Road Network Design with Space Syntax in Vendas Novas

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Abstract. The city of Vendas Novas, Évora, Portugal, is crossed by a national road. Currently, 30.000 to 35.000 vehicles cross the city, of which more than 2.000 are heavy motor vehicles. Due to the negative effects of the high levels of traffic, the city council as long proposed an alternative route to Estrada Nacional 4.

To better understand the effects of an alternative route to the city of Vendas Novas our study applies an axial map analysis to the city current road network system and the two proposals currently being studied by the local city council and national infrastructure management entity. Based on this analysis a new proposal was drawn by our team to optimize the diversion of traffic from the city centre.

Through the application of an axial map analysis, in this study our team hoped to demonstrate and disseminate near the local city management entities the potential and validity of this tool to the current and future planning of cities and, in particular, road networks.

Keywords. *Space Syntax, Vehicular Traffic, Road Network*

Introduction

Our team premise is that Space Syntax can be used, not only as an analysis tool of urban projects, but also to inform the design process of road networks due to its capacity to cheaply and quickly estimate vehicular traffic.

Space Syntax, in particular Axial Maps, is commonly used as a quantitative analysis tool, mainly to predict pedestrian use preferences and flows. Although research on traffic has been carried out, this use isn't yet a common practice. Though other tools are capable of yielding a more detailed simulation of vehicular traffic, e.g. SATURN, they demand a larger amount of preliminary data and highly detailed proposals. Additionally, these simulation systems aren't as comprehensive as Axial Maps or Angular Segment Analysis, which allows a broader funderstanding of the effects of a proposal on an urban area.

Our work follows Turner's (Turner, 2007) observations of the correlation between vehicular traffic and choice levels in angular segment analysis, in addition to previous work in pedestrian and cycling traffic.

We present a comparative analysis between three proposals for an A road alternative route in Vendas Novas, Portugal. For this process we utilized a conjugation of methods to analyze the various proposals that range from a traditional comparison of Space Syntax spatial measures to traffic estimations.

This work was accompanied by the Urban Management Department of the Municipality of Vendas Novas with various meetings to receive feedback throughout the process.

The remaining sections of this paper are structured as follows: Section 2 summarizes related work in the areas of Space Syntax and traffic prediction; Section 3 describes our experimental methodology; the current road network and the various proposals are presented in Section 4; in

Section 5, we discuss our results; and finally, we close the document with our conclusions and suggestions for future work.

Related Work

Space Syntax theory introduced in 1976 by (Hillier et al., 1976) and his colleagues at University College of London brought forward a novel analytical and quantitative methodology to describe complex patterns of spatial organization capable of highlighting causal relationships between form and social patterns of use and occupation (Ourique, 2014).

Initial studies on Space Syntax indicated a high correlation between Integration and use of space (Dalton et al., 2010; Hillier et al., 1993; Penn et al., 1998; Serdoura, 2006; Turner, 2007). Since then research (Barros et al., 2007; Emo et al., 2012; Freeman et al., 1991; Kazerani and Winter, 2009; Kivimäki et al., 2016; Newman, 2005) have broaden the use of syntactic measures, showing that angular segment analysis and new measures yield higher correlations with pedestrian flows when compared with previously established methods.

In 2007, Turner developed a study indicating that Angular Segment Analysis, or ASA, in particular Choice, yield promising correlations levels to pedestrian flows. Jiang, in 2009, published a study comparing the correlation between various pedestrian and vehicular counts and multiple syntactic measures, further validating Space Syntax as a predictive tool for pedestrian and vehicular flows.

As of 2012, Hillier, Yang and Turner introduced the new measure Normalised Angular Choice, or NACH, to ASA. This new measure was introduced due to the rising need to use Choice on movement prediction in research and design. It provides a renewed understanding of cities, allowing not only for visual but also numerical comparison of various urban systems.

Methodology

Axial Map Design and Analysis

The work here presented used a base axial map (Figure 13) which considered all paved roads within a 10 kilometres radius from the urban limit of the city of Vendas Novas. Exceptionally, road segments beyond that limit were considered when a major intersection occurred within an extra 2 kilometres range.

Figure 1. Base Axial Map – ASA NACH r1000

This base axial map considered not only the city of Vendas Novas, but also 11 other surrounding villages.

Variations of this axial map were then created for each alternative route proposal. The original proposals – the PDM (Câmara Municipal de Vendas Novas, 1999) and the CM 2020 (Município de Vendas Novas, 2005) – didn't consider intersections of the pre-existing roads, which were introduced during our design process, mainly through the extension of the existing streets and avenues. The various axial maps were then converted into segment maps with the open-source software DepthmapX.

