AN ECONOMICS-BASED ROAD CLASSIFICATION SYSTEM FOR SOUTH AFRICA

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ABSTRACT

Many road authorities, including those in South Africa, are unable to reliably identify and prioritise the maintenance of two essential road categories: roads that are required to satisfy citizens' constitutional right to access basic services; and roads that maximise potential economic growth. This issue stems from reliance on the current set of classification systems, which lack the requisite detail to determine a road's significance in connecting communities to basic service facilities, the volume and type of economic activity it supports, and overlaps between these functions. This paper therefore presents an economics-based road classification system customised for the South African road network. The new system disaggregates roads into four classes: Basic Access Roads; Strategic Roads; Tactical Roads; and Surplus Roads. The characteristics and maintenance priority level of each road class are addressed, along with an identification methodology that authorities can use to include this information within their asset management systems to improve expenditure and investment outcomes.

1 INTRODUCTION

Ross and Townshend (2015) follow the 1996 White Paper on National Transport Policy to set out the road network's priorities: to satisfy citizens' constitutional right to access basic services; and to maximise potential economic growth. But current road classification systems, which are covered in Section 2, inadequately account for either function. The implication of this oversight is potentially inaccurate road prioritisation, which in the context of limited budgets imply inefficient public expenditure. This paper therefore follows fundamental classification criteria listed in Section 3 to develop an economics-based road classification system for the South African road network, with focus on the definition and identification methodology for each class. The final section describes how authorities can incorporate this information into their asset management systems to improve expenditure and investment outcomes.

2 CRITIQUE OF CURRENT CLASSIFICATION SYSTEMS

Road classification systems categorise roads and order them in relation to each other. Amongst other contributions, these classification systems should improve the administration, financing, and management of road networks. Constrained budgets, which are a reality in most countries including South Africa, force authorities to choose between roads. In this context, it is imperative that the classification system identify and prioritise roads within the network that respectively facilitate access to constitutionally protected public services and maximise economic growth.

This is reiterated by the National Department of Transport (NDOT) (2004), who state that road classification cannot be considered from a one-dimensional perspective that does not account for the socio-political and economic imperatives of the country. Because basic access and economic growth are the primary functions of the road network, the classification system must clearly define and individually identify these services within the road classes.

The South African road network is primarily classified according to administrative, geometric, and functional characteristics. Additional classification systems exist, such as naming, route numbers, and road traffic signs. Each system is designed for a specific purpose, but none are individually or cumulatively sufficient to support economic prioritisation of the network.

2.1 Naming hierarchy

The naming hierarchy classifies roads according to their names. Numbered mobility roads are the first class and are referred to as a freeway, bypass, motorway, expressway, route, highway, or arterial. The next class are numbered and named mobility roads and include avenues, roads, drives, and links. Access and activity streets are the lowest class and identified as boulevard, collector, street, lane, loop, crescent, place, way, terrace, close, grove, court, square, or mall. The main benefit of this system is public information and management of users' expectations. From an economic prioritisation perspective, however, the classes provide little detail about characteristics like economic activity, potential cargo, and connected service centres.

2.2 Road Traffic Signs Manual classification

This system categorises roads into four classes: Class A1 dual carriageway freeways; Class A2 single carriageway freeways; Class B1 non-freeway numbered national, provincial, regional and metropolitan routes; Class B2 un-numbered surfaced routes; Class C1 low volume surfaced routes, local collector-distributor streets; Class C2 un-numbered gravel and industrial streets; and Class D local access roads with no public destination. The classes are roughly based on traffic volumes, but there are instances where roads in lower design classes facilitate more economic activity than roads in higher classes. For example, some numbered routes in densely populated cities facilitate more economic activity than single and dual carriageway freeways in smaller centres. Moreover, no provision is specifically made within these classes for access to basic services.

