

Quantifying the impact of access management on urban planning

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ABSTRACT: Besides the obvious direct impacts that proper access management has on accessibility, road safety and other related issues, there are significant further aspects that are often overlooked, or not clearly assessed. In this paper, we look at the relationship between access management practices and urban planning, in a systematic, rigorous way. In fact, while the relationship between these two aspects of planning is easy to demonstrate, a systematic approach that identifies the links and quantifies their interrelationship appears to be missing. It is clarified that the objective here is to quantify the deviations from access management guidelines and not develop a single numerical index that could easily be combined across areas.

A structured methodology is developed, building upon the state-of-the-art on the topic, including pertinent legislation. This methodology includes a phase dealing with the development of a number of suitable indices, a data-collection phase, an application phase, and an evaluation phase.

For each individual road element, a number of indicators are calculated and ultimately aggregated into a single, weighted composite index. These segment-specific scores can then be aggregated to a single score for the network covering a specific subdivision. From an urban planning perspective, property-level indicators, such as distance from the road and lot coverage, are considered as individual indices, which are then aggregated into subdivision-level aggregates.

The final product of this research comprises two aggregate, composite indices; the first reflects the level of road safety of the study area, while the second captures an index of the urban functionality. A sensitivity analysis of the relative impact of key parameters to the final quantitative output is also performed.

The methodology is applied to a specially selected subdivision in the rapidly developing suburb of Agios Stefanos in Athens, Greece. Finally, conclusions are

drawn and recommendations are made for future refinements and extensions of this approach, as well as applications in other regions.

INTRODUCTION

Access management is a very important topic, in the intersection of transportation engineering and urban planning. The importance of the field can be seen from the large number of handbooks and manuals that have been developed, mostly in the United States (Williams et al., 2014; Maze et al., 2000; CPASI, 2008; SWRPC, 2001).

Access control is a key safety consideration for arterial streets (Brown and Tarko, 1999). One way to evaluate the safety of urban arterials is through the development of accident prediction models (Sawalha and Sayed, 2001). Dumbaugh (2010) used negative binomial regression models to examine the safety effects of three roadside design strategies: widening paved shoulders, widening fixed-object offsets, and providing livable-street treatments. The results suggest that only livable-street treatments led to road safety improvements. Dumbaugh and Rae (2009) conclude that community design is strongly associated with crash incidence and underline that the speed and operating characteristics of arterial roads, as well as the design and configuration of commercial and retail uses, appear to be particularly important. The authors indicate that designing communities to have higher-density, more urban design configurations generally appears to help reduce crash incidence, although four-leg intersections pose potential traffic hazards.

Ewing and Dumbaugh (2009) reach two conclusions that counter common expectations, from a transportation point of view, as they find that (i) dense urban areas are safer than lower-volume environments, and that (ii) –at least in dense urban areas- less-“forgiving” designs (such as narrower lanes and traffic calming measures) tend to enhance safety. The first “paradox” may be attributed to the lower speeds, while the reason for the second apparent anomaly may be that less-forgiving designs provide drivers with clear information on safe and appropriate operating speeds.

Dumbaugh and Li (2010) found miles of arterial roadways and numbers of four-leg intersections, strip commercial uses, and big box stores to be major crash risk factors, while pedestrian-scaled retail uses were associated with lower crash rates. The results suggest that improvements to road safety require that planners attempt to balance safety and traffic conflicts, “rather than simply designing roadways to be forgiving”.

The objective of this research is to develop a methodology for the quantification of access management on urban planning. The approach is structured and easy to follow and implement, so that it can be easily adopted. The structure of the remainder of this paper is as follows. The next section provides an overview of the criteria that are used for the development of the methodology, which follows in the next section. An application of the methodology in a case study in a suburb of Athens, Greece, is presented next, followed by a concluding section, which includes suggestions for further research.

BACKGROUND

Based on a literature review and a review of the state-of-the-art and the practice (which have been omitted here due to space constraints), the following road safety and urban planning criteria have been selected:

- Road grade;
- Cross-section (design elements and widths);
- Corner clearance;
- Access point density (on each individual road); and
- Distance (of the plot) from the nearest interchange;

while the following urban planning criteria have been selected:

- Land use; and
- Lot coverage rate.

