An Investigation into the Need for Highway Bypass Development

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Abstract

With the relationship between transport networks and land use often already conflicted, modern transport planning and infrastructure delivery need to be focused on more holistic outcomes for a broader stakeholder base. This paper provides an investigation into the contributing factors for highway bypass development to regional centres. It includes a literature review with an analysis of highway bypass case studies, comparatively assessing the benefits of bypasses with the alternative options of through-roads and formulating mechanisms for the need for bypass development. A representative sample of regional centres of populations approximately between 5,000 and 110,000 from Queensland, Australia were then selected to compare and contrast findings including road hierarchy assessments in accordance with Austroads guidelines. This paper presents findings suggesting that bypass routes have universal benefit to regional centres and motorists. The findings indicate that the need for highway bypass development to regional centres can be determined based on allowable flexibility in a comprehensive road hierarchy model, but where road safety, road capacity and freight efficiency outcomes are not adversely compromised.

1 Introduction

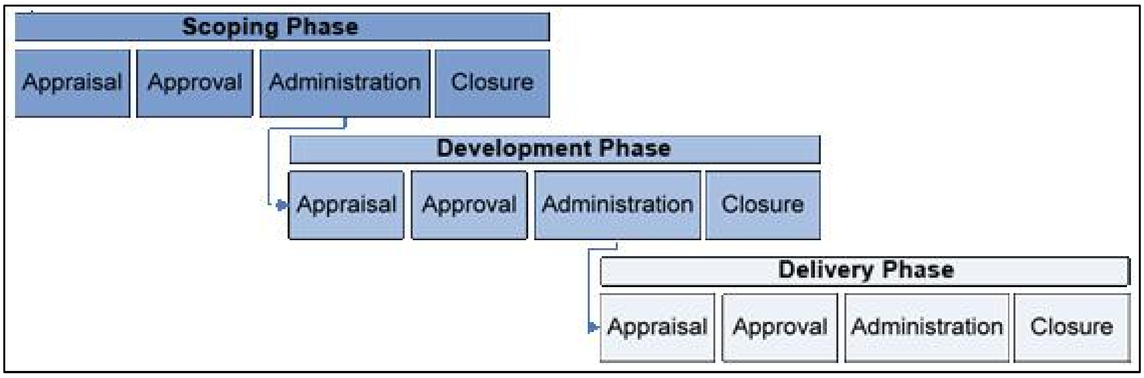
Bypasses of regional centres are becoming more common in Australasia due to an increasing demand by the community for safer and more desirable highways. However, the development of bypass routes has raised concerns of community severance, social wellbeing and economic stability (Elias, et al., 2006). With such significant government investment required for regional centre bypasses, queries are raised over the effectiveness and benefit associated with bypass developments, prompting the question: “What is the driving need for highway bypass development?”

For this paper, a regional centre shall defined as a non-metropolitan urban area with a population falling within the category of a Statistical Area Level 2 (SA2) as defined by the Australian Bureau of Statistics (ABS). SA2s are generally regional areas with populations of between 3,000 and 25,000 people, but in some instances may exceed this population due to regional structure (Australian Bureau of Statistics, 2016). In some instances, Statistical Area Level 3 (SA3) may be applicable for certain regional centres within this thesis. SA3 are typically semi-urban regional centres with populations of between 30,000 and 130,000 (Australian Bureau of Statistics, 2016).

The paper aims to identify the time when a highway bypass development to a regional centre becomes necessary due to a particular mechanism. With modern planning comes flexibility in road design principles such as road hierarchy framework. However, the amount of flexibility allowable from design and planning purposes is often unclear or ill-defined.

This paper provides an illustrative approach, demonstrating the importance of mechanisms considered in establishing the need for bypass development. The purpose of this paper and subsequent investigation is to assist road authorities in the scoping phase of bypass development. The findings from the bypass mechanism needs can be channelled to commission a corridor study or feasibility study of specific case studies, where further businesses cases can be undertaken. Figure 1 shows the QDTMR model for infrastructure investment staging.

Figure 1 - QDTMR Infrastructure Investment Staging (QDTMR, 2017)



With infrastructure funding and award often subject to time, budget and resource constraints from State and Commonwealth Governments, efficiency in the scoping phase of infrastructure is key. This paper will create a more efficient model of scoping the need for bypass projects at a high level, by providing a set of mechanisms and criteria to determine whether the full scoping phase is required to be executed.

The methodology used to determine the mechanisms included an examination of published literature, with the objective to identify the relationships between bypasses and regional centres. Specific areas of investigation included; regional centre economies, land development, road safety, social wellbeing and network efficiency. This examination of published literature adds to the method to identify key arguments which explain the rationale for and against the development of bypasses adjacent to regional centres. Using the literature review findings, the methods of this paper will expand to assess the application of road hierarchy theory to regional centres and identify areas of framework flexibility. The examination of modern Australasian bypass case studies will assist in the establishment of a critical set of mechanisms in the need for bypass development for each regional centre.

