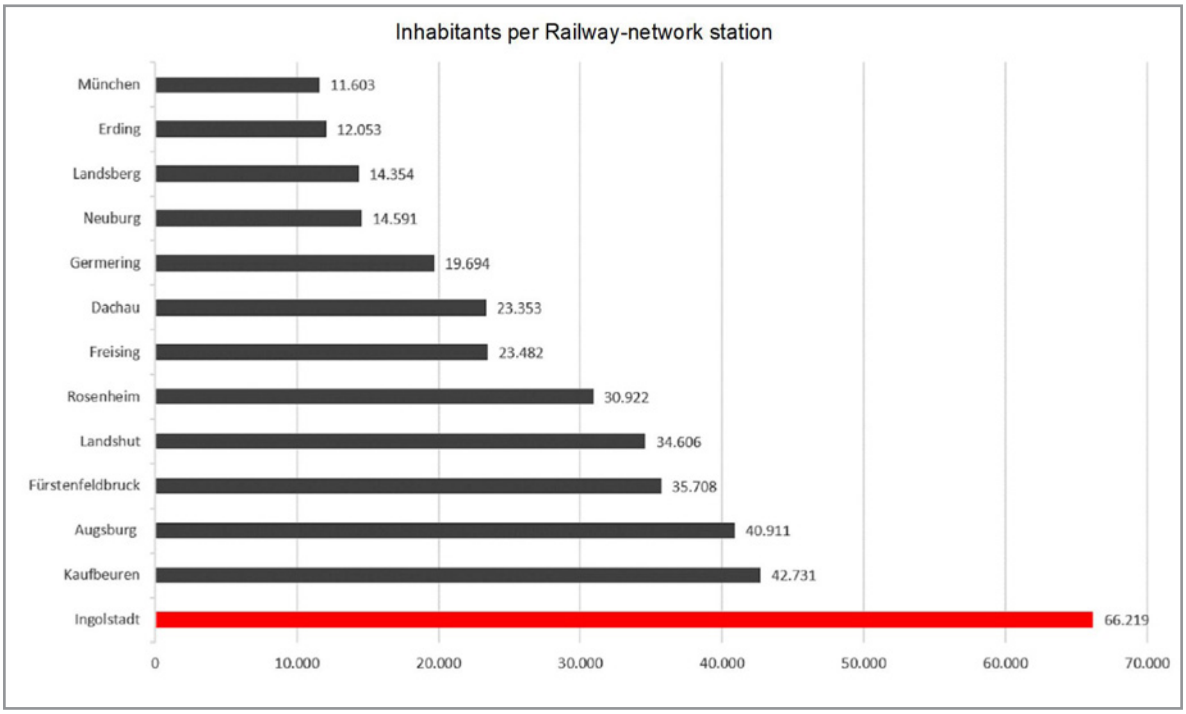


Figure 11: Inhabitants per Railway-network Station in the Cities of Metropolitan Region.
Source: Authors' calculation

An adapted calculation is needed as a result of our examination of the city's public transport system and scale. The hypothesis was that a systematic adaption of the node-place model is needed for the suggestion of interventions to reduce the centrality and accessibility deficits in cities such as Augsburg, Ingolstadt or Rosenheim in the MMR. These cities' public transport is highly dependent on their bus networks. We concluded that an adaptation was necessary since the role of the bus system in these cities was not incorporated in the prior calculation.

