

Using an integrated land use and transport planning approach for urban road design

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Abstract

Road safety issues in urban areas are often concentrated at locations where there is a mismatch between urban road design, local road users and neighbourhood characteristics. Although there is a general consensus in the transport planning field to address the issue of sustainable development, road design practice still tends to produce infrastructure that prioritises the needs of the private automobile.

The paper describes a method to use contextual information for the purpose of improved road design. The context is defined in terms of a range of land use, socio-economic, environmental and transportation information, presented spatially, which are used as inputs to a spatial multiple criteria analysis (SMCA). The results of this analysis describe the relative suitability of different modes of transport to locations along an arterial route. Using clustering analysis, sections of the routes are identified with a similar context. The cluster attributes can be used to develop proposals for road infrastructure configurations. The approach helps to bridge the gap between integrated land use and transport planning and road design. The method has been applied to a corridor in Cape Town, South Africa.

Keywords: contextual information, Spatial Multiple Criteria Analysis, transport modes, urban road design.

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Introduction

South Africa has the third highest number of road deaths per 100,000 population in the world (Iaych et al, 2009). Mabunda et al. (2008) found that, in contrast to high-income countries, pedestrians make up the largest group of road traffic injuries and fatalities in low- and middle-income countries. In 2005 in Cape Town, South Africa, 35.4% of all casualties recorded involved pedestrians (City of Cape Town, 2005).

In developing countries such as South Africa, mode choice is often dictated by income. Specifically, lower-income people are, generally, captive to public transport and non-motorized transport (NMT) modes, while higher-income people are more likely to use private motorized transport (Dargey et al, 2007). Furthermore, even in metropolitan areas, the overall levels of car ownership are low relative to developed countries, which is symptomatic of the high proportion of low-income earners and the high numbers of unemployed. The South African National Household Travel Survey found that 42% of respondents used public transport as their primary mode of travel to work and that 30% either walked or cycled to work. The remaining 28% used private vehicles. This highlights the importance of public transport and NMT to trip making in South Africa.

There is a need to provide road infrastructure planners with an alternative planning methodology that can draw on the policy objectives of multimodalism and contextually sensitive planning to recommend alternative solutions. This paper describes a method that uses a geographic information system (GIS)-based spatial multi-criteria analysis (SMCA) first to define the contextual setting in terms of a set of relevant factors and then to identify regions along a route with very similar contextual settings. Thereafter, those contextual settings are analyzed within the framework of modal suitability, and conceptual planning parameters are developed.

Contextual Road Design

In recent years, context-sensitive design (CSD) has been promoted as a best practice. CSD is a collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic and environmental resources, while maintaining safety and mobility. It is defined as “a philosophy wherein safe transportation solutions are designed in harmony with the community” (De Cerreño et al., 2004).

The need for CSD arose in part from the realization that the majority of urban streets serve multiple roles, in that they have to accommodate the needs of multiple modes of transport and needs related to mobility (through users) and access (local users). As a result, a certain amount in flexibility in design is required to meet all these needs (Hebbert, 2005). Moreover, urban streets may perform a variety of civic, ceremonial, political, cultural, and social roles, as well as commercial and economic role, in addition to their movement role (ARTISTS, 2004). The multiplicity of roles implies that the functions performed by the road and the needs of those who are expected to use it must be thoroughly evaluated and understood before an appropriate planning recommendation can be made.

Current road and network design methods that rely almost exclusively on traffic and transportation information to recommend service levels and design parameters have been found to have a significant impact on mode choice (Cervero et al., 1996) and vehicle miles travelled (Kitamura et al., 1997). This research posits that contextual factors are equally as important as traffic and transportation factors when planning roads. Consequently, it is important to take all of these factors into consideration when developing designs.

Context can be defined as including aspects related to adjacent land uses, the socioeconomic profile along the route, the environmental (ecological and cultural) landscape along the route, and the traffic and transportation characteristics along the route. These contextual aspects will vary spatially and temporally.

Each mode in use on a road has its own specific characteristics and needs, and these determine the design parameters for that mode. Also, each location in a network or along a road is defined by a set of contextual parameters that determine how and by whom it is most often used. It is in the intersection between the modal characteristics and the locational factors that an ideal planning solution can be found. Accordingly, certain modes are better suited to a certain set of contextual circumstances than others. Therefore, under a given mix of contextual circumstances, certain modes should be given a higher priority than the rest.