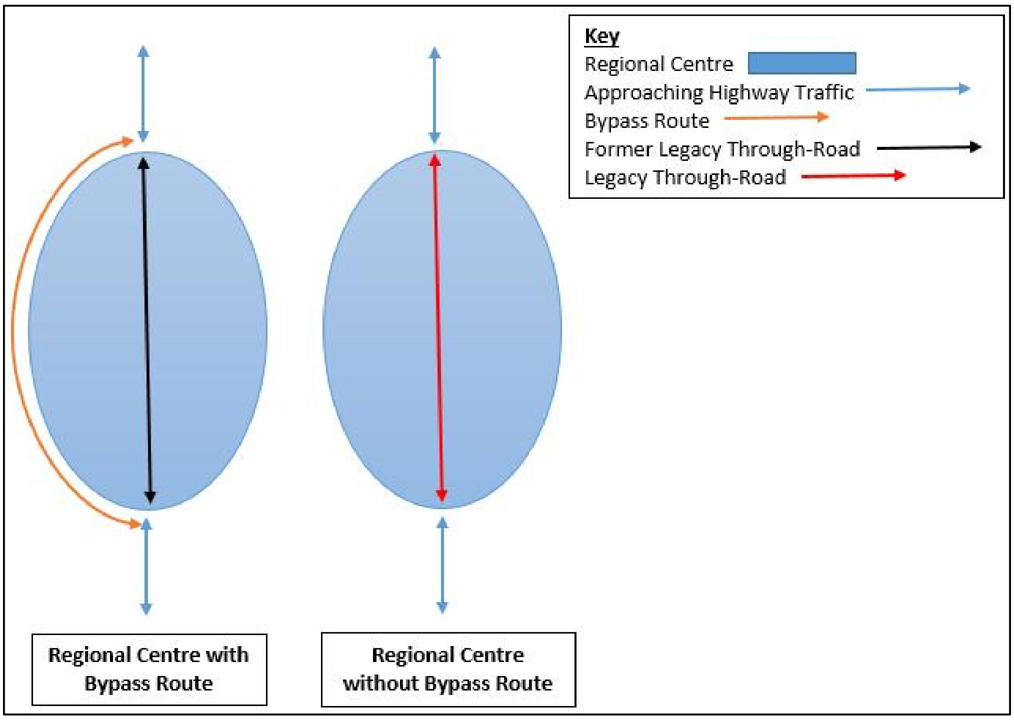
2 Literature Review

The section presents a review of the literature on the effects of bypass development and defines the key terms used subsequently.

2.1 Regional Centres and Through-Roads

Regional centres can be categorized as those which have a bypass route and those which do not. Figure 2 depicts these two categories.

Figure 2 - Regional Centre Categories in relation to Bypass and Through-Road



In this paper the arterial or sub-arterial road through a regional centre will be defined as the legacy through-road (LTR). The adjective "legacy" is used to acknowledge that in the far majority of cases, regional centres have developed around highways that have originally had a primarily through function, but over time with centre development has been subsumed within a more complex range of functions. Bypasses are primarily "…*an alternative route which enables through traffic to avoid urban or congested areas, or other obstructions to movement. Usually to divert heavy vehicles away from residential areas*." (Standards Australia, 2002). With the completion of a bypass development to a regional centre, the LTR changes its function due to the change in traffic that uses that road and the changes that need to be adopted by the steward agency to manage that road accordingly. For this reason, it will be defined herein as a former legacy through-road (FLTR). Highway bypasses shall be denoted as (HB) onwards.

2.2 Road Safety Considerations and Bypass Development

The purpose of this review was to identify whether there were associated impacts, positive or negative, with bypass developments.

Findings conducted by the Australian Automobile Association (AAA) produced the Australian Road Assessment Program (AusRAP) reported six of the 15 most improved roads in Australia between 2000 and 2009 were due to bypass development (AusRAP, 2011).

Research carried out in Europe presented findings of five studies which incorporated a total of 58 bypass case studies across Denmark, Norway and the United Kingdom (UK). The findings are summarised in Table 1. The results suggest that bypass development reduces the number of injury accidents and casualties. It is noted the findings from the studies in Denmark showed a lower percent decrease in injury accidents in comparison to the other studies. This suggests these bypasses were potentially developed to satisfy an alternative need, subject to further investigation.

Table 1 - European Bypass Road Safety Findings (Egan, et al., 2003)

No. Roads Studied	Average Decrease In Injury Accidents	Study Location
11	4% decrease	Denmark
20	19% decrease	Norway

1	No notable change	Denmark
19	33% decrease	UK
7	25% decrease	UK

An examination of regional centres in Iowa, United States of America (USA), analysed 25 regional centres over a period between 1982 and 2005, where 19 regional centres were subject to bypass development and six were not (Lorenzo, et al., 2011). The results of the bypass developments highlighted findings for the newly formed networks as a whole in conjunction with the LTR becoming a FLTR. The findings outlined an average reduction in crash frequency of 44% on the FLTR and 66% overall reduction in crash frequency on the total network. Further findings indicated crash rates were reduced by average 35% on the FLTR and reduced 59% on the total network. *“These results suggest that the construction of highway bypasses increases traffic safety both on the main road, the old road system running through town and the bypass road.”* (Lorenzo, et al., 2011). In this research, (Lorenzo, et al., 2011) defines the LTR as the “main road”.