2.3 Route number classification

The route numbering system expresses ownership, with the prefixes N, R, and M for national, provincial, and municipal roads, respectively. Provinces further differentiate their roads by using D for district roads, T for tourist routes, and respectively adding two- and three-digit numbers to major and minor R routes (COTO, 2012). Route numbers help guide motorists, but are inadequate for economic prioritisation due to the system's separation from the service or value provided by a road and the high incidence of exceptions, inconsistencies, and un-numbered routes in the system (COTO, 2012).

2.4 Administrative classification

Administrative classification categorises roads according to the responsible authority, either national, provincial, or local government. Each authority is accountable for management of their designated road network. There is, however, no standard methodology to determine the assignment of roads. Current legislation simply defines national, provincial, and municipal roads as those proclaimed as such with no set rules for doing so (COTO, 2012). Despite the revised inception of this classification system post-1994, approximately 144 000 kms remain as unproclaimed roads (Kannemeyer, 2016). Unwillingness by authorities to assume responsibility for these orphaned roads means that potentially important basic access and mobility roads cannot be legally maintained using public funds. Moreover, the necessary information to inform onboarding and upgrade schedules for these unproclaimed roads is missing within the system.

The NDOT (2006) noted that administrative classification cannot coordinate overlap of services between roads assigned to different authorities. The origins and destinations of many economic activities are on sub-national roads, making them part of strategic supply routes. But this system only classifies national roads as strategic assets. The NDOT has thus called for a new system that can identify strategic roads at all levels of administrative classification.

2.5 Geometric classification

Geometric classification draws on structural determinants such as road width, surface type, wet weather condition, gradient, load bearing, and height restrictions to class roads according to their design (Intergovernmental Committee on Surveying and Mapping, 2006: 5). Freeways, for example, are in a higher class than dual carriageways, which in turn are above undivided arterials. The system is complicated by the fact that different segments of the same road can have different structural determinants and geometric design. The system is used in South Africa to aid design processes and communication between engineers and administrators. No direct relationship, however, can be drawn between geometric road types and economic contribution. The NDOT (2006) actually state that undivided, two-lane roads can be more important for freight and passenger mobility than geometrically superior dual-carriageway multi-lane collectors.

2.6 Functional classification

Functional classification uses expected traffic movement to rank roads. The system assumes that roads provide traffic mobility or land access. Mobility roads are higher speed through-routes that link centres of economic activity, and because of this have limited access points as this slows traffic. Access roads are shorter in distance and cater specifically for

access to land, activities, and services. The proportion of mobility and access provided by a road determines the functional class to which it is assigned.

The NDOT began with the functional road classification system in the early 2000s due to the need for a uniform classification methodology across the spheres of government. TRH 26 (COTO, 2012), which is the official functional classification manual, uses three criteria to distinguish between the six road classes. The size and strategic value of the trip generator is the first criterion. According to TRH 26, mobility roads link large or important trip generators and rural and urban centres of development. Access roads give direct or indirect access to properties and collect and distribute traffic between those properties and mobility roads. The next criterion is the reach and connectivity of the road. While mobility roads cater for longer travel distances, access roads only facilitate shorter trips. To avoid speeding in urban areas, access roads should not exceed 1 km before connecting with a mobility road. Lastly, the travel stage is considered. Trips are undertaken in three distinct stages: local at the origin, through when away from the origin or destination, and local again at the destination. TRH 26 states that the local portions of a trip should be on access roads, while the through portion should be on mobility roads.

The NDOT (2006) conclude the Road Infrastructure Strategic Framework for South Africa by stressing the need to develop a framework to support economic growth sectors through the provision of road infrastructure. One of the reasons functional classification fails to fulfil this demand is the exclusion of economic value. Although high order mobility roads usually facilitate more economic activity than lower order mobility and access roads, this cannot always be assumed. For example, the NDOT (2006) compare long-distance mobility roads required for through travel in areas with low levels of trade and production to lower order mobility and access roads connected to key service centres or in densely populated urban areas.

Functional classification also lacks the requisite detail to identify which facilities are serviced by a road, making it impossible to systematically identify the roads connected to basic services essential to some specific population. It is erroneous to treat all Class 5 roads as equivalent or to assume that all Class 4 roads are more important than Class 5 roads, as each road provides a unique service that will affect the prioritisation exercise. As such, the NDOT (2004: 15) admit that this functional classification system was “not intended to suggest how priorities and funding allocations should be made”.