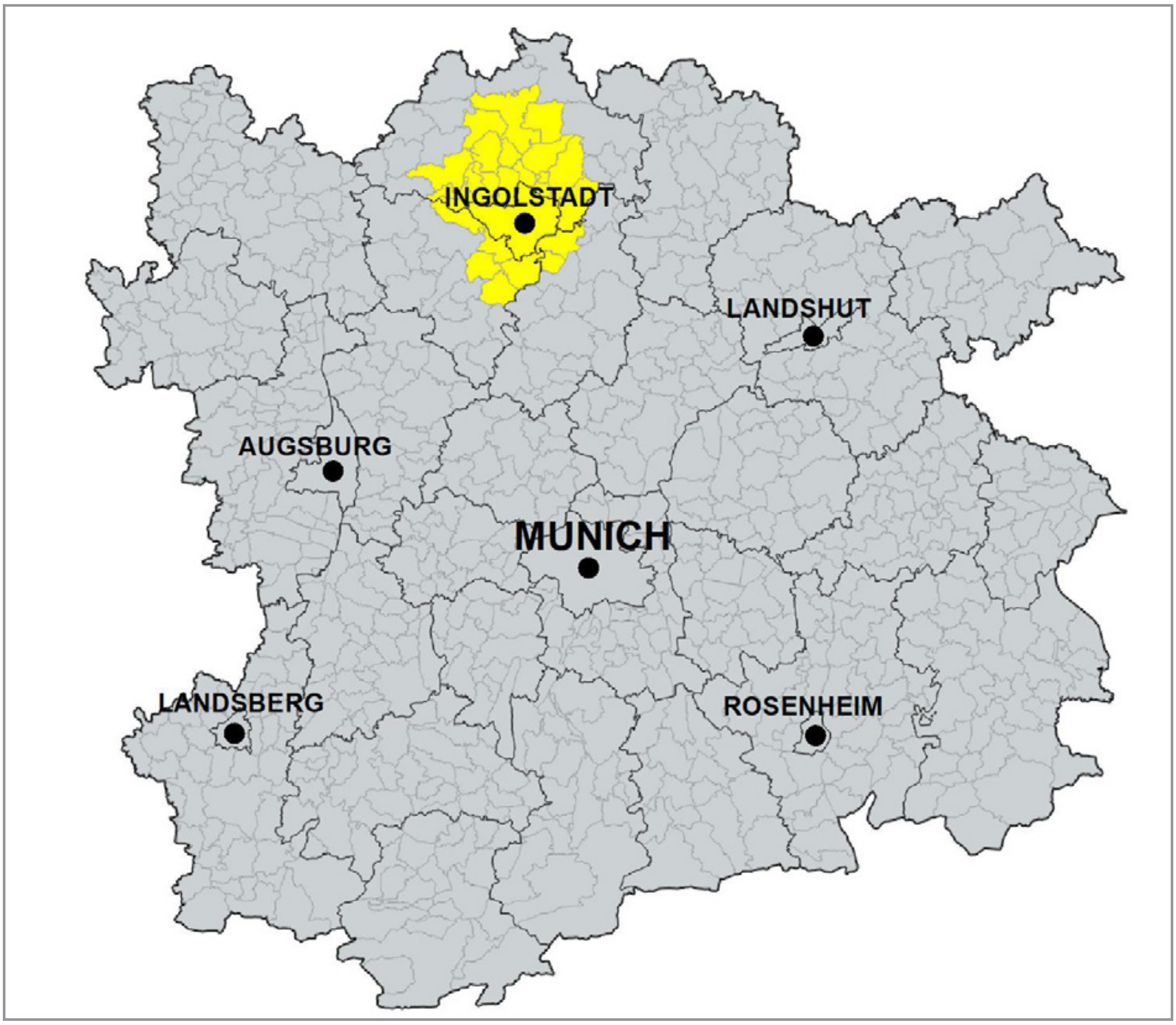


Figure 12: Munich Metropolitan Region. INVG area highlighted. Source: Authors' account

The main reason to examine the City of Ingolstadt is shown by the calculation of inhabitants per railway station (Figure 11), which is the highest in the metropolitan region. The conclusion, as suggested by the results, that there is no working public transport, is misleading. Rather it is because the public transport is organised through a bus system - a system that was completely neglected in the first phase of our analysis. Resultantly, the second phase included a focus on this bus system. To ascertain the values of place and node, all stations in the bus network of the INVG (the city's public transport corporation) were analysed (Figure 12). The place value for each bus station consisted of the same factors as in the first phase calculation, but the catchment area was defined smaller; 200 metres. The radius of 200 metres was chosen because it represents a reasonable walking distance for users of the bus network. The data of gravity and between-ness, in accordance with the definition described above, was calculated by GIS Analysis for every bus station in INVG's network through the Urban Network Analysis Tool designed by the City Form Lab of Harvard University. We then set up a new node-place-diagram for the INVG bus system (Figure 13).