2.3 Transport Planning and Bypass Development

There is a close relationship between land use and transport planning. Historically, transport planning was measured on the basis of criteria including; speed, convenience and affordability of motor vehicle travel, often considering land use and land planning as an aftermath. Research suggests there is a progressive trend with transport planning to become more multimodal and interrelated with land planning (Cervero, 2009), steering away from the existing transport planning paradigm that was outdated and unsustainable (Litman, 2013). Table 2 provides a summary of the changing transport planning paradigm from the old to the new.

Table 2 - Changing Transport Planning (Litman, 2013)

	Old Paradigm	**New Paradigm**
Transport Definition	Mobility	Accessibility
Travel Mode	Primarily automobile	Multimodal
Planning Objective	Congestion reduction, cost savings, reduced crash rates, reduced emission rates.	Congestion reduction, reduced crash rates, cost saving, access for disadvantaged, reduced emissions, energy consumption, public health, strategic land use.
Impacts Considered	Travel speeds, delays, costs, distance-based crash and emission rates.	Economic, social and environmental impacts including indirect impacts.
Performance Indicators	Travel speeds, roadway level of service, crash and emission rates	Multimodal level of service, multifaceted accessibility modelling including calculation of time, cost, safety, security, and environmental impacts.
Improvement Options	Roadway capacity expansion.	Improve transport options, transport demand management, pricing reforms, and more accessible land development.
Planning Scope	Limited; transport planning is separated from other planning issues.	Integrated and strategic planning; individual, short-term decisions should support strategic, long-term planning goals.

One notable difference between old and new appears to encompass development within brownfield as well as greenfield areas, in contrast to the old paradigm which appeared to focus on greenfield developments. The indicators listed in Table 2 demonstrate planning objectives, performance indicators and impacts considered as aligning with the typical design and planning philosophy of bypass development.

2.4 Social Disturbance and Bypass Development

Social disturbances are an element of transport planning that have the potential to negatively impact land use and associated developments through; noise, dust, vibrations and fumes. Ten studies were undertaken (Egan, et al., 2003) investigating the social disturbance caused by bypass developments. Findings detailed in Table 3 indicate a trend across all case studies, that the respective disturbance, particularly noise, was reduced with the development of the bypass under the particular case study.

Table 3 - Bypass Social Disturbance Research (Egan, et al., 2003)

Study No.	Bypass Routes	Noise	Vibration	Fumes	Dust	Severance	Study Location
1	5	-35%	N/A	N/A	N/A	N/A	UK
2	2	-6%	-5%	-3%	-5%	N/A	UK
3	9	-39%	N/A	N/A	N/A	N/A	UK
4	2	-40%	-27%	-23%	-36%	-17%	UK
5	2	-41%	-16%	-17%	-13%	-8%	UK
6	2	-31%	-44%	-23%	-41%	N/A	UK
7	1	-45%	N/A	N/A	N/A	N/A	Australia
8	9	-4%	-3%	-4%	-8%	N/A	Sweden
9	1	-7%	N/A	N/A	N/A	N/A	Germany
10	1	-41%	-45%	-45%	-48%	-50%	UK

The average percentage decrease is taken as the measured figures prior to, and after bypass development, dividing by the original measured figures.

In order to comparatively assess the difference between bypass developments and LTRs, the findings from four case studies, featuring eight LTRs were examined (Egan, et al., 2003). Results are presented in Table 4. Whilst the volume of results are not as significant as the bypass studies, the findings for LTRs suggested a consistent trend of increased social disturbance, in contrast to that of the bypass developments. *"New bypasses reduce disturbance among residents of bypassed towns, especially small towns..."* (Egan, et al., 2003). The results shown in Table 4 are based on before-and-after comparisons of LTR upgrades where, the average percent increase displayed is taken as the measured findings prior to, and after the LTR upgrade, dividing by the original measured figures.

Table 4 - Legacy Through-Road Social Disturbance Research (Egan, et al., 2003)

Case Study Number	Legacy Through-Roads (LTRs)	Noise	Severance	Study Location
1	1	+3%	N/A	Australia
2	1	+24%	N/A	UK
3	5	N/A	+14%	UK
4	1	Significant Increase	N/A	UK

2.5 Economic Impacts and Bypass Development

The most common conceptions of potential bypass developments relate to the fear of economic loss as a result of through-traffic using an alternative route to the LTR. Research of bypass conceptions highlighted that *"…such projects are often accompanied by tremendous* *fears on the part of local proprietors and businesses regarding the scope of their business revenues, the value of their properties, and the impact of the road on land use."* (Elias, et al., 2006).

With these conceptions in mind, this review states a hypothesis that bypass developments have negligible adverse economic effect on regional centres. It is now tested based on a review of case studies.