Methodology

GIS has emerged as a useful platform for analyzing the spatial complexities of urban planning and transport planning problems. Planners are often confronted with alternative scenarios to assess, and these assessments are often driven by a range of both quantitative and qualitative variables, with numerous stakeholders and viewpoints to be considered. GIS is well suited to evaluating large databases of spatial information (Eastman et al., 1995). GIS-based spatial decision support tools, particularly SMCA tools, have emerged as effective techniques for assessing these cumulative impacts and for carrying out suitability analyses in order to evaluate the alternatives (Laaribi, 1996). SMCA has been successfully used to assess alternatives in a range of areas, including environmental impact assessment (e.g. Brown et al., 2002), public transport and land use development planning (Sharifi et al., 2006), and evaluating routing problems for roads (Keshkamat et al., 2009).

To evaluate the suitability of one mode over another, an SMCA was conducted using the five main road-based modes commonly found in Cape Town (private vehicles, walking, public transport, bicycling and freight) as alternatives. Variables were selected from each of the four contextual categories (land use, socioeconomic profile, environmental landscape, and transportation characteristics) to describe the context of each location along the route. The variables that are considered relate specifically to the what, who and how questions that can be asked of any locality:

- What are the characteristics that define the locality?
- Who are the people using the locality?
- How are these people using the locality?

Land use type, property density, and property values were used to describe the location. Land use encompasses issues related to the activities at a particular location and the intensity of activity at that location. Commonly used parameters include zoning, density, diversity, and land value. In terms of road planning, these parameters provide information on the expected number of trips and the modal split at a location.

To describe the people using the location, demographic information such as income levels (using education level as a proxy) and the proportion of vulnerable road users were used. The socioeconomic profile along a route encompasses issues related to (among others) neighbourhood demographics such as age and gender, income levels, and employment levels. This information is critical to the route context, since it details the types of users, their levels of ability, and the modal split at a location.

The proximity to environmentally sensitive or historic significant sites and wetlands was used to describe the environmental qualities of the location. In terms of the National Environmental Management Act, infrastructure provision must give consideration to the physical, biological, social, economic, and cultural aspects of the environment that may be affected by the proposed activity. Road infrastructure must, therefore, be planned so as to minimize the expected impacts it may have in this regard.

The demand for public transport and the demand for private vehicle transport (derived from the origin-destination matrix for the area), as well as proximity to public transport stops, were used to describe the traffic and transport characteristics of the location. Demand in terms of traffic volume, supply in terms of capacity, and travel speed are the primary parameters that typically dictate road design. However, traffic and transportation factors that inform context also include modal split and the location of public transport stops.

The data sources used included data from the 2001 South African National Census, the 2003 South African National Household Travel Survey, and data acquired from the City of Cape Town's Corporate GIS department. A case study road was selected that initially displayed a wide variety of land use, social, economic, and environmental characteristics along its length and that was known to have high accident rates. Spatial data sets were constructed using the available data, and converted to raster images to conduct the SMCA. In the context of transport planning, SMCA is typically used to identify suitable routing alternatives for a particular mode of transport. In case of this research, the route is predefined, and it is instead the suitability of the various modes that use the route that must be determined. Each mode was evaluated individually, thereby producing a set of five preference or suitability maps, one for each mode. Image-processing techniques were used to aggregate the results along the route centre line for each map.

A mode is more suited to a particular location if the numerical score it achieves through the SMCA at that location is greater. The numerical score, indicating the priority or contextual suitability, equals the weighted sum of standardized criterion scores for each factor. The inputs to the process are the raster maps of the criterion scores, and each cell

of the raster is evaluated for each mode. Standardization is required as with any multi-criteria analysis, and was done in the simplest possible way using linear functions to map criteria scores to a scale between 0 and 1.

The weights used in the procedure can be calculated using the analytical hierarchy process introduced by Saaty (1980). However, to investigate the contextual differences along the case study route and the influence that the criteria have on suitability of the various modes, a uniform weighting regime was used so as not to introduce any biases within the criteria set. The results, therefore, only reflect the summation of transformed criterion scores along the route.