3 FUNDAMENTAL CLASSIFICATION CRITERIA

The Intergovernmental Committee on Surveying and Mapping (ICSM) (2006), which published a seminal report on road classification developments, list a set of fundamental criteria for an effective road classification. The first criterion is a small number of road classes, allowing officials to effectively manage and work with the system. The ICSM note the need for trade-offs between simplicity and accommodation of all classes. But practically relevant road classes must not be excluded in the process of rationalising the theoretically possible classes.

The second criterion is that classification systems use unambiguous descriptive terminology for the road classes. The definitions should be distinct, clear, and concise to ensure simple and objective application of the classification system. Broad definitions of classes allow more scope for interpretation and thus impair consistent application of a classification system.

The third criterion is that classes are scaleless and ubiquitous across the network. The entire network must be consistently classified, not sections in isolation from one another. Because modifications to classes to account for regional significance detract from the countrywide effectiveness of the system, the classification system should only contain distinguishing variables that are applicable across the whole spectrum of roads.

The final criterion is hierarchical contiguity, which requires that roads of the same class connect to form a continuous network. The idea is that by creating seamless networks, the classification system would ensure that assignment of ownership would allow each responsible authority to schedule maintenance in such a way as to preserve network integrity. However, this criterion undermines the efficiencies that are obtainable from prioritising across the South African road network as a whole. It could enjoin maintaining or upgrading a tactical road A only because it connects tactical roads B and C, even in a case where B and C are relatively efficiently connected by a strategic road D. This system therefore does not aim to satisfy this criterion.

4 ECONOMICS-BASED ROAD CLASSIFICATION SYSTEM

The proposed economics-based road classification system uses four classes: Basic Access Roads; Strategic Roads; Tactical Roads; and Surplus Roads. These classes are designed to identify: roads that primarily satisfy citizens' constitutional right to access basic services; roads that maximise potential economic growth; and roads making a negative economic contribution.

The prioritisation rule for these new road classes, shown in Figure 1, is based on the normative reasoning applied by Ross and Townshend (2015). Basic Access Roads are the first lexical priority, ensuring that all citizens enjoy at least the minimum level of access to constitutionally protected primary and secondary schools and healthcare facilities. The second lexical priority is contribution to economic growth. Both Strategic and Tactical Roads perform an economic growth function, but the former are prioritised due to their larger contribution to expected economic growth. Surplus Roads make a negative economic contribution, meaning that their maintenance cost exceeds the value of the economic activity they facilitate. Authorities are advised to unproclaim Surplus Roads, thereby freeing the sector's resources for more efficient allocation to higher priority roads.

A road is essential for basic access only if it is the only viable means for communities to access basic service centres, and in its absence citizens fall outside prescribed norms and standards for access to these facilities. Government's constitutional obligation prevents it from being able to trade off basic access for contribution to economic growth. Thus, Basic Access Roads that make low contributions to growth must nevertheless be maintained in the top priority tier. Of course, some roads, which we call 'multi-functional', are essential for basic access and also contribute to economic growth. The more such roads there are, the lower is the medium-run fiscal drag due to the morally mandated constitutional requirement. Single-function Tactical Roads should be the final call on resources, with Surplus Roads unproclaimed.