Extensive studies have been performed in North America about bypasses and the associated economic effects. Coupled with research from New South Wales (NSW), Australia, the economic findings of bypass were investigated across six states as highlighted in Table 5.

Table 5 - Economic Effects of Bypasses Summary

State & Country	No. Case Studies	Outcome
Oklahoma, USA	1	*"In our analysis of the highway bypass around Stonewall Oklahoma, we find no significant impact on the local business economy."* (Marshment & Rogers, 2000).
Kansas, USA	21	*"…bypasses in Kansas have not had significant negative effects on the local economy."* (Burress, 1996)
Texas, USA	6	*"…the economic impact of highway bypasses on small cities in a rural setting is not uniform across cities and in most cases appears to be rather minor."* (Leong & Weisbrod, 2000).
Wisconsin, USA	17	*"In most communities, highway bypasses have had little adverse impact on overall economic activity."* (Wisconsin Department of Transportation, 1998).
Iowa, USA	11	*"The results from analysing the secondary data indicate that the overall levels of retail sales in a community are not significantly affected by the presence of a bypass."* (Anderson & Otto, 1995).
NSW, AUS	3	*"…the findings of this study mirror those identified in the review of literature – that in the longer term highway bypasses do not have adverse economic impacts on towns…"* (NSWRMS, 2015)

While some evidence from the NSW and Texas, USA studies suggested minor effects, both studies elaborated that these findings were not consistent, and not significant enough to confirm that there is an adverse economic effect to a regional centre as a result of bypass development. The results of the case studies listed in Table 5 supports acceptance of the hypothesis that bypasses developments have negligible adverse effects to regional centres can reasonably be confirmed as true.

2.6 Summary of Literature

The findings of literature relating to the development of bypasses to regional centres are summarized as follow:

- Bypass developments provide a general improvement in safety of the regional centre road network by reducing the frequency and rates of vehicle crashes on the bypass itself and the FLTR in comparison to the LTR;
- Modern transport planning is broadly compatible with bypass development with the new transport planning paradigm highlighting the need for multimodal planning, underpinned by accessibility.
- In contrast to the findings about LTRs, bypass developments reduce noise, vibrations, fumes and dust to regional centres and reduce severance within the regional centre; and

- Bypass developments were found by and large, not to have adverse negative impacts to the economy or associated land and business values within a regional centre.

3 Implications between Bypass Development and Road Hierarchy

The development of bypass routes to regional centres are typically associated within brownfield contexts. This is because the operation of the regional centre's existing road network, which has an existing road hierarchy designated by the steward agency, is altered by the development of the new bypass road. It is therefore necessary to examine the implications between bypass development and road hierarchy.

The concept of road hierarchy is *"...a means of defining each roadway in terms of its function such that appropriate objectives for that roadway can be set and appropriate design criteria can be implemented."* (Eppell, et al., 2001).

Roads serve two primary purposes. These two purposes are summarised in a traditional road hierarchy as the following (QDTMR, 2013):

- **Provide Access:** Local traffic for access and circulation within an area; and
- **Allow Movement:** Through traffic with no business or relationship with the area.

The Austroads Guide to Road Design features current practice for a road hierarchy and associated road functions recreated in Table 6 (Austroads, 2009).

Table 6 - Austroads Road Hierarchy Components and Functions (Austroads, 2009)

Type (Classification)	Movement Function	Access Function
Arterial (motorway)	Sole function	Nil
Arterial (non-motorway)	Major	Minimal
Sub-arterial	Significant	Minor
Collector	Minor	Significant
Local	Minimal	Major

Motorway – full access control
Non-motorway – partial or no access control

Whilst each steward agency features its own unique road hierarchy model, the general guidelines in Table 6 set an exemplary framework for a regional centre road hierarchy.

Roads that approach regional centres are generally classified as arterial roads (motorways/highways) as their primary purpose is to facilitate movement over long distances. As Table 6 shows, according to Austroads (2009) the allowance for access for an arterial road (motorway/highway) is nil (Austroads, 2009). However, flexibility is often required in the application of the steward agency's road hierarchy model, because properties within suburban and peri-urban areas to the outskirts of regional centres are often reliant upon highway approach roads to regional centres for their access and local movement to and from the regional centre.

Traditionally, LTRs in a regional centre would be classified according to their steward agency's road hierarchy model as arterial roads (non-motorway), as their functions are twofold. First, they carry long-distance through traffic through the regional centre, and second they carry intra-centre traffic. With the LTR accommodating both traffic functions comes the need for robustness in the steward agency's development and application of its road hierarchy model. In many circumstances, LTRs tend not to be managed adequately when they are strictly classified as arterial roads, because of a lack of flexibility within the application of the road hierarchy model itself. In many instances LTRs cannot be classified in a clear-cut sense.

Further review into road hierarchy development identified a four-level framework for road classification, offering a broader allowance of flexibility in comparison to the traditional Austroads framework identified in Table 6. The traditional classification of Arterial Roads, was broken into three sub-classifications of Highway, Arterial and Arterial Main Street (Eppell, et al., 2001). As presented in Table 7, under the developed four-level road hierarchy framework by (Eppell, et al., 2001), the classification of Arterial Main Street accommodates the unique characteristics of many LTRs.