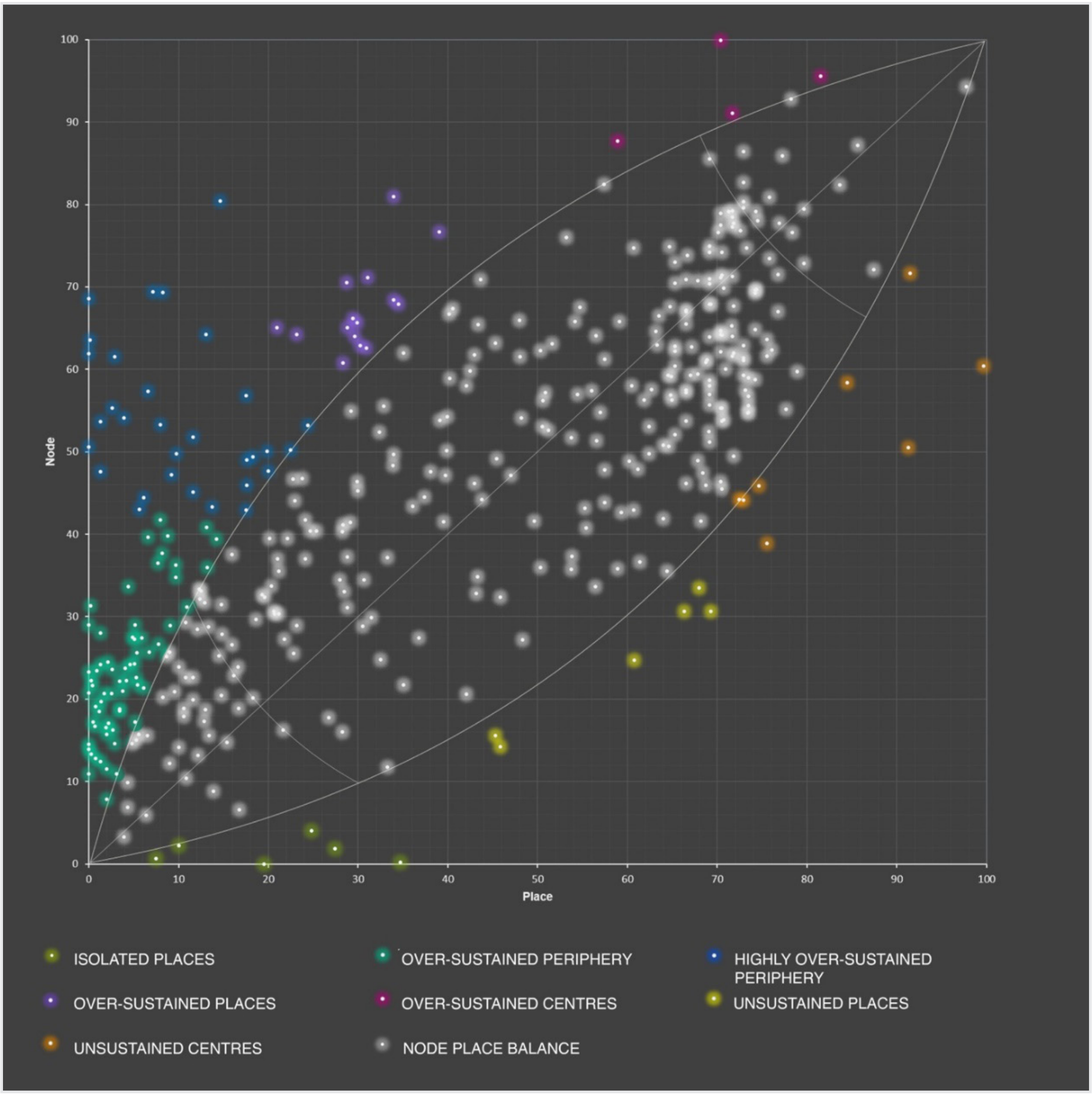
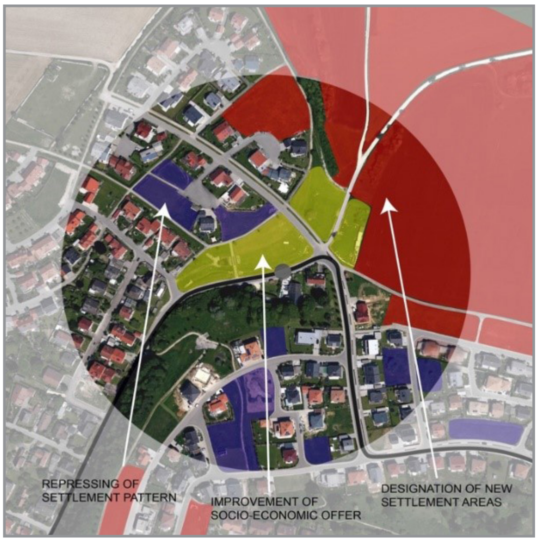
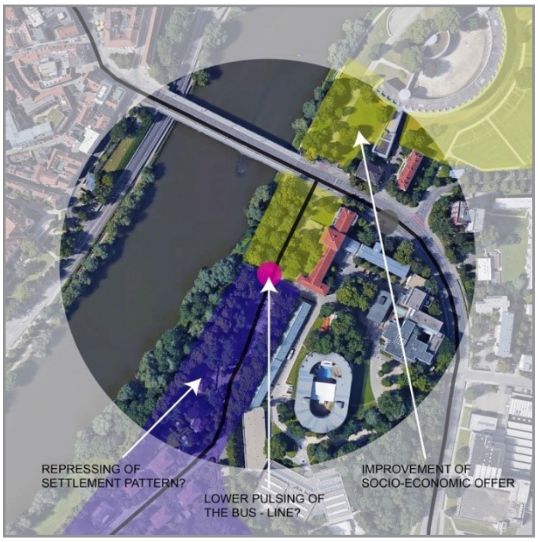