From DepthmapX we extracted several measures from the axial map analysis (ASA) –within radii N, 3 and 5 – and from de segment map –within radii N, 500, 1000 and 2000. Although we focused on ASA with NACH, due to their previously verified correlation with traffic counts, the Normalised Angular Integration, or NAIN, was also considered in addition to the more traditional AMA analysis with Integration, Depth, Connectivity and Choice.

Current Traffic Data

For this project the team used the traffic data collected in 2005 by (Farias et al., 2007; Transitec, 2005). Even though the traffic data were collected in 2005, there's no new data currently available for the roads considered in our study (EN4, Misericordia Avenue, 25 de Abril Avenue).

Traffic Estimation

For the estimation of the traffic variation generated by the various proposals, our team used a Simple Linear Regression between the available traffic counts and NACH values of the corresponding street sections, achieving a moderate correlation of 0,6.

The original traffic counts were expressed in Equivalent Vehicle Unit/Day (UVE/d) where a large vehicle represents 2 UVE and all the other types of vehicle represent 1 UVE.

Previous work in this area used similar methodology for retrospective analysis, yielding correlation levels of 0,818 and higher (Hillier et al., 1993; Penn et al., 1998).

Current Road Network and Proposals

The city of Vendas Novas is divided into four main sectors (Figure 14): the historical quartier established around the old Royal Palace, currently the Military School of Artillery; in the east, the Industrial Hub; in the north-east, a low density suburban residential area; and in the west, the newest urban expansion area that remains underdeveloped.

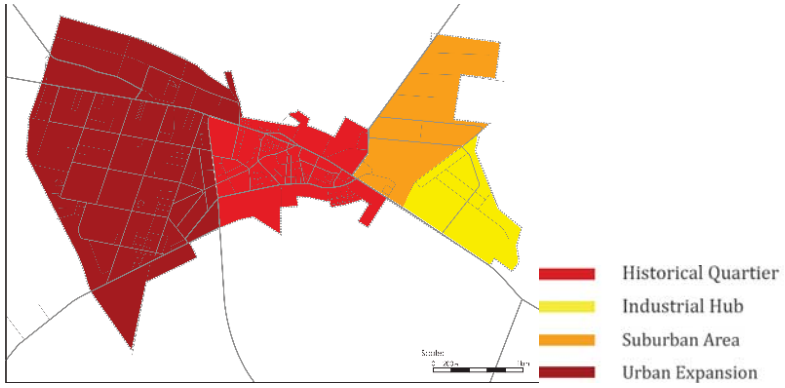

Figure 2. City sectors

Current Road Network

The current road network of Vendas Novas (Figure 15) is, in its majority, constituted by small local streets and three main avenues: the EN4, Estrada Nacional 4 – Estrada do Alentejo Central, that crosses the city centre, from west to east; 25 de Abril Avenue that crosses the public service centre, from west to south-east; and Misericordia Avenue which separates the historical quartier from the western urban expansion area.

The EN4 is an A Level Road that begins in the Metropolitan Area of Lisbon, in Montijo, crosses Central Alentejo, ending in the Portuguese-Spanish border in Elvas-Badajoz.

In Vendas Novas, the EN4 crosses the city centre, where the speed limit is reduced from 90km/h to 50km/h, with a 500m stretch where 30km/h speed limit is implemented. Additionally, the EN4 cuts through the main commercial area of the city, separating the main city plaza from the shopping promenade. With the increase of traffic flow, the promenade was redesigned with a high density green barrier to mitigate the negative effects caused by the road.