Table 7 - Arterial Main Street Characteristics (Eppell, et al., 2001)

Dominant Linkage	Traffic Carrying Function	Heavy Vehicle Movement	Speed Environment	Abutting Land Use
Metropolitan/ Sites	<20,000 vpd	Should bypass except for access	40-50 km/h	Retail/Commercial

For reference, Table 8 shows an extract Highway characteristics, under which bypass routes would fall.

Table 8 - Highway Characteristics (Eppell, et al., 2001)

Dominant Linkage	Traffic Carrying Function	Heavy Vehicle Movement	Speed Environment	Abutting Land Use
Regional	No restrictions	Primary freight routes	>=100 km/h	Non-sensitive to traffic

Flexibility in the application of the road hierarchy model is often required to address the transport and land use conflict of a category of roads. Often this conflict is a result of strip mall developments. *"Strip malls (also known as mini-malls) are a common urban land use, historically promoted by U.S. zoning practices that concentrate retail and commercial development in a narrow band along arterials and major streets"* (Wolf, 2009). Strip malls increase demand for on-road parking in some circumstances, driveway turning movements (access traffic), and numbers of pedestrians, often conflicting the functions of a traditional LTR, and prompting the requirement for even greater flexibility in the application of the steward agency's road hierarchy model for the regional centre.

Whilst LTRs do not fluently comply with the classical road hierarchy, we contend that there is sufficient flexibility available within many road hierarchy models, in particular that proposed by (Eppell, et al., 2001), in order to accommodate flexibility. Literature regarding the theory of road hierarchy prior to the 1990s or early 2000s is scarce, suggesting that formal road hierarchy modelling is relatively modern in transport planning and engineering. In contrast, many LTRs of regional centres were developed over a period of decades prior to the adoption of formal road hierarchy modelling, highlighting the need for flexibility.

Allowance for flexibility within a road hierarchy framework for a regional centre ties in with the theory of brownfield development, where modern planning needs to be robust enough to allow for efficient development. The Queensland Department of Transport and Main Roads (QDTMR) road design guidelines, titled the Road Planning and Design Manual (RPDM), highlight how *"Over the last 10 years, additional guidance for designing brownfield sites has been progressively introduced to the RPDM"* (QDTMR, 2013). The guidance listed by the

RPDM for the development within brownfield areas includes the concept of design exceptions in circumstances of new development adjacent to historical development (QDTMR, 2013).

While we contend that a certain amount of flexibility in application of a steward agency's road hierarchy model can be applied to accommodate the diverse functions of LTRs, there comes a time when the LTR's performance and potentially that of the wider road network become excessively compromised. This is generally due to too much strain on one or more of its functions as a result of road safety, efficiency, and/or sustainability problems. This prompts the need for bypass development.

As was established in Literature review, the resulting effects of through-traffic using the LTR are social disturbances such as noise, vibrations, fumes, dust and severance as through-traffic often carries more significant volumes of freight traffic. Furthermore, road safety is potentially compromised with through-traffic requiring to transition from highway approach roads, to centre arterial roads, which generally impose frequent stopping, lower speed limits, narrower lanes and sometimes single, undivided carriageways. Notably, the sense of velocitation for high-speed through-traffic transitioning to lower speed centre arterial roads may cause further road safety concerns. However, the findings from literature suggest that the development of bypass routes has the opposite impact, providing an improvement in road safety to FTLRs.

The completion of highway bypass development to regional centres presents a change in the regional centre's road network structure, whereby the LTR becomes a FLTR, prompting the need for it to be reclassified under the steward agency's road hierarchy model and managed appropriate to its newly established function. For instance, it may be classified as an arterial main street, in which case it can properly fulfil its function, whether it be as a strip mall or as a traditional main street. In some instances it may be appropriate to downgrade it to sub-arterial road status when the majority of its traffic is expected to be shorter distance, intra-centre traffic.

The exact stage when flexible application of the steward agency's road hierarchy model becomes exhausted in terms of acceptable functioning of the LTR requires careful consideration, particularly because this stage precipitates the need for bypass development. The next section examines Australian bypass case studies, determining the objectives for each, in order to ascertain the mechanisms for permissible flexibility in application of the road hierarchy model and the identification of the point of need for bypass development.

4 Case Studies to Understand Bypass Development Mechanisms

This section critically analyses a number of cases of Australian regional centre bypasses to understand the objectives of their development in the context of the considerations of Section 3. Determining these objectives will assist in identifying a set of mechanisms that trigger bypass development.

These Australian bypass case studies are listed in Table 9. The population of the regional centre and the approach highway/s are provided for each case. It is noted that the Hume Highway & Pacific Motorway were two unique case studies linking Sydney and Melbourne, and Brisbane and Sydney respectively. Each of these routes incorporates numerous bypass case studies of regional centres.