The nature of the SMCA method means that the introduction of weights will have an impact on the results produced. Because it is undesirable that slight changes in weighting lead to radically different results and, conversely, that significant changes in weighting do not have any noticeable impact on the results, a sensitivity analysis was conducted to test the impact of changes in the weighting scheme. The analysis involved increasing the weighting of each category of criteria with 20% and then comparing the results using nonparametric correlation and a dependent *t*-test (Beukes et al., 2011). The analysis found that for each mode the adjusted results were very strongly correlated with the base case result. It was concluded, especially when considering the strong correlations between the base and the weighted cases for all the test pairs, that the method produces results that are robust enough to be reliable. The dependent *t*-test results showed that the method is able to produce results that are flexible to variations in weighting schemes without inducing radically altered outcomes.

Selection of case study

Voortrekker Road from Salt River in the west of Cape Town to Kuilsriver in the east of Cape Town was selected as a case study route, as it is one of the corridors with severe safety issues. Voortrekker Road is a major arterial that links suburbs in the west of Cape Town with suburbs in the east. The section of the route selected for the study is approximately 17 km (approximately 10.5 mi) long. A variety of modes, land uses intensities of land use, and population groups are served along it.

For the large majority of the study section (>90% of the route length), the road constitutes a two-lane, dual carriageway roadway with a narrow central median and is flanked by sidewalks of varying width. This uniformity of cross section is striking giving the range of locational contexts the road passes through.

Figure 1 shows the extracted suitability scores by mode along the corridor for the case study route. The figure illustrates the strong fluctuations in suitability of location for each of the modes, as well as the alternating ranking of modes at locations along the corridor.

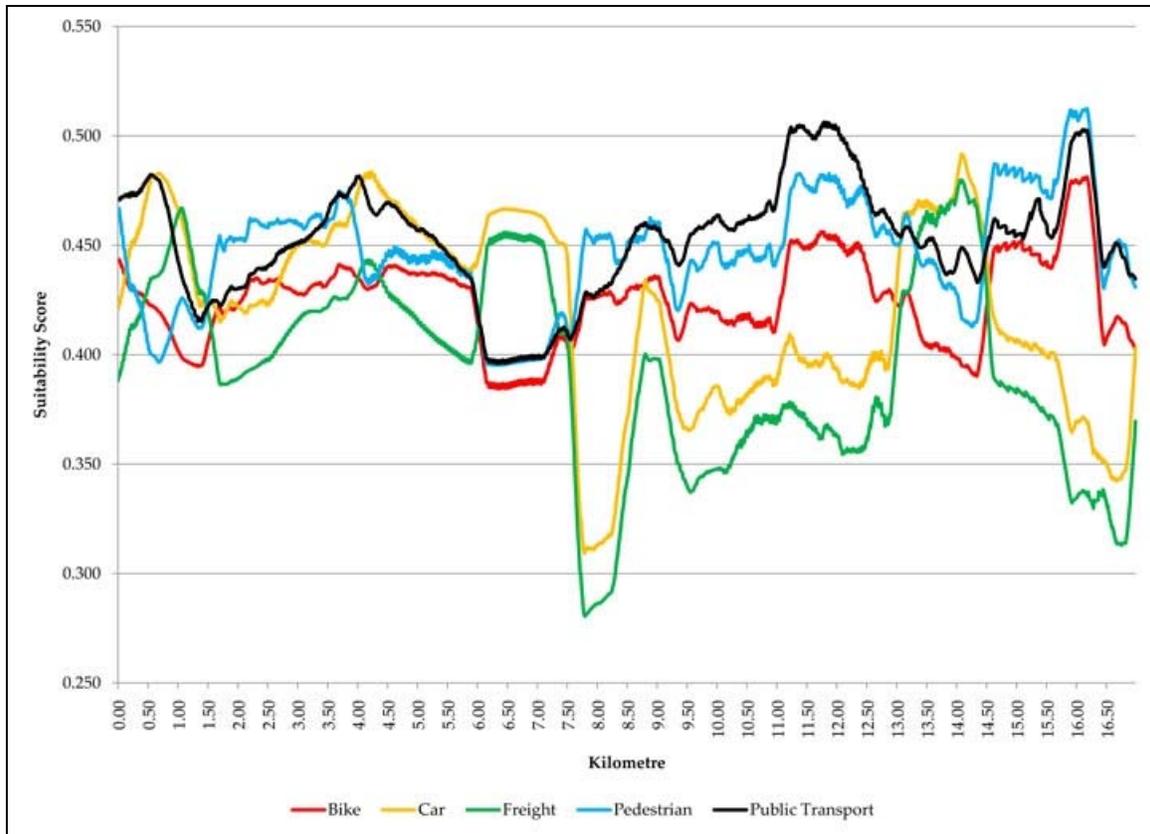


Figure 1: Suitability scores along Voortrekker Road

Clustering contextual suitability results

The SMCA provides a means of quantifying the context and describing the implications thereof, in terms of the relative suitabilities of the different modes of transport to various locations along the case study route. Although the analysis of this data can provide useful information for the road planner, the variability within the output makes it necessary to simplify the results that are produced by clustering similar sections into groups that can then be analyzed further and used as proxies for the actual scores. These proxy results can be thought of as modal suitability types, for which road design proposals can be developed that would be sensitive to the locational context.