Although it has not been possible to include all potential highway design and urban planning values and criteria that affect the quality of subdivision, the selected criteria are easily measurable and have a high impact on land subdivision design quality. Additional design criteria and considerations are planned to be incorporated in the analysis in a second improvement phase of the assessment methodology.

METHODOLOGY

The assessment methodology proposed in this study aims at determining the degree of non-compliance of the selected parameters with accepted design values as documented in the U.S. Access Management Manual (2014) and street design background described in design policies, guidelines or regulations. The methodology comprises the following main steps:

Step 0: Preparation of input data

In this step, all required data are prepared, including:

- *Building block data*: These data include the number of the block and the type of land use allowed in that particular area. In addition, information regarding the roads surrounding the building block were collected.
- *Plot data*: These include area, built area, and land use of each individual lot in the building block.
- *Access Data*: For the access management analysis, for each existing driveway, its geometric characteristics and location data was collected.

Step 1: Road Functional Classification

In order to evaluate the area properly, the functional category of each road segment of the subdivision pattern is determined. The conventional road classification system was followed in this case (Gluck et al., 1999): (i) Freeway, (ii) Arterial, (iii) Collector, and (iv) Local street.

Step 2: Determination of Road Grade Score

- a. The measured slope is compared with the maximum slope set by the regulations or policies for each road category (Step 1). The compliance rate was calculated for each road.
- b. This process is repeated for each road individually and the scores referring to the roads are calculated.
- c. The individual scores are combined in a weighted average score for each road type.
- d. A generalized grade score is calculated for the entire road network (all road categories) of the area the category scores were further aggregated.

Step 3: Determination of Road Width Score

- a. The measured width is compared with the maximum width set by regulations or policies and the degree of compliance is computed.
- b. This process is repeated for each road segment individually and the scores referring to the roads are calculated.
- c. The generalized road width compliance score of the entire road network is finally determined.

Step 4: Determination of Sidewalk Score

- a. The existence or absence of a sidewalk is assessed through field observations.
- b. Scores are computed for each street.
- c. The study area's total score for the existence or not of sidewalks was determined; accident severity indicators were used to provide the safety effectiveness of a sidewalk for a specific road category.

Step 5: Determination of Driveway Density Score

- a. The driveway density on each road is calculated, and compared to the proposed maximum density per street.
- b. A weighted score is determined for each road category.
- c. Finally, the overall score is calculated using as weights the proportion of traffic volume passing through each road category.

Step 6: Determination of Distance from the Nearest Interchange Score

The accesses on both sides of each road that leads to the interchange are considered. After measuring the distance of the closest to the interchange edge of the access, the measured distance is compared with the minimum distance an access point should have from the nearest interchange, as it is determined by the Access Management Manual (Williams et al., 2014) depending on the type of the interchange. The compliance rate of the road is formulated as the percentage of lots that comply with regulations.

- a. To determine each road category's score, the scores described before are combined.
- b. Finally, the overall average is calculated using as weights the proportion of traffic volume passing through each road category.

In case that an interchange does not exist in the study area this variable can be omitted and one has to properly adjust the weights of the other elements in the final

area scoring as shown in Step 11.

Step 7: Calculate Corner Clearance Score

- a. Corner clearance distances are calculated for each lot (the distance of the access's left (right) edge to the left (right) edge of the building block). The data collected are compared to the ones set by regulations. The compliance rate is calculated for each building block as the percentage of the lots that are within the regulations' limits (both on their left and right side). This process is repeated for each building block individually and the scores referring to each building block are calculated.
- b. In order to export a final score for all blocks, weighting factors for each building block are determined. The weights may relate to the trip generation of the building block according to the land uses it hosts based on the results of other studies (e.g. ITE, 2003; Harwood et al. 2007).

Step 8: Calculate Land Uses Score

The existing land uses are compared to the ones approved by law. The compliance rate is calculated for each building block as the percentage of the lots that are consistent with legislation:

- a. If they are totally consistent, the compliance of each building block to regulations set by urban city plan is 100%.
- b. To draw a conclusion for the entire area, the percentage of total trips, which begin from each building block, is used as a weighting factor.