Table 9 - Australian Bypass Case Studies

	Population	Road Authority	Approach Highways
Toowoomba, QLD	111,000	QDTMR	A2 Warrego Highway passing through East-West;

			A39 Gore Highway approach from the Southwest; and A3 New England Highway passing through North-South.
Gympie, QLD	21,000	QDTMR	A1 Bruce Highway passing North-South.
Tugun, QLD	6,000	QDTMR	M1 Pacific Motorway passing North-South.
Beaudesert, QLD	6,000	QDTMR	A13 Mt. Lindesay Highway passing from North-South.
Hume Highway, NSW	Varies	NSWRMS	M31 Hume Highway passing several regional centres, typically North-South.
Pacific Motorway, NSW	Varies	NSWRMS	M1 Pacific Motorway passing several regional centres, typically North-South.
Brighton, TAS	3,500	TDSG	National Highway 1, Midland Highway passing North-South.
Vasse, WA	1,700	DMRWA	State Route 10, Busselton Bypass passing East-West.

Whilst there is variation in the size, location, road authority, population and regional structure between all case studies listed in Table 9, the objectives for bypass development consistently aligned, which were identified as:

- Increased road capacity resulting in reduced congestion for both local traffic and through traffic;
- Reduction in heavy vehicles through CBDs resulting in reduced noise, fumes, dust and vibrations to local residents and businesses;
- Improvement in freight efficiency by avoiding lower speed limits, signalised intersections, pedestrian crossings and other intersections;
- Improved safety for local pedestrians and cyclists by removing larger volumes of traffic from local areas;
- Improved road safety by separating traffic with different movements into local traffic and through traffic; and
- Flood immunity to applicable locations.

The findings from the analysis of case studies correlated with the findings from published literature. *"One of the principle reasons for the construction of bypass roads in towns in the removal of through-traffic from the centre of a town or city to the periphery, for the purpose of improving the flow of traffic, reducing travel times and reducing road accidents."* (Elias, et al., 2006).

Using the objectives established across the Australian bypass case studies, a representative set of mechanisms was identified, being those that jointly or severally have the potential to exhaust the flexible application of the steward agency's road hierarchy model in terms of acceptable functioning of the LTR, thereby precipitating the need for bypass development. The mechanisms were developed based on findings from a review of each of eight case studies in which bypass routes were either recently completed, recently commissioned or with construction underway. The scope of this examination presented the following five mechanisms when examining the need for bypass development to a regional centre:

- **Road Capacity:** The findings from the case studies and literature review suggested a significant objective in almost all bypass projects was to offer an improvement in road capacity. This mechanism is primarily generated by highway traffic using roads internal to the regional centre causing congestion, which manifests in significant delays to local and through traffic on the LTR.

- **Road Safety:** The road safety mechanism is broad as it offers a number of contributing elements. LTRs can present a number of safety concerns, including the effect of velocitation when transitioning from highways approaching regional centres to LTRs themselves. Additionally, LTRs offer high interaction between pedestrians and cyclists with through-traffic, without accommodating the same safety features as highways, such as; divided carriageways, safety barriers, increased lane and shoulder widths and grade separation (AusRAP, 2011).
- **Freight Efficiency:** The literature review detailed the issues of long distance freight traffic using LTRs and how this generally causes an increase in cost and time of transport in addition to adversely impacting local areas with noise and dust (QDTMR, 2016). An example of poor freight efficiency is the regional centre of Toowoomba, Queensland. The most efficient route for freight and long-distance traffic to travel from the East to the West of Toowoomba, is via the LTR being the Warrego Highway, whereby 18 signalised intersections are encountered (QDTMR, 2017).
- **Social Disturbances:** The social impact mechanism is a consistent factor for all bypass projects as a desirable living environment hinges on transport and land use interaction. Findings from the literature review present evidence to show that LTRs are subject to social disturbance in terms of; dust, noise, fumes and vibrations (Egan, et al., 2003).
- **Flood Immunity:** Unlike the four previously listed mechanisms, flooding does not apply to all case studies and in the first instance might not be expected to be related to road hierarchy modelling. However, flooding in regional centres that are reliant on low lying LTRs can cause widespread impacts due temporary closures to through traffic including freight and long-distance traffic, as well as intra-centre traffic. An example of this mechanism is the application to Gympie, Queensland, where the regional centre has highway traffic that is reliant upon the low lying LTR, which in periods of high rainfall is subject to closure due to flooding (QDTMR, 2009). Functioning of local and broader road networks become compromised when closures occur frequently due to flooding.

These elements contribute to the need for highway bypass development at a certain stage in the lifecycle of the LTR.

5 Determining the Need for Bypass Development

5.1 Comparative Examples of Bypass Development

Having identified a set of mechanisms that jointly or separately have the potential to precipitate the need for bypass development, the application and importance of each with the need for bypass development must be examined. A more focused sample of regional centres in Queensland, Australia was selected for assessment to identify how each mechanism is relevant and impacts upon flexible application of the road hierarchy model in terms of acceptable functioning of the LTR and/or broader road network accordingly. The regional centres include Toowoomba, Maryborough, Gympie and Stanthorpe whose details are presented in Table 10.