The clustering approach used in this research is an adaptation of the Silhouette validation technique (Rousseeuw, 1987). This technique uses a measure of how close each point in one cluster is to points in the neighboring clusters to ascertain the coherence of the clusters produced for a given k clusters. This data is represented as a silhouette value, which is the ratio of the average dissimilarity of a point to all other objects in its cluster, and the average dissimilarity of that point to all objects in the closest other cluster. The mean silhouette value for all the clusters in the plot is an indication of the overall strength of the clustering. Any measure of dissimilarity can be used but distance measures are the most common, and this is what was used in this research as well.

Silhouette values were calculated for all the clusters produced between $k=1$ and $k=100$. Several k values will produce a set of well defined cluster centres. The choice of which of these to select was made by defining a minimum threshold range for the distance between adjacent cluster centres (or the least acceptable difference between adjacent clusters). Using this methodology, the analysis produced 6 unique clusters and the cluster centroids are shown in table 1. The cluster means for each cluster within the data set describes the contextual characteristics of each section of the route in a much more compact form than can be achieved by simply analyzing the raw SMCA data.

Table 1: Cluster centroid details for case study road

Case Study Route	Cluster	Bike	Car	Freight	Pedestrian	Public Transport
Voortrekker Road	1	0.4294	0.4305	0.3985	0.4436	0.4512
	2	0.4289	0.4646	0.4298	0.4644	0.4436
	3	0.4184	0.3817	0.3568	0.4564	0.4434
	4	0.4205	0.3301	0.3030	0.4350	0.4479
	5	0.3950	0.4611	0.4502	0.4178	0.4112
	6	0.4525	0.3936	0.3652	0.4824	0.4824

Plotting the clusters along the route (Figure 2) allows for the identification of areas along the route with similar contexts, and that should, in terms of the decision problem, receive similar road treatments along the arterial being assessed (see also Beukes et al., 2011).

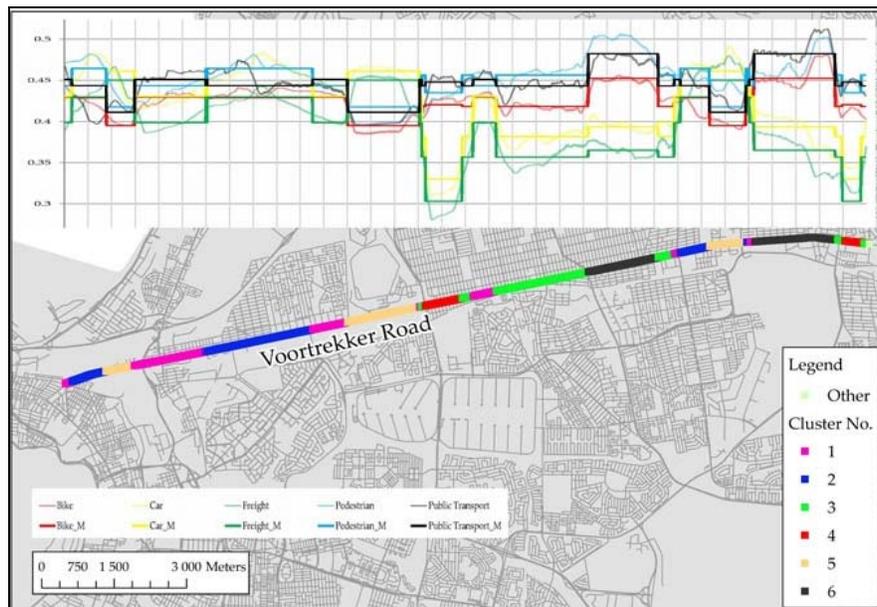


Figure 2: Comparison of Cluster Means and Cluster Location on Voortrekker Road.