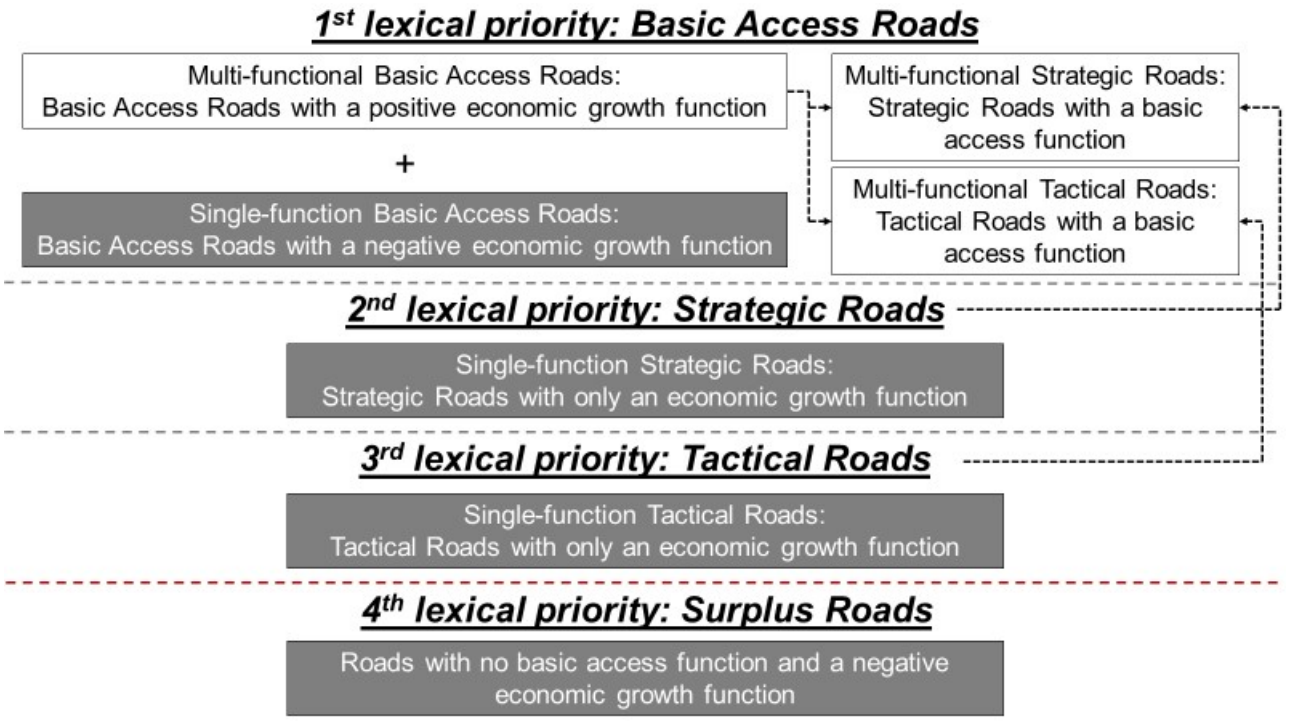

Figure 1: Prioritisation rule

4.1 Basic Access Roads

Without the option of alternative access routes to basic service centres, households are reliant on authorities to ensure that Basic Access Roads are maintained. The provision of these roads is a constitutional obligation, as well as a tool to help keep rates of rural-urban migration within manageable limits. As cyclical economic fluctuations have no bearing on the need for children to attend school and the number of people requiring medical attention to reach healthcare facilities, the demand elasticity for these roads is zero. Although this area of demand should be seasonally consistent, controlling for the effects of migration, it is possible that factors such as poor road conditions, a non-all-weather road surface, and the availability of public transport might force users to alter their travel patterns.

The procedure to identify the most efficient access routes is to geospatially locate all households in the region and map the roads which form the shortest route from their place of residence (or closest point to it) to the nearest public primary and secondary school and healthcare facility. The potential Basic Access Road Network presented in Figure 2 was estimated using 2011 Census data at the enumeration area level, GPS coordinates for the 25 137 registered ordinary and special needs primary and secondary schools and 5 389 healthcare facilities, and the additional conditions for Basic Access Roads introduced below (Department of Basic Education, 2017; National Department of Health, 2017).