Step 9: Lot coverage rate

- a. Existing lot coverage rates are compared with the ones allowed by law.
- b. To draw a conclusion for the entire area, the percentage of total trips, which begin from each block, is used as a weighting factor.

Step 10: Criteria Evaluation

To evaluate the characteristics a subjective rating scale from 0 (severe problem) to 3 (insignificant problem) was used, with 0 corresponding to ratings of 0-25%, 1 assigned to ratings of 25%-50% and so on.

Step 11: Determination of the Subdivision Quality Indicators (SQIs)

After each criteria's individual score has been calculated, as shown in steps 1 to 10, it is possible to identify the parts of the study area that need remedy. Furthermore, aggregate indices can also be calculated, which combine all assessment criteria and can be used to succinctly capture the overall picture of the study area.

The first aggregate indicator SQI1 refers to the highway design criteria and expresses the score that the area achieves in terms of safety:

$$SQI1 = \frac{\left(\frac{FSg + FSw}{2}\right) \cdot Wrd + FSS \cdot Ws + FSc \cdot Wc + FSd \cdot Wd + FSad \cdot Wad}{Wrd + Ws + Wc + Wd + Wad} \quad (1)$$

where:

SQI1: Generalized Road Safety Score of the Area under study
 FSg: Road grade score as determined in Step 2
 FSw: Road width score as determined in Step 3
 FSs: Sidewalk score as determined in Step 4
 FSad: Driveway density score as determined in Step 5
 FSD: Distance from the nearest interchange score as determined in Step 6
 FSc: Corner clearance score as determined in Step 7
 WrD: Road design elements weight as determined in Step 1
 Wcs: Cross section weight as determined in Step 11
 Wc: Corner clearance weight as determined in Step 11
 Wd: Distance from nearest interchange weight as determined in Step 11
 Wad: Driveways density weight as determined in Step 11

The second indicator refers to the urban planning assessment criteria and results from the average of the two individual urban planning parameter scoring according to steps 8 and 9 and expresses the functionality of the road network as it relates to the urban pattern imposed by the subdivision of the study area.

$$SQI2 = \frac{FSlu + FScr}{2} \quad (2)$$

where:

SQI2: Generalized Urban Planning Score of the Area under study
 FSlu: Land Uses Score as determined in Step 8
 FScr: Lot coverage rate as determined in Step 9

Indices SQI1 and SQI2 represent the quality of the subdivision pattern of a given area. Because they incorporate a variety of basic design and operational aspects of the subdivision pattern, the described indices could be used as comprehensive measures.

CASE STUDY

The northeast suburb of the Athens metropolitan area in Greece called Agios Stefanos (Fig. 1) was selected for this case study to demonstrate the presented methodology, as this suburb is gradually transforming to a local center for surrounding Athens Northeastern suburbs. Among the reasons making this area suitable for this analysis is its proximity to the national freeway (visible in the north-south direction in the western part of Fig. 1), which has led to an urban plan that considers supra-local activities. Furthermore, due to intense urbanization and development during the previous years, the road network is receiving high traffic volumes, while it has not been upgraded to cope with them. It is clarified that access management needs related to the changing character of the area have not been taken into consideration, so the area is lagging in this respect.