These regional centres were selected on the basis of providing an even spread of representative case studies. The purpose of this even spread was to incorporate a variety of regional structures in different bypass development phases with different needs for bypass development to be undertaken. While the highway steward agency is the Queensland Department of Transport and Main Roads, each regional centre is located in a different local government area. Distances were taken from (Google Maps, 2016), while population statistics were extracted from (Australian Bureau of Statistics, 2016), and Average Annual Daily Traffic (AADT) were taken from (Queensland Government, 2016).

Table 10 - Representative Regional Centres

	Toowoomba	Maryborough	Gympie	Stanthorpe
Distance from Brisbane (Capital of Queensland)	125km West	260km North	170km North	220km South-West
Bypass Development	Under Construction	Completed	Under Construction	Completed
Population	111,000	27,000	21,000	5,600
LTR(s) AADT (2015)	85,739		21,374	
FLTR AADT (2015)		7,999		3,533
HB AADT (2015)		10,724		5,170
LTR(s) AADT/person	0.77		1.02	
FLTR AADT/person		0.30		0.63
HB AADT/person		0.40		0.92

Table 10 provides a means of assessing and comparing the through-road network structure of each case study regional centre at a strategic level. The comparison of LTR, FLTR and HB figures of AADT/person is a critical means of identifying an area of high utilisation given a regional centre structure. It is important to note that Maryborough, Gympie and Stanthorpe are each located on a single approach highway in contrast to Toowoomba, of significantly larger population, which features three approach Highways.

Whilst these figures are indicative, they suggest that the Toowoomba and Gympie LTRs are subject to high utilisation, resulting in freight inefficiencies. The AADT/person in the case study of Gympie identified extremely high impact of through traffic on the community, as a result of the smaller population relative to the volume of through-traffic. Table 10 identifies a notable trend, which demonstrates how non-bypassed case studies of Toowoomba and Gympie have significantly higher ratios of AADT/person in contrast to the bypass case studies of Maryborough and Stanthorpe.

Table 10 suggests that each of the bypassed regional centres of Maryborough and Stanthorpe has no significant concerns regarding high utilisation of the FLTR in contrast to the LTRs of Toowoomba and Gympie.

5.2 Case Study Ranking of Mechanisms for Bypass Development

Toowoomba and Gympie feature bypasses that are currently under development and planned respectively, so are still reliant upon their LTR/s. In contrast, Stanthorpe features a bypass route and as a result, its FLTR serves an intra-centre arterial road function. Meanwhile, Maryborough does have a bypass road for the A1 Bruce Highway, but through traffic between the A1 and B54, which provides access to Maryborough's twin regional centre of Hervey Bay, must pass through the centre's FLTR.

Table 11 provides a summary of the analysis of the four representative Queensland regional centres.

Table 11 – Bypass Development Need – Case Study Assessment

	Toowoomba	Maryborough	Gympie	Stanthorpe

LTR Acts Like	Arterial Main Street	NA	Arterial Main Street	N/A
HB Acts Like	N/A	Highway	N/A	Highway
FLTR Acts Like	N/A	Arterial Main Street	N/A	Arterial Main Street
Flood Risk	Medium	Very Low	High	Very Low
LTR LOS	E	N/A	E	N/A
FLTR LOS	N/A	B	N/A	C
HB LOS	N/A	A	N/A	B
RH Functions Appropriately:	No	Yes	No	Yes

The appropriate road hierarchy function listed in Table 11 is based on a general assessment of the regional centre's network.

Table 11 details the performance of the respective roads applicable to each case study in comparison to the Austroads road hierarchy model (Austroads, 2009). An observation from Table 11 is the flood risk relative to each cast study. In particular, the bypass case studies of Maryborough and Stanthorpe demonstrated low flood risks in contrast to Gympie and Toowoomba, which featured lower-lying LTRs and thus presented more significant risks of flood impacts.

The Highway Capacity Manual (HCM), provide guidance on the examination of road performance. Chapter 12 of the HCM, titled Highway Concepts, presents the theory of Level of Service (LOS), measuring road performance based on criteria of percent time-spent-following and average travel speed (Highway Capacity Manual, 2000). LOS is described alphabetically with LOS A as a figure of best-practice road performance to LOS F where the road's flow rate exceeds segment capacity. Using the road parameters, the legacy through-roads of Toowoomba and Gympie were analysed to operate at LOS E, highlighting the high utilisation of these routes. In contrast the HB in Stanthorpe and Maryborough were found to be both LOS A in addition to the FLTR featuring a LOS B and LOS C respectively.

For each case study, the mechanisms were applied and ranked in terms of importance. They were ranked in order from five to one, as a measure of importance with five being the most important and one being the least important. The basis of this ranking system was to determine the universally most critical mechanisms that should be assessed in regional centre case studies, where bypasses are not developed and the particular road hierarchy is potentially conflicted.