Urban roads are excluded as Basic Access Roads given the availability of alternative routes to service centres in these areas. Geospatial land use data, such as those prepared by the CSIR (2018), can be used to remove all urban roads from the Basic Access Road Network. The naming hierarchy is a useful, albeit less accurate, reference as certain road names, such as Avenues, Lanes, and Streets, are generally associated only with urban areas.
The identification methodology also applies the gazetted access norms and standards, which stipulate that public primary and secondary schools must have a feeder zone with a radius of 5-kms (Government Gazette 33283, 2010). Because this zone reflects the

acceptable walking distance to schools, it creates a buffer within which authorities are not constitutionally required to provide access roads. No formal standard exists for healthcare facilities, which is sensible as it is unreasonable to expect people who require medical care to walk non-trivial distances. Bearing in mind the importance of direct and all-weather road access to schools, authorities should include the lowest volume of direct access routes within 5-km of all households.

As mentioned, some roads will simultaneously fulfil a basic access function and contribute to economic growth. These multi-functional roads are efficient as they allow authorities to address access needs at the same time as promoting economic growth. While overlapped basic access, strategic, and tactical road functions can occur in any rural setting, most multi-functional roads are likely to be in areas with higher economic activity. Using the CSIR's (2017) 2010 Gross Value Added (GVA) data, which is the most geospatially detailed dataset available for economic activity, Figure 2 illustrates the possible distribution of multi-functional versus single-function Basic Access Roads. Potential Basic Access Roads in areas with the lowest GVA account for less than 5.0% of the total road network. This supports Ross and Townshend's (2015) argument that much of the demand for basic access can be addressed through multi-functional roads.

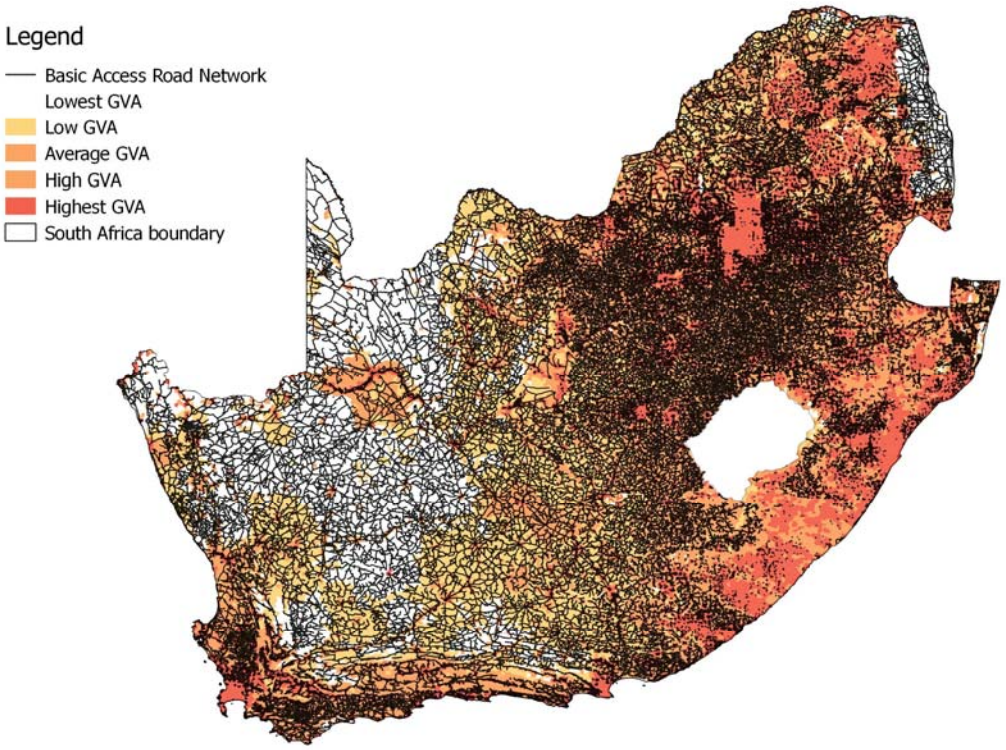

Figure 2: The potential Basic Access Road Network, 2018.