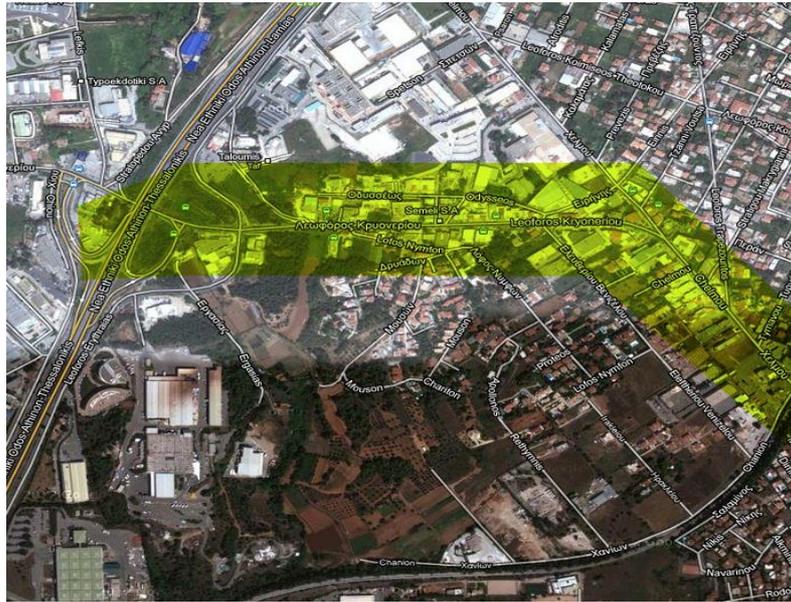


Fig. 1. Part of the Agios Stefanos suburb (major arterial and its surrounding area are highlighted).

In order to collect the data necessary to carry out the described methodology (step 0), the input data of the area were coded, so that it can be possible for designers to cross check easily. Every individual building block, every plot in that building block, and every building located on the plot was named and numbered. Moreover, custom questionnaires were developed and completed, in order to record the data and specific characteristics of each lot or building.

Area Assessment-Performance Management Area (Scorecards)

Tables 1 and 2 show the results of the area assessment according to the methodology described above. The weights were calculated following the procedure described in Step 11 of the methodology.

Table 1. Scores of each traffic planning variable and their weights

Standards	Weight	Score
Road design characteristics	0.15	3 (steps 2 and 3)
Sidewalks	0.3	0 (step 4)
Driveways density	0.2	3 (step 5)
Distance from nearest interchange	0.15	3 (step 6)
Corner clearance	0.2	2 (step 7)
Final score		1.9 (step 11)

Table 2. Scores of each urban planning variable and their weights

Standards	Percentage	Score
Land uses	100%	3 (step 8)
Lot coverage rate	67%	2 (step 9)
Final score	2.5 (step 11)	

Sensitivity analysis

In order to draw a conclusion on how the selected design parameters and their weighting are suitable as an assessment basis for a subdivision area a sensitivity analysis was carried out. In this way, the effect of each variable and its weight in the final result could be measured. For the weighting procedure of each parameter, in particular, it is important to evaluate how sensitive the final result is to their influence, since they have not been calibrated to the specific parameters of the study area, but instead have been transferred directly from international literature. Therefore, the initial uncalibrated weights derived by the formulae in Steps 2 to 7 were modified by 10%, 20% and 30% and their influence was calculated. The perturbations did not result in a significant change of the individual design parameters scores. The most extreme deviations found were around 10 percent from the initial uncalibrated score value, i.e. the impact of the perturbations has been muted.

CONCLUSIONS

In this research, we have presented a straightforward approach for the assessment of the impact of access management on road safety and traffic conditions in an urban area. The objective of the approach is to quantify the degree of deviation from the existing handbooks and guidelines, and provide guidance for policies aimed at improving of this critical situation. The methodology relies on field surveys using structured questionnaires and is based on highway design and urban planning criteria. The proposed methodology results in two subdivision qualitative indicators; one for highway design and one for a limited set of urban planning parameters. These indicators may be utilized at the initial stage of an area development process by all involved stakeholders to identify design shortcomings in the property pattern in a timely fashion. In that way, costly and time consuming development remedies, especially with respect to increased land acquisition requirements, can be avoided.

The outcome of this effort can be improved in two ways. First by enriching the set of assessment parameters used in the presented methodology both with respect to highway design and to urban planning criteria. Secondly by extending the proposed methodology to include also areas belonging to different contexts and settlements than those included in this paper. This version of the methodology has been intentionally kept parsimonious. Following up on the successful piloting in the

suburb of Agios Stefanos in Athens, a revised and extended methodology can be designed, considering a deeper level of detail.

While there is nothing location-specific in the methodology, as always, it is recommended that it is carefully studied prior to its application in any other situation. A small pilot application could help identify operational parameters that might require additional parameters, or modifications. One of the main lessons that was learned during the case study application was that it is very important to take and carefully archive a lot of photographs of the properties and the parameters of interest, especially those related to access management. Geographic Information Systems (GIS) could be very useful in automating and streamlining this work, and making its results more vivid and useful to a wider range of designers, planners and policy makers. Furthermore, other advanced data collection techniques, such as LIDAR could also prove very useful in making the wide-spread application of this approach more practical.

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