Infrastructure and context

Using the rank order of the modes, the groupings of modes within the clusters, the score differences between individual modes or mode groupings and the range of scores within each group, it is possible to develop descriptive statements regarding the priority of each mode at each point along the route, with reference to the contextual setting for that location. Again a standardized scale is required. Since the range of scores in the case study is limited, it is necessary to re-scale the cluster means to amplify their differences. To this end, a route maximum and minimum score was defined as being the highest and lowest score obtained by any mode, in any cluster along the route. The cluster means were re-mapped to a linear scale, with the route maximum and minimum being rescaled to 1 and 0 respectively.

The scale lends itself to a stratification of mode suitability. This stratification forms the basis for comparing mode operations, in any cluster. In turn, describing the operational characteristics for each mode in any given cluster forms the basis for identifying the types of infrastructure that best suits a location, given the context as identified by the analysis. The approach adopted to describe the operational conditions for a mode in terms of its suitability ranking was to reinterpret mode suitability in terms of three parameters: access to the segment, right of way or ease of movement within the segment and the level of independence afforded to the mode within the segment. This interpretation of mode priority develops a description of the level of operation for each mode, at all sections of the route (Table 2).

Table 2: Mode suitability in terms of operational permissions

Suitability	Access	Priority	Independence
Unsuitable	Restricted - physically prevented from accessing the road	Not applicable	None provided
Low	Access allowed, but movements physically restricted	Lowest priority afforded	Shared infrastructure, with minimal dedicated mode specific features
Medium	Partial access levels provided	Priority given according to need and in subservience to main mode	All needs catered for, mixture of shared and dedicated infrastructure
Highest	Highest access allowed	Priority of movement given for all circumstances	Dedicated infrastructure wherever practical, minimal interaction with other modes

Access

In terms of the operational characteristics of a mode, in a particular section of the route, the defining characteristic of that section is to what extent a particular mode is afforded access to it. Modes are restricted access to certain areas for a range of reasons. In certain circumstances, it may be undesirable or unsafe for a mode to operate in an area at any time, or only at certain times of the day. Restrictions such as this are common around the world. Obvious examples may include restrictions placed on pedestrian activity on high speed roads, or time of day restrictions on freight or delivery vehicles in residential areas. Some roads are designated for pedestrians only, others may allow for both pedestrians and cyclists.

Restrictions such as this also apply to the operations of modes along routes. In many areas, vehicles are allowed to access the area, but may not stop or park. Similarly, pedestrians are often afforded access to a route, but their crossing opportunities are limited to only certain controlled locations. Although access to an area is permitted, the mode is not allowed to operate unencumbered. A combination of infrastructural and regulatory measures is put in place to enforce these restrictions.

The location's context is often the deciding factor when determining where, when and to what extent a mode is afforded access to an area. Aspects, such as the land uses and the most common activities associated with them, the efficiency of the area from a traffic operations standpoint, and interactions with other modes, commonly influence these decisions. In this sense, the use of the context, as defined in this research, is well suited as a basis for describing the level of access afforded to a mode at any location.

Modes that, in terms of the analysis, are poorly suited to the context at a location, should most probably be excluded from accessing that location. Conversely, modes that are well suited to the context at a location, should be afforded unencumbered access. Infrastructure should be planned so as to facilitate and enforce these various levels of restriction. There are a range of measures that could be used to enforce such restrictions.

Restrictions, as discussed, can be full or partial, and can affect many aspects of the operations of a mode. For motorized modes, speed restrictions are ubiquitous, and there are well documented measures that can be used to allow access to a location for a mode, but only at restricted speeds. Similarly, parking restrictions, and time of day based access restrictions, are common as well. Other measures include access control booms and bollards, that allow only certain types of vehicles, or certain drivers (such as residents), to access an area.

For pedestrians and cyclists, median barriers or fencing are commonly used to discourage mid-block, uncontrolled crossing. Of course, not providing infrastructure, such as sidewalks or cycling lanes, and prohibiting Non-Motorized Transport (NMT) modes from accessing an area, can also discourage access in areas where it is unsafe for these modes. Similarly, Public Transport (PT) access to an area can be controlled by not allowing

vehicles to stop for passengers, or limiting vehicle speeds. Of course, PT vehicles could also be prohibited from an area depending upon the routing.

Right of Way

The other defining characteristic of a route is the right of way, or priority of movement, allowed for the mode. Right of way is an aspect of traffic control that can have dramatic implications for the operations of a section of road. The determination of the right of way is important at conflict points along the route, since practice generally dictates that modes should be kept separate from each other. As such, at these conflict points, time needs to be allocated for each mode to use the space, in as efficient a manner as possible.

