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ACCESSIBILITY AND ISOLATION IN TRANSPORT NETWORK EVALUATION

Dr Ken Davidson

This paper is written as a companion to a seminar presentation.

The concepts described here have the potential to provide performance indicators for higher level objectives of transport network investment. They also have value in assessing the status of transport networks, evaluating network improvement alternatives and in prioritising investment programs. Because they include a relationship between accessibility and land use, they may be used in assessing and modelling specific land use effects of transport network changes and in the assessment of the quality of different arrangements of community facilities. They provide a basis for strategic comparison of roads in widely different locations, and of the relative quality of public and private transport networks.

April 1995.

ACCESSIBILITY AND ISOLATION IN TRANSPORT NETWORK EVALUATION

ISOLATION:

An indicator of:

- **the economic performance of transport networks**
- **the distribution of benefits from transport improvements**
- **the total benefits from a transport system change**
- **the general appropriateness of a transport network**
- **the spatial performance of transport networks**
- **the land use and urban or regional development effects of transport system changes.**

The basis for an evaluation of alternative transport network changes and developing priorities.

The basis for an assessment of the value of transport and land use policies on a common scale.

The basis for a volume normalising factor allowing the strategic significance of roads with different volumes to be compared.

The basis for an urban land use model, particularly with respect to the effects of transport changes.

The basis for an activity location model.

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Applications

Computation & Presentation written by Peter Davidson (in a separate document)

Relevant publications written by K B Davidson:

"Accessibility in transport/land-use modelling and assessment" *Environment and Planning A,* Volume 9, 1977

"Use of accessibility in metropolitan strategic planning" *ARRB Proceedings,* Volume 9, Part 6, 1978.

OVERVIEW

Accessibility is generally understood to describe the ease with which a place may be reached from elsewhere. It is defined here as the ease with which person at a point may gain access, via the transport system (or whatever modes or sub-systems of it are nominated), to all other places in a defined area, taking into account their varying attractiveness and the perceived cost of getting to them. A location with high accessibility will tend for most purposes to be more attractive than one with low accessibility and hence to be more highly valued.

This is not to say that accessibility is the sole determinant of a location's value: rather that it is one determinant - the one changed by action on the transport system and land use arrangements. Thus changing the transport system or land use pattern in such a way as to increase an area's accessibility will increase that area's value and attractiveness.

Thus it can generally be said that one way to promote regional or urban development of an area is to increase its accessibility. Taking an action which reduces, relatively or absolutely, an area's accessibility will have social justice implications, particularly if it is an area which is already suffering some other disability.

Accessibility so defined can be seen to be a joint consequence of the transport system and the distribution of activities (e.g. population or employment are simple measures of activity). A change in either the transport system or the distribution of activities will change the value of accessibility and the value will change differently for different places. Herein is the power of the concept in that the impact, on regional or urban development or social disadvantage, of any change to the transport system (or any policy designed to change the distribution of activities) can be measured. This power is enhanced if the accessibility measure can be expressed as a measure of utility (or disutility) for in this form it is able to be inserted directly into evaluation equations.

A Measure of the Transport-Induced Utility of Location

Accessibility deals with the same variables as feature in the trip distribution model and can easily be calculated as a by-product of it. Accessibility at a point is the sum for all other places of the quotient of its population (or other measure of size) divided by a function of the cost of travel to that other place, the function being the same impedance function as used in the trip distribution model. For a simple gravity model it is population divided by travel cost squared summed over all places. The author has shown that there is an inverse function of accessibility, which he has called "Isolation," which is a proper measure of disutility. It can be thought of as a properly weighted average travel cost for the place for which it is the value of all travel in the defined study area.

Accessibility, or its partner Isolation, is thus a characteristic of a place defined by the transport system and the distribution of activities. It also has included in its definition the impedance function of the model used for trip distribution or, if no specific model has been calibrated, a generic function such as the simple gravity model.

Plotting values for different places in contours can be enlightening. The plot can give an overview of the relative performance of the transport system in various areas. Inspection of the plot as though it were a contour representation of a landform reveals a landscape with holes of low Isolation around major centres, valleys of transport corridors and ridges as areas with relatively poor accessibility. Sometimes contours become very close as in a cliff. This suggests a complete lack of a transport link and/or a very rapid reduction in activity density. Areas on ridges or beyond such barriers can often have their accessibility improved dramatically with a new or more direct or improved link. If such areas are populated, the plot may thus indicate where such effort could be worthwhile. Ridges or cliffs where they should not be is a sure sign of an inadequacy in the transport system. Wide areas of steady, smooth contours indicate stable areas where major improvement is less likely to be required.