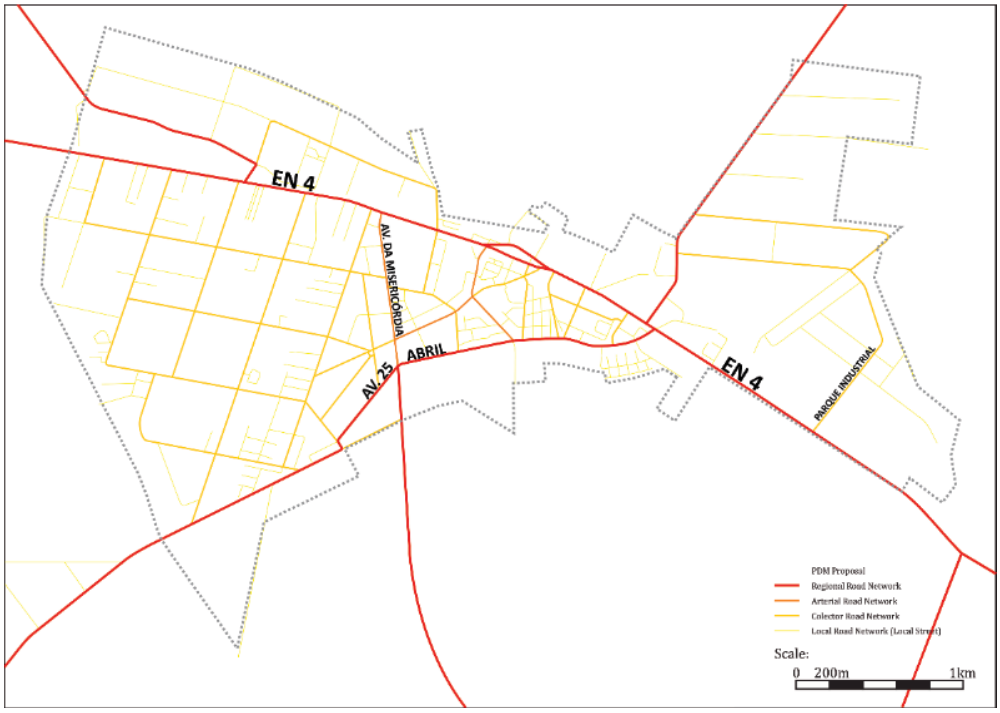

Figure 3. Current Road Network

PDM Proposal

In 1999, the Municipality of Vendas Novas published the current City Plan (Câmara Municipal de Vendas Novas, 1999) (Figure 16) that introduced the western expansion zone and proposed an EN4 alternative route. This design consolidated the southern urban limit of the city and tried to divert as much traffic as possible from the city centre.

Figure 4. PDM Proposal

CM 2020 Proposal

In 2005, the Municipality created a new Strategic Plan for the City (Município de Vendas Novas, 2005) where it redesigned the original proposal for the EN4 alternative route (Figure 17), expanding it to include the village of Bombel, 3km west from the city limits, allocating this area as

a new urban expansion zone. This plan wasn't well received by the population resulting in an amendment that removed the proposed urban expansion zone but kept the new road design.

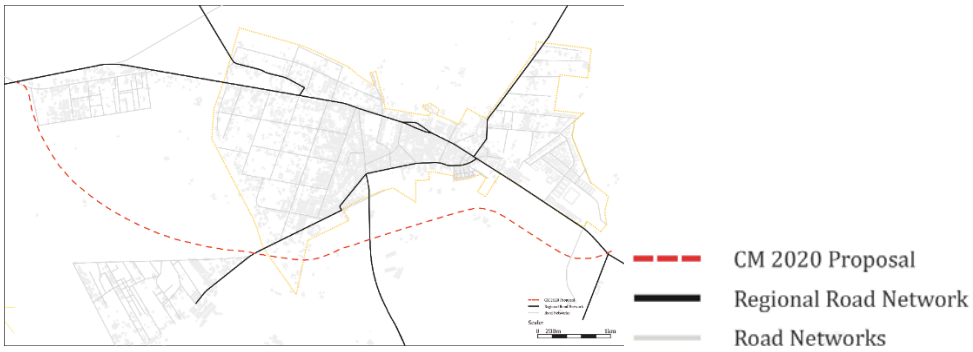

Figure 5. CM 2020 Proposal

Team Proposal

Our team proposal (Figure 18) considered the results of the previous designs and created a circular road that encloses the current city and planned expansions areas.

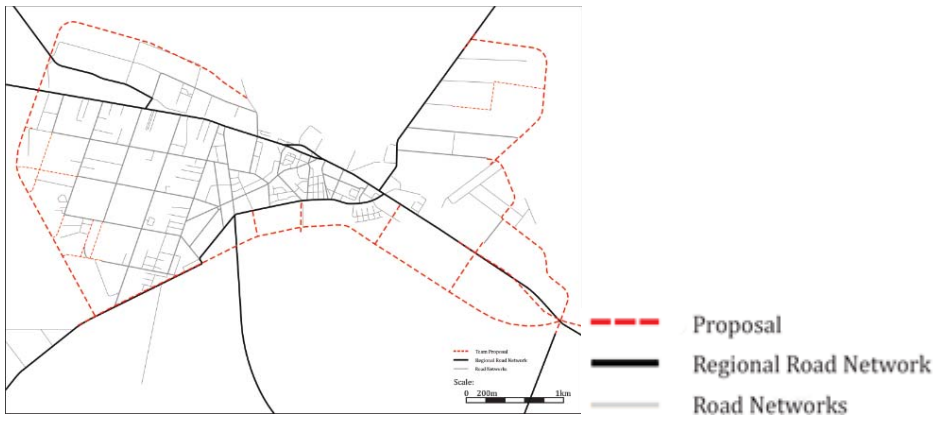

Figure 6. Team Proposal

The design process was incremental, recurring to Space Syntax to optimize the traffic diversion and the general benefits to the city as a whole. That was achieved by increasing local measures' results in the pre-existing road network and global measures in the proposed circular road.