4.2 Strategic Roads

Strategic Roads include high value transport routes, which are generally within or between key areas and locations. These include cities, major towns, international and local trade corridors, and high-volume freight and passenger terminals. While the concept of a Strategic Road Network is often used to refer to national roads, this network should extend to all roads that are core enablers of economic activity. Accordingly, the Road Network Study identified a 9 200 km Core Strategic Network, 9 600 km Secondary Strategic Network, and 14 000 km Primary Road Network (SANRAL, 2015). The Secondary Strategic Network provides

alternative routes to the Core Strategic Network, which are required in areas where low road density makes the Core Strategic Network difficult to reach. The Primary Road Network feeds the two strategic road networks. The Core and Secondary Strategic Networks are designated as national roads, while the Primary Road Network is a combination of provincial and national roads. Importantly, user demand for Strategic Roads is inelastic. Adding this criterion to Strategic Roads prioritises the maintenance of roads that make the highest contribution to economic growth over cyclical alternatives.

It follows that urban roads, which have similarly inelastic demand, are classified as Strategic Roads. From an economic perspective, urban roads also combine to form integrated networks that support vital daily mobility and access functions; including the transportation of all goods consumed within urban boundaries and the movement of residents between their homes, public facilities, and places of work. Incorporating urban roads in the Strategic Road Network aligns maintenance schedules with population density and trends in urban sprawl.

Figure 3 provides an illustrative estimation of the Strategic Road Network. This example of the network combines the 32 800 km of Core Strategic, Secondary Strategic, and Primary Roads with all urban roads. The urban roads were identified by overlaying the CSIR's 2018 geospatial land use data with the total road network. Additional provincial and municipal roads may warrant inclusion in the Strategic Road Network following more detailed economic analysis.