Typically, right of way is determined by regulatory infrastructure, such as road markings, signage or traffic control devices, but these may be supported by infrastructure, such as vertical grade changes (as in the case of raised pedestrian crossings), or special colored surfacing, to reinforce the right of way hierarchy.

If a mode is better suited to a location, in terms of the contextual analysis and, consequently, receives a higher priority in that location, this implies that it should be given priority of movement, or the right of way in that location, wherever possible. This dictate should, naturally, be tempered by safety considerations. But there are a range of methods that can be used to implement, or enforce, the right of way without sacrificing safety.

Traffic control devices, such as stop or yield signs, appropriately placed could enforce, from both a legal and a traffic control perspective, the right of way of the preferred mode. Remotely activated, or actuated, traffic signaling, as is sometimes used on BRT routes, are used to afford priority at signalized crossings. Whole sections of road can be redesigned to afford priority to a certain mode. Examples of such initiatives are the woonerf in the Netherlands, and 30 km/h zones in Germany. These areas are noted for being specifically designed to create the impression that the automobile is the 'guest', and that the primary mode in these areas is NMT. A range of measures, going beyond simple traffic calming, is employed to create this impression, and enforce the modal hierarchy.

Independence of Operations

One of the guiding principles of multimodal road planning is that, as far as possible, it is best to keep modes separate from each other. To achieve this, separate infrastructure must be provided for all modes operating in the corridor. Although this is ideal, given constraints of space and cost, it is not always possible in practice, and may not always be desirable, given the operational aspects of that section of the route. The question of space allocation, of course, falls away, when space and cost are not constraints. However, these are often limiting factors, and allowing a mode to operate independently from the others in the corridor does afford that mode significant benefits. These benefits cannot be realized if the mode shares space with other modes. Space allocation which, in essence, translates to independence of operations is, therefore, the third way in which to afford one mode priority over another.

There are well established norms relating to the various infrastructural mechanisms that can be used to confer various levels of independence of operations to a mode. The Guidelines for Human Settlement Planning and Design (CSIR, 2000) lists a range of infrastructure classes for pedestrians and cyclists that are differentiated from each other by the extent to which they have to share space with other modes. The allocation of separate road space for PT vehicles is starting to be implemented throughout urban centres in South Africa, and abroad. The BRT systems being implemented around the country are noted for having physically delineated bus lanes as part of their trunk networks. On higher order arterial routes and freeways, freight vehicles are often limited to using a particular lane. None of the physical requirements for affording a particular mode priority, through the allocation of road space, is new, or untested in South Africa.

Interpreting Modal Suitability

Defining modal suitability in terms of operational parameters, provides the planner with some guidance as to what combination of infrastructural interventions or components would be appropriate in that particular context, whilst still allowing for innovation and flexibility in planning choices. This is important for two reasons, contexts are spatially and temporally fluid, and design circumstances may vary from place to place, even in areas with similar contexts. There are, thus, many possible design solutions for any given context that could function equally well, and only a careful analysis of each option, preceded by a thorough investigation into the reasons for the cluster means in any area, would lead to contextually appropriate infrastructure.

The adjusted cluster mean values for the Voortrekker Road data set, redistributed into the four categories described in Table 2 are used to demonstrate the application of the method.

Considering cluster number 1, all the modes are relatively well suited, but the pedestrian and PT modes are the best suited to the context. Accordingly, these modes should receive unrestrained access to the area, priority of movement over the other modes, and should have infrastructure dedicated for their exclusive use. This has a number of immediate important implications. Firstly, the pedestrian mode should receive full access to the area, implying that pedestrians should be allowed and expected to cross the road anywhere in the area. This would necessitate very low vehicle speeds. Secondly, there should also be dedicated PT infrastructure, which implies the provision of a dedicated lane for buses and taxis.

The other modes, car, bicycle and freight, all fall within the medium access range. This implies that these modes should be allowed access to the area, but with some restrictions on their operations. It may be appropriate to limit freight access to delivery vehicles only, and to not allow parking for private cars. Cyclists may be required to stay within a designated cycling lane, or may be required to dismount during certain times of day. Figure 3 shows a typical street scene along Voortrekker Road in a cluster 1 area. This particular area is characterized by mixed land uses, including small retail stores, offices, and apartments along the road, and residential suburbs further away from the road. The

road itself consists of two undivided lanes with on street parallel parking, and sidewalks on either side of the road.