Figure 13: Node-Place-Diagram of INVG Area. Source: Authors' interpretation

In the third and last phase of the project, the applicability of this new model was tested. A catalogue of very different planning tools (such as settlement densification, founding of new settlements, changing frequency of bus lines) in the field of public transport in spatial and urban development were introduced. Each single intervention of this catalogue was classified by its impact on the position of a station in the node-place model, whether or not it changed the node or the place value. To validate these evident actions in other contexts, working examples of stations in Ingolstadt were highlighted. To make a selection, a cluster analysis of all the bus stations was undertaken. The clusters were defined by the station's position in the node-place-diagram in relation to the 45° line. Seven different kinds of stations were identified: isolated places, over-sustained places, over- and highly over-sustained periphery, over-sustained centres, unsustained centres, and places. For each of these clusters one outlying example was selected. Every suitable intervention of the catalogue was taken into consideration. In some cases, this approach delivered logical and working solutions. In other cases, the outcome was not definitive and, in some instances, illogical. This was because the actions demanded by the station's position in the model did not fit with the actual place and its surroundings. It does not make sense to densify the urban structure around a station which is classified as an over-exploited place just because the charted results suggest this. Sometimes an overstated infrastructure provision is a result of factors far beyond planning mistakes. It just makes sense that, for instance, a station near an attractive park needs to have high accessibility so as to make the park fully open to the public. To claim densification here is not just illogical but counterproductive.





Figures 14 and 15: Useful Instructions Deducted from the Model for the Station Andreas-Schmöller-Strasse (over-sustained periphery, left) and Questionable Instructions for the Station Brückenkopf (over-sustained centre, right). Source: Authors' interpretation

To conclude, working with the NPM is, at first sight, helpful in analysing the relationship between public transport and urban development. The model, and especially its visualisation in terms of a diagram, is comprehensible and gives a better understanding of the interdependency of transport and development. It offers a good base for discussion of the various participants in urban development. Urban researchers, municipalities, investors, and all other actors in the development of cities have an easily discussable and understandable model.

However, there are problematic aspects. The diagram leads to quick and often false assumptions based on the oversimplification of a rather difficult and complex field. The simplicity of the XY-chart leads to reductionist conclusions. Another problem was identified: the well-served station 'Brückenkopf' in Ingolstadt (node=87, place=40) is a touristic place, where a museum and the nearby Klenzepark are located. The area is characterised by wide green and open spaces (Figure 15). According to the model's high node value, densification was suggested to position the station in the accessibility area of the diagram. This case demonstrates that the model gives a first-hand, simple overview of the stations and their future strategies. Irrespective of this, the spatial situation of all stations also needs to be considered.

Furthermore, the systematic thinking of the calculation of node and place values is only indicative of the current situation. Future investment and development are not considered or projected. The model and diagram can only be seen to support initial research and to be indicative of possible interventions. Additionally, the calculation results are only relative to each other. There are no absolute values. The selection of parameters for the calculations and the quantification can be questioned as more subjective than objective. To simplify the process, only one city public transportation network (Ingolstadt) was examined. The interaction between different cities was not considered. Therefore, the gravity and between-ness values were not accurate, especially on the boundaries of the public transportation network of the municipality.