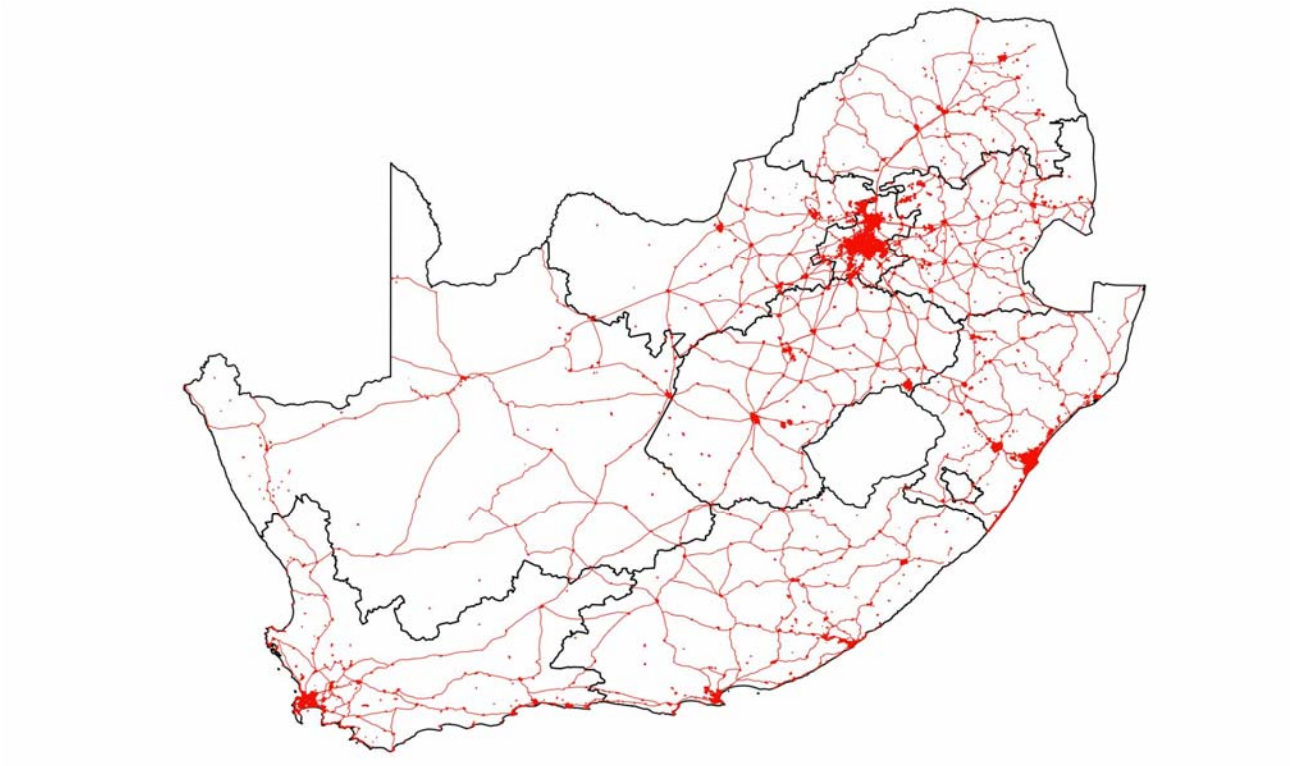

Figure 3: The estimated Strategic Road Network, 2018.

Survey responses provided by senior provincial road officials and the provincial Road Asset Management Plans reveal that many authorities have based their strategic road networks on functional classifications. But as discussed, classification as a higher-order Class 1 or Class 2 mobility road provides insufficient economic information to singularly warrant inclusion within the Strategic Road Network.

4.3 Tactical Roads

Tactical Roads comprise rural and peri-urban roads that facilitate cyclical and low to medium levels of economic activity. The NDOT (2006) stress the importance of an effective Tactical Road Network for the sector to fulfil its mandate as service centres and the origins, trade routes, and destinations of many economic activities are located along secondary and tertiary roads that are not part of the Strategic Road Network.

The next criterion is that Tactical Roads make a positive contribution to economic growth. This determination should be based on a structural growth model that comprises two terms: the expected cost of the road; and the road's contribution to economic growth. The cost term should reflect the present value of the future cost of road maintenance, bearing in mind Ross and Townshend's (2017) conclusion that, due to the relative labour intensity of sealed road maintenance compared to gravel road maintenance, and the low shadow price of labour in parts of South Africa where there is scope for surface upgrades, if a road is worth maintaining at all it is worth sealing.

4.4 Surplus Roads

Surplus Roads neither fulfil a basic access function nor contribute positively as sealed roads to economic growth, based on the same structural growth model used to identify Tactical Roads. Because the present value of the cost of maintaining these roads exceeds the economic contribution, authorities should unproclaim Surplus Roads and reprioritise any allocated funding towards the other productive classes. This action is permissible as none of these roads form part of a household's essential access route to basic service centres. Better value-for-money can therefore be achieved without violating any citizen's basic access rights.

It is important to stress the need for authorities to formally unproclaim Strategic Roads, rather than simply neglecting their maintenance. Although the immediate budgetary effects of both decisions are similar for road authorities, neglecting the maintenance of a road has deadweight costs. For example, provincial education or health departments – which operate in isolation of the road departments – may decide to locate a school or clinic on a road slated for neglect. The provincial road departments, however, may be unwilling to unproclaim roads as network length is one of the factors that determine the Provincial Roads Maintenance Grant allocation.

5 APPLICATION OF THE CLASSIFICATION SYSTEM AND CONCLUSION

The proposed economics-based classification system is aligned with the fundamental criteria that underpin classification systems: the classes are easy to understand and use; the definitions and identification procedures are clear; and the system is ubiquitous across the whole network.

Once determined, these classifications can be immediately added as a decision variable in the asset management systems by pairing the road IDs with the relevant class. The intention is not to overwrite the existing classification data, as these serve specific purposes, but rather to complement the engineering variables in the asset management systems, which include: visual condition; roughness; rut depth; macro texture; deflections; and traffic. These technical variables prescribe remedial works, which budget allocation systems then reference to allocate the limited resources in a way that minimises the whole life cost of the

network. This often means roads in better condition are maintained, as delayed routine and periodic maintenance exponentially increases the total cost, and deteriorated roads are ignored. While the same strategy may still apply, the economics-based classification system ensures authorities set their maintenance schedules with full information about which roads they have a constitutional obligation to maintain, which support high levels of economic activity, which support lower levels of cyclical economic activity, and which make a negative economic contribution.

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