Figure 3: Voortrekker Road in a cluster 1 area [Source: Google Earth, accessed 15/04/2011]

In order to more closely comply with the requirements of Table 2, this section of the route might be reconfigured to more closely resemble the example in Figure 4. The allocation of space in this road, as well as the priority and independence of movement, quite closely matches what is suggested, given the context described by cluster 1. There is dedicated infrastructure for PT, and a large amount of space is given over to the pedestrian, who is free to cross wherever required. Private Motorized Transport (PMT) movement is restricted to one lane, which, in this instance is one way only, and parking is not provided. Cyclists and cars share the same road surface, with bicycles not being allowed to cycle on the pedestrian only areas.



Figure 4: Damrakstraat, Amsterdam [Source: Google Earth, accessed 15/04/2011]

An immediate problem with this solution is that this section of Voortrekker Road is much narrower than the example shown in Figure 4. Compromises will, therefore, have to be made, but these should be made in deference to the mode ranking, and issues around road safety first. For example, it may not be possible to provide a dedicated bicycle lane.

However, since vehicle speeds are likely to be low, and bicycles and motorized modes have almost identical suitability scores, they could be made to share a lane. This demonstrates the need for flexibility in the approach since, often, compromise solutions will call for design innovation. Figure 5 shows the existing cross-section for this section of the route, and two proposals for context sensitive cross-sections, given the cluster mean scores for each mode, and the discussion above.

The two proposals highlight the road space allocation compromises that are required as a result of the road reserve constraints. In the existing section, approximately 70% of the road space is allocated to motorized modes (including PT). In both of the proposals presented, parking has been eliminated, and in Proposal 1, only one direction of flow has been allocated to PMT modes. This frees up significant amounts of space for the other modes, but could be argued to be impractical, and not truly representative of the suitability scores, since the Car mode does score comparatively well overall. Nonetheless, the space allocation has been changed to: 34% to PT, 16% to PMT and 46% to NMT. The remainder is made up by drainage and street furniture.

In Proposal 2, both directions of flow have been accommodated for all modes. To accommodate the extra PMT lane, some of the space for NMT had to be reassigned. However, the remaining NMT space is also now more fragmented, since refuge islands must be provided between PT and PMT lanes to assist with the unregulated crossing required by the context. The narrow PMT lanes can also be interspersed with raised humps to keep speeds down.

Discussion

The basis of the approach presented in this paper is that there are a range of factors that can be used to describe the characteristics of the local road users, and the activities they are involved in along it. This information should play a more direct role in the design of these roads. The factors, collectively termed the context, have tended to be overshadowed by concerns around efficiency and cost, and there has not been a comprehensive framework within which the context could be evaluated, and its implications investigated. The way in which infrastructure interfaced with, or suited the context has, thus, always been left to the discretion or judgment of the engineer or planner of the facility. The research identified which factors could be used to describe the context of a location, and demonstrated that it is possible to quantify the context in terms of its effects on the suitability of the various modes of transport.

Quantification has a number of advantages for planning and designing infrastructure. Being able to quantify the suitability of a mode of transport to a particular location, given the context, allows for the prioritization of modes in terms of infrastructure provision, which can then be used as the basis for planning and design.