Transport Network Performance Indicators

More analytically useful are plots of changes in Isolation consequent upon any change in the transport system. Such a plot shows clearly and unequivocally the areal distribution of the impact of the change. The total value of the impact can be calculated by multiplying the change in Isolation value at each point by the population at each point. It is usually valuable to sum positive and negative impacts separately prior to a final summation because strong or extensive negative impacts, even if more than balanced by positive ones, are often pointers to an inadequate proposal and certainly draw attention to a likely community backlash. The author has used this sort of analysis powerfully in Adelaide, Canberra, Brisbane and Toowoomba to assess the effects of a range of different land use/transport scenarios.

Comparative Evaluation of Transport Network Changes

Effects of transport infrastructure projects are generally measured principally through the impacts on the users of the system: the traffic benefits from reduced total road user costs as experienced by existing and attracted traffic are usually by far the most important components of project evaluation. Yet such an approach causes some problems, particularly in evaluating the benefit of generated traffic, and particularly in the longer term when such traffic increases travel costs to all users. The whole issue can be looked at in a totally different way.

Consider this: when a transport improvement occurs, the only beneficiaries are the existing property-owners whose properties get an immediate gain in accessibility. The gain is either enjoyed by the owner personally or capitalised so a new buyer pays for the improvement in accessibility in the purchase price or incorporated in increased rent payments. Thus public investment in infrastructure can be seen as simply a transfer to those property-owners whose properties gain in accessibility and the magnitude of the value transfer increases with the magnitude of the accessibility improvement.

This has some very important equity implications, but for our purposes here it is important because it signals an alternative way to measure the benefits of transport infrastructure improvements. Because Isolation is expressed in disutility terms, this transfer value is linearly related to the reduction in Isolation which the improvement causes. If Isolation is seen as measuring locational disutility, an increase in accessibility is a reduction in Isolation or locational disutility and so indicates an increase in the utility of the location.

There are thus two ways of looking at the value of transport improvements: traffic cost reductions and improvements in locational utility. These measures are not additive but may be complementary or alternatives. We believe that Isolation reduction alone covers more of the total than traffic benefits alone. The difficulty with Isolation at this stage is in determining its "exchange rate." Without this it cannot be used directly in calculating benefit-cost ratios but it can be used in ranking alternatives. It is possible that Isolation could be expressed in normal monetary terms: say money units per head per day by multiplying Isolation at each point by the number of trips produced per head at each point per unit time and multiplying this by the value ascribed to travel time or to the generalised cost measure in which Isolation is expressed. (This has not actually been done in a formal study to date but initial indications are promising.)

Relative, and possibly absolute, benefit-cost evaluation of alternative network changes can be obtained by comparing the total reduction in Isolation (Sum of the product of Isolation reduction of each zone and its population) consequent upon each alternative, with its cost.

Further evaluative insight may be obtained from an examination of the footprint of Isolation reduction benefits. This is obtained by drawing contours of Isolation change induced by each alternative or by one alternative against another. By this means a plot of the distribution of areas with each size of gain and loss is obtained.

Where land use impacts are relevant, these too can be included in the evaluation as discussed below.

Land Use Impacts of Transport Change

Because transport investment affects accessibility, it changes relative locational values of properties or areas or regions. It thus changes the development potential of places both absolutely and relatively. Improving accessibility can therefore be used as an instrument to foster regional or urban development or to redress any social justice inequities in a particular area. A particular expression of this effect is a relationship the author has developed between Isolation and equilibrium urban density. Empirical studies suggest a linear relationship between Isolation and the logarithm of density. This relationship can be used as the basis for a model to predict the urban land use effects of transport system or activity distribution changes. A similar effect would be expected at a regional scale but a specific relationship has not so far been suggested. However the lack of a specific relationship should not preclude Isolation being used powerfully in a regional context to assess the regional development or social justice impacts of alternative transport proposals. Clearly regional development or social justice objectives can be fostered simply by ensuring that transport network investment programmes have as one outcome a relative increase in accessibility in such target areas.

Similarly if particular land use outcomes are being sought, this type of analysis would indicate to what extent transport network alternatives and/or land use changes elsewhere would foster (or act against) the achievement of a particular land use outcome.