The development of importance rankings was based on the assessment criteria outlined in Table 12. The capacity, safety, freight and flooding mechanisms are measurable in each case study with figures and collected data to analyse and develop the importance ranking. However, the social disturbance mechanism may be ambiguous with the measurability of this importance rank based upon field study and engineering judgement.

Table 12 - Mechanism Assessment Criteria

Mechanism	Capacity	Safety	Freight	Social Disturbance	Flooding
Criterion	LOS	Crash Frequency Data	%HV of AADT	%HV of AADT and evaluation of residential areas	Road design levels & ARI Rainfall Events

Table 13 shows a tabulated comparison of regional centre case studies with the five mechanisms ranked in terms of importance. This study has retrospectively ranked the mechanisms for the case studies of Maryborough and Stanthorpe in order to gauge the variation between historical bypass mechanisms and modern day case studies in the instances of Toowoomba and Gympie. The importance ranks displayed in Table 13 were determined based on a comparative assessment of the statistical criteria for each mechanism outlined in Table 12. The ranking of one (1), signifies the most important mechanism to a particular regional centre with five (5) being the least important.

The development of the importance rankings displayed in Table 13 was based on field study findings and comparatively assessing LOS figures, crash statistics, %HV and flood risks to each regional centre. Using the example of Gympie, literature (AusRAP, 2011) and statistics strongly indicate there is an overwhelming need for bypass development due to road safety concerns in addition to capacity concerns. The frequency and associated impacts of the crashes and congestion were identified as the two primary drivers in the need for bypass development. Furthermore, flood impacts, which occur less frequently, were identified in various corridor studies (QDTMR, 2009) as contributing to the need for bypass development. Whilst the impacts associated with freight efficiency and demand for social improvements have been less prevalent. Hence the ranking system in Table 13 shows the importance in the need for bypass development to Gympie as; safety, capacity, flooding, freight and social impacts listed in ascending order.

Table 13 - Mechanism Assessment - Case Studies

	Mechanisms				
Case Study	**Capacity**	**Safety**	**Freight**	**Social**	**Flooding**
Stanthorpe	5	3	1	2	4
Gympie	2	1	4	5	3
Maryborough	2	5	1	3	4
Toowoomba	1	4	2	3	5

Table 13 demonstrates that ranking of mechanisms varies considerably between all regional centres, regardless of the stage of bypass development. The mechanisms identified in the findings from this paper apply to all of the case studies, but at differing degrees in establishing the need for bypass development.

The findings tabulated in Table 13 suggest that the mechanism assessment must be undertaken for each regional centre on a case-by-case basis as mechanism impact can vary depending on the performance of the LTR. There is insufficient evidence to suggest that any mechanism is of higher or lower importance as there is no notable trend in the ranks provided in Table 13.

Conclusively, the five mechanisms are the principal drivers that facilitate the need for bypass development projects. There is evidence to suggest that road capacity, road safety, freight efficiency, social disturbances and flooding effects need to be comparatively assessed against a regional centre’s LTR functioning when establishing the need for bypass development.

6 Conclusion

The literature review of bypass developments and associated transport planning reveals the effects of bypass routes to regional centres to be beneficial. Additionally, the literature review indicated that bypass developments have a positive impact to regional centre network safety and social disturbance. There was also research found to suggest that modern transport planning is becoming more accustomed to incorporating developments such as bypass routes to previously established networks.

This investigation into the need for highway bypass development found that the "need" is generated by potential inconsistencies in the application of a road hierarchy model to a regional centre. The highlighted road hierarchy inconsistency is best described as a gap in transport planning activity, specifically in the development of a road hierarchy model for a regional centre.

An examination of Australian bypass case studies was undertaken to determine the objectives for bypass development and identify when flexible application of the road hierarchy model becomes exhausted. The key mechanisms that can jointly or separately trigger the need for highway bypass development were identified as; road capacity, road safety, freight efficiency, social disturbances and flooding risks. Furthermore, the results of this assessment indicated that road hierarchy inconsistencies need to be analysed on a case-by-case basis as variation between mechanisms is evident.

Application and testing of these mechanisms with four Queensland sample case studies outlined the effectiveness for each in establishing the need for highway bypass development. Notably, road capacity, road safety and freight efficiency were deemed most critical on the basis of the four representative samples.

This paper presented findings that suggest bypass routes have universal benefit to regional centre transport planning and ultimately to the community. The findings indicate that the need for highway bypass development to regional centres can be determined based on allowable flexibility in a comprehensive road hierarchy model, but where road safety, road capacity and freight efficiency outcomes are not adversely compromised.

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8 Glossary

- AADT – Average Annual Daily Traffic
- AS – Australian Standards
- AusRAP – Australian Road Assessment Program
- CBD – Central Business District
- FLTR – Former Legacy Through-Road
- HB – Highway Bypass
- HCM – Highway Capacity Manual
- LOS – Level of Service
- LTR – Legacy Through-Road
- NSWRMS – New South Wales Roads and Maritime Services

- QDTMR – Queensland Department of Transport and Main Roads
- RPDM – Road Planning and Design Manual
- TRB – Transportation Research Board