Results and Discussion

Space Syntax analysis of road proposals

The Axial Map and Angular Segment Analysis revealed that the C.M. 2020 proposal has the weakest ability to divert traffic. It has the lowest results across all measures, especially in NACH r1000 (Table 1) where it is 47,13% lower than all the other proposals.

	Global	r500	r1000	r2000
PDM	5,310	1,197	2,141	3,215
CM2020	4,813	0,644	1,132	1,997
TEAM	5,944	1,111	2,187	3,326

Table 1. Values of Global, r500, r1000 and r2000 NACH for each proposal

It is our understanding that this discrepancy is due to the original proposal containing an extension to the west urban expansion zone that was later removed.

Comparing the other two proposals, both are well balanced. The Team proposal attains a lower NACH R500 and slightly higher values in NACH Global, R1000 and R2000 than the PDM proposal, characteristics that are in line with the main purpose of the new route.

In the remaining syntactic measures – NAIN, Axial Integration, Depth, Connectivity and Choice – no major difference was observed between the PDM and Team proposal.

Effects of the proposed road on the current road network

By analysing the various measures, we verified that the C.M. 2020 proposal does not meet its intended goal, the diversion of traffic from EN4. Visually no major effects are registered on the system, while quantitatively the only major effects are registered in 25 de Abril Avenue, with an estimated 41% decrease of traffic, and in Misericordia Avenue, with an estimated 44% increase of traffic (Table 2).

	Current	PDM	CM2020	Team
EN4	13000 UVE/D	- 18%	- 10%	- 33%
25 de Abril Avenue	9000 UVE/D	- 41%	- 30%	- 66%
Misericordia Avenue	5000 UVE/D	+ 44%	+ 54%	+ 53%

Table 2. Current Traffic Count (UVE/D) and estimated variation for the 3 main roads in the city

The PDM proposal registered an 18% decrease of traffic in EN4, in addition to a small increase across Axial measures on the Historical quartier. This indicates a potential lowering of non-stop traffic in the EN4 and no major influence in other types of traffic.

On the Team proposal, there are major variations in all measures. Visually, comparing the Axial measures, we recorded a large increase of values on the historical *quartier*, indicating a consolidation of this area as the city centre.

By analysing the estimated traffic variation, we concluded that our team proposal effectively diverts traffic from the EN4 with an estimated traffic decrease of 33%. Additionally, we registered a significant increase of traffic in *Misericordia* Avenue, possibly indicating the potential transformation of this road into the main traffic distributer of the city.

Proposed routes traffic predictive analysis

By comparing the traffic estimation of the various proposals, Table 3 allows us to verify that between all of them, the C.M. 2020 has the lowest ability to divert traffic from the city, with only 1220 UVE/D utilizing the new route.

	PDM	CM2020	Team
Proposed routes	5422 UVE/D	1220 UVE/D	10798 UVE/D

Table 3. Traffic Estimations for Each Proposal

The PDM proposal, though achieving significant levels of estimated traffic (5422 UVE/D), did not achieve the levels desired by the Municipal Council – 6500 UVE/D or half the current EN4 traffic.

On the other hand, our team proposal attracted almost 11000 UVE/D, not only exceeding the minimal traffic volume requested by 66%, but also establishing the proposed route as a clear alternative to the EN4.

Considering the data presented in the previous sections, the team believes that our design generates a good alternative route to EN4 not only in a national level, but also for regional traffic.

Conclusions and Future Work

Throughout this project, the use of Space Syntax as a rapid analysis tool to refine a project proposal was essential. It allowed our team not only to adjust the outline of its proposal, but also to understand the effects that the various modifications had on the road network at a city-wide scale. This gave us the opportunity to steer the proposal towards a regional distributor, in addition to a national alternative to EN4.

We consider that traffic prediction capabilities of Space Syntax need refinement but revealed to be significant in this preliminary design stage. Although our team is confident in the results obtained, none of the proposals had, at the time of this analysis, detailed intersection or cross-section design which could ultimately create specific traffic dynamics that Space Syntax overlooks, generating the need for a full-fleshed traffic simulation.

The project was well received by the Municipality, even though it met some resistance in the beginning of the process, probably due to the unfamiliarity with Space Syntax. This leads us to believe that there is a clear need to disseminate Space Syntax to key Portuguese stakeholders in urban planning.

Finally, we believe that additional work is needed to understand where the introduction of other traffic flow simulation tools is optimal in the design process of road networks and to guarantee the validity of the Normalised Angular Choice as a vehicular predictive measure.

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