In the case of Ingolstadt, the predominant public transport provided is the regional bus system of the Ingolstädter Verkehrsgesellschaft GmbH (INVG). However, in the earlier analysis, just rail-bound traffic was considered. Thus, the transport system of Ingolstadt could not be evaluated on a smaller spatial level. This fact does not prove the model false. Rather, it makes it more difficult and time-consuming to analyse and calculate the values in order that they are comparable to the rest of the stations in the MMR. An exact alternative for such assessment is not suggested. This points to the vulnerability of the model and more subjective evaluations. The evaluation of node and place values for every city has to be done at both the macro and micro level spatial standard, although this makes the model less comparable where a wider spatial scale is used.

Furthermore, the calculated values are specific to the public transportation system. Node and place values cannot be compared across systems. Another critical point is that the public bus network is a flexible and small-scaled system. The system of the node-place model is based on transport-oriented development. The bus system is not based on this approach. Finally, all outcomes - clustering as well as indicated interventions - need further examination and discussion.

4. Conclusions

The reflections of both the Architecture and Urbanism students pointed out various issues while operationalising Bertolini's NPM. These can be categorised into three groups of issues: underlying assumptions, calculation and interpretation.

Bertolini (1999, p.201) defines a node as the 'potential for physical human interaction' and place as the 'realisation of potential for physical human interaction'. Implicitly, he argues that public transportation infrastructure is a 'given' resource, which planners can exploit by redeveloping areas around stations. Our analysis shows that this argument is plausible as long as the majority of public transport is realised on rail infrastructure. Both the railways and its stations are long-lasting investments that are relatively resilient to changes in funding and planning policy. It is, therefore, not only in the developer's interest, but also in the interest of public authorities to utilise the potential created by such infrastructure investments. The studio work on Munich demonstrates that the NPM leads us to areas that are worthy of consideration for redevelopment.

This was unfortunately not the case for the city of Ingolstadt. The students' first attempt to identify potentials across the entire region were quickly limited by the extent of rail-based transport infrastructure. An initial NPM that only included rail services rendered most areas of major cities across the MMR undesirable for redevelopment, despite the fact that these cities are important economic centres. Instead redevelopment should have happened around stations in peripheral areas. This would lead to a clustered, but dispersed settlement structure, while potential for general inner-city and brownfield developments in cities without rail-based public transport were neglected.

The inclusion of bus services puts the underlying assumption of public transport as a resource into question. Bus services require little specific infrastructure. Transportation authorities change bus services frequently to satisfy demand. Taking the bus-service-based public transport network as a given infrastructure is, therefore, unjustified and led us to conclude that the premise of the studio should be adjusted to development-orientated transportation (DOT). This is obviously a fallacy, because DOT is the simple adjustment of public transport according to demands and – as argued – this is only possible for bus services. The application of the NPM in the Ingolstadt case distracted us from the main issue; that the city is in desperate need of rail-based public transportation instead of ineffective optimisation of its bus services.

We conclude that Bertolini's NPM should only be applied in regions where rail services carry the majority of public transit across the entire region. Even in the much more successful application of the model (in the case of the City of Munich), we realise that, despite the density of rail and tram services, the calculation of the node value does not easily account for non-motorised transportation modes such as cycling and walking. An underlying problem of the NPM is that it is a mono-modal concept. Though this issue limits the applicability of the NPM geographically, it does not necessarily impair its usefulness to boundary objects that bring together students from various disciplinary backgrounds.

The second group of issues arises from applying the abstract NPM and calculating concrete node- and place-indices. Bertolini's (1999) paper implies the model's intent to be applied by citing its application as part of two master's theses at Utrecht University. He does not, however, provide a proven and tested way of calculation. It is suggested that multi-criteria analysis is used. Our experience shows that the results are not necessarily improved with more criteria applied. Choosing, collecting and weighing data requires a deep understanding of the interrelation of various criteria affecting public transit service and commuters' behaviour. Whilst we do not doubt that advanced modelling could yield excellent results, we cannot verify the expectation that the NPM can be easily used by both transportation and development experts. Planners with limited expertise in modelling will quickly reach their limits and will just change their calculations for the worse by introducing additional criteria. Moreover, the more criteria introduced, the more difficult the interpretation of the values becomes. Perhaps the success of the NPM is explicable by the intriguing nature of most popular games - that they are easy to understand but hard to master. This may be an excellent feature of a game, but it makes the NPM less functional as an easy-to-use layman's tool for planning across disciplinary fields.