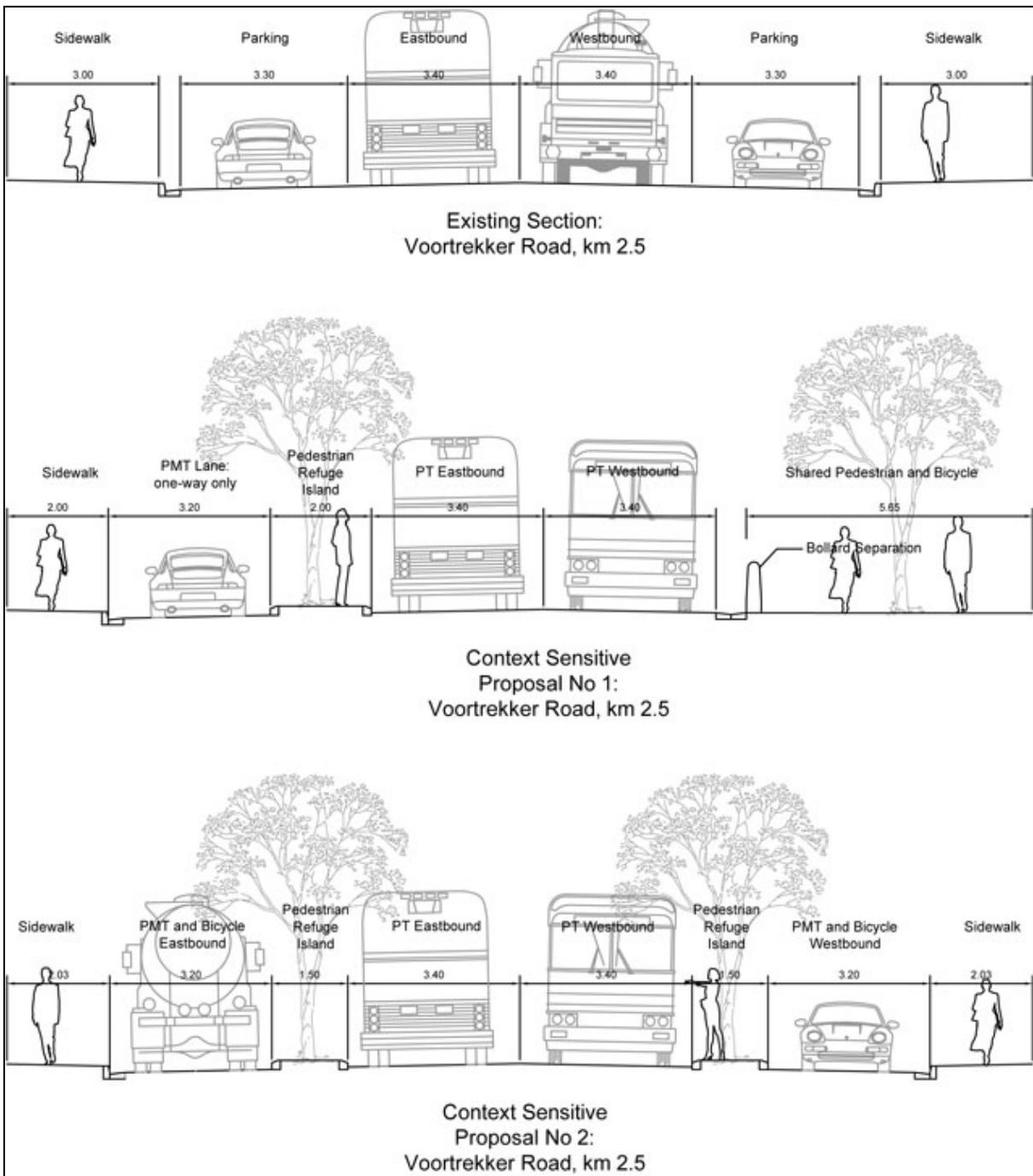


Figure 5: Existing Layout and Proposal for Context Sensitive Upgrade in a Cluster 1 area on Voortrekker Road.

Quantification also has the benefit of facilitating accurate comparisons between different locations along the route. This is useful for planning and design, in that the subtleties in the variation of the context along the road, are retained during the analysis, allowing for a fine grained tailoring of the required infrastructure. It is also possible to show that context varies spatially, that it is not static, and that for infrastructure to be contextually sensitive it must, therefore, vary to suit.

The paper employs a novel application of the principles of multiple criteria assessment to conduct the evaluation. Whereas SMCA had previously been used to compare the suitability of a number of sites for a development, or to identify routing alternatives in an analysis space, the application developed here assesses suitability of a number of alternatives in a constrained space and, uniquely, no alternative is necessarily taken as being the one correct solution. Instead, it may only be the correct solution at that location. Also, none of the other alternatives are abandoned if they do not rank highest. Instead, their relative suitability is used to determine their priority in terms of the operational aspects of the road being planned.

The context, being an amalgam of a range of disparate factors, does not have any intrinsic meaning by itself. Instead, it is the implication of the context that has meaning and, therefore, context can only be understood in terms of its implications for other aspects of the facility. In this research, context is defined in terms of its implications for the suitability of the various modes of transport. The translation of contextual suitability into infrastructure recommendations, therefore, relied on defining the operations of the modes of transport on the road. The paper, therefore, successfully develops a definition of the context, demonstrates its importance, explores its characteristics and implications and translates these into descriptives that can be used to inform infrastructure provision. The method is also intrinsically multimodal in nature. Since all modes receive equal treatment, the method is able to highlight any existing disparities in the provision of infrastructure for the various modes (Beukes et al., 2010).

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