Interpreting the results is the last, but perhaps most important, challenge in using the NPM. Both groups of students pointed out that the premise of Bertolini's model is easy to grasp. It quickly led both groups to discuss measures that could be taken to bring both the node- and place-value of an area into equilibrium. However, a tendency towards generalisation and oversimplification resonated consistently. Almost all top-down approaches reveal, under closer inspection, other criteria that may play a bigger role than the ones calculated as part of the model. Obviously, it is surprising that an area with great potential for redevelopment according to the NPM cannot be redeveloped due to environmental, economic, social or aesthetic concerns. It would, however, be unfair to accuse the NPM of being misleading in such cases because it does not promise to combine these domains with urban development. The NPM is however introduced to facilitate transport-orientated development – hence the interplay of transportation and development planning. As such, it delivers interesting results in many cases whilst failing in others. One of the Munich design projects demonstrated that the appropriate measure can be related neither to node- nor place-value but to the qualitative improvement of public space.

After testing the NPM for two semesters, we conclude that the NPM cannot necessarily serve as the sole boundary object in order to connect the fields of transportation and development planning. We identified three shortcomings, of which the latter two impair significantly the NPM's ability to serve as boundary object:

The NPM is most applicable under spatial conditions of dominant rail-based transportation, since bus networks can easily be redesigned and do not justify changes in the built environment as strongly.

Using the NPM as a calculation model requires a deeper understanding of modelling to be sufficient for robust interpretation.

The NPM is prone to oversimplification - working across the boundaries of development and transportation planning requires a multi-method boundary practice.

5. Further Research and Implications for Planning

Spatial planning bases itself on various disciplines, each of which holds valuable conceptual and methodological knowledge. Planners are, therefore, constantly challenged by the need to gain deeper insight into a specific discipline while keeping an overview and interrelated understanding across several of them. It is important that educators raise awareness amongst students as to the need for this duality of knowledge in planning. Otherwise, planning graduates may fall into the trap of applying planning principles and concepts blindly.

It is well established among planning scholars that, besides universal challenges, local specificity plays an important role in planning practice. There is no typical planning case. Planning problems are essentially unique (Rittel and Webber, 1973). The internationalisation of research and practice has led to an increase of transnational flows of ideas (Healey, 2012). As such, scholars in Germany as well as other countries have embraced Bertolini's NPM. Although the contexts of the Netherlands and Germany seem to be very similar, local differences are enough to bring into question some of the underlying assumptions of the NPM.

The key learning outcome is perhaps not the application of the appropriate boundary object to link transport and development planning, but the awareness that multi-methodological planning approaches across disciplinary boundaries need to be developed. The NPM can be a valuable didactic instrument. Its simplicity prompts us to think about the connection of transport infrastructure and land-use development, but it also quickly reveals its insufficiency as a singular tool to bridge the gap between disciplines. Using a boundary object such as the NPM prevents students from relying on disciplinary ways of thinking and doing, and it replaces intricate disciplinary knowledge with simplistic interdisciplinary concepts. Hence, the NPM needs to be combined with progressively more abstract and complex spatial theories from complementing courses.

Preparing students for the interdisciplinary field of planning practice requires the development of fully-fledged cross-boundary experts. Bringing together disciplinary experts such as architects and engineers in a course is a valuable exercise to raise awareness of each other's disciplines but it does not replace the planner as the mediator between spatially relevant disciplines. Spatial development requires a boundary discipline that is able to broker knowledge between various disciplines (Gilliard and Thierstein, 2016).

Thus, we recommend that planning educators look further into two issues:

- The core of the planning curriculum could be competencies for brokering knowledge between spatially relevant disciplines – such as boundary objects and boundary practices. We feel that these competencies are more likely to be of a methodological nature. We should therefore shift our focus from better planning outcomes to better planning processes. It may not be the built city that we should study as planners but the way that the city has formed over time.
- Planning degrees must connect to other disciplines. Learning to broker knowledge between disciplines requires disciplines to broker knowledge between each other. This trivial statement is easily neglected when planning as a discipline establishes its own unique ways of thinking and doing. Perhaps, therefore, a planning department must sit horizontally within otherwise vertically organised universities.

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