Activity Location Model

Isolation can be used as a basis for an activity location model. By calculating and plotting profiles of Isolation to the activity in question, areas of poor accessibility to the activity are disclosed. Various size/location scenarios for extra sites for the activity can be tested for their effect in overcoming the deficiencies. Activities amenable to location by such analysis include primary or secondary schools, shopping centres or any other distributed community facilities. Conversely, the size of their markets can also be assessed by looking at the activities' accessibility to population or those segments of it of interest (such as children of primary school age if the activity is a primary school).

Mode Split Model.

Strategic Comparison of Traffic Volumes in Different Areas

Although it is tempting to assert that the economic significance of a road is closely associated with its traffic volume, most of us feel intuitively that a low volume road in a sparsely settled area can have strategic significance which could surpass that of some very busy roads in metropolitan or other high density areas. For reasons that are not yet completely clear, it appears Isolation may be able to be used as a multiplier of traffic volumes to normalise them for comparison of their strategic significance. By this means volumes on busy near-metropolitan highways can be brought to the same scale for strategic significance purposes as volumes on low volume roads in low density areas. This approach may also be able to be interpreted as an indicator of under- or over-development of a route. This concept needs testing in a wide range of locations. Initial work which multiplied actual volumes by Isolation squared gave normalised values which varied by a factor of only an extreme of 1.6 along the complete lengths of Queensland highways which had been assessed as being of the highest level of strategic significance despite volume variations of up to 100 fold (Warrego, and New England National Highways when equated with the Bruce Highway just north of Brisbane).

Summary

Isolation, an expression of accessibility in utility terms, can thus be used in a number of ways to measure and compare the performance of transport networks:

- to assess the general quality of the network in serving an area and to indicate areas of network weakness by using a topographic analogy in studying the Isolation contours

- to check spatial impacts of proposals or to develop effective proposals to meet specific spatial objectives generally of a regional development or social justice nature: any change in a network element (e.g. any road construction project) will change Isolation profiles. A change in Isolation at a point means there is a change in the utility or value bestowed by the transport system to a community or landholder at that point. Every potential project therefore has a different profile of utility gifting. For example, social justice can be promoted by ensuring this utility gifting is spread among the community in equitable ways, and especially by ensuring that disadvantaged communities gain relatively more than others. The appropriate way to distribute this increase in utility is clearly a political question. This approach simply allows the distribution of benefits of particular works programmes to be determined. Similarly regional development can be selectively promoted by ensuring utility increases are concentrated in areas where increased development is sought

- as one way to measure the economic value of proposals or to develop proposals which maximise economic impact: since Isolation is a measure of locational disutility, an improvement in accessibility, which corresponds to a reduction in Isolation or locational disutility, is a measure of the economic impact of a proposal to an individual. Summing the effect over all individuals or all those in target groups (for example, a particular industry) is a measure of economic impact to that group or the whole community

- as the basis for a model to assess the urban land use impacts of changes in an urban transport system through an empirically derived equilibrium relationship between Isolation and urban density: a change in Isolation will change the equilibrium density and set in train pressures which will tend to move the density to the new equilibrium value. Areas for growth and blight are thus identified and the new equilibrium value suggested which then allows future populations to be estimated or given future populations to be distributed

- as the basis for location optimisation of community facilities (such as schools and shopping centres) and to assess their markets

- as the basis for a normalising parameter which allows direct comparison of the local significance of traffic volumes between widely different areas.

THEORY AND DERIVATION

This is described in the first attached paper and is outlined in the section below.

CONCEPTUAL BASIS

Accessibility

It will readily be agreed that communities build transport facilities for the purpose of making individuals and organisations accessible to each other and that an important factor in location decisions is the accessibility of a location to other locations of interest or importance to the locater.

The accessibility provided by a transport system will vary from location to location and will depend upon its structure, its relationship to the pattern of land use, the amount of traffic using it and its efficiency in handling that traffic. A change in any of these dependent elements will change the accessibility at each location.

Since the provision of accessibility is a principal purpose in the construction or operation of transport facilities the quality of the accessibility provided may be an appropriate way to evaluate the effectiveness of those facilities. Further, since accessibility at a location is a determinant in location decisions, the effect on the land use pattern of particular transport arrangements may thus be able to be inferred.

Success in such an approach would overcome the major problems of the traditional approach to transport planning: the difficulty in evaluating the relative merits of alternative proposals and the lack of feedback from the transport proposals to the land use assumptions on which they were based.

Although the concept of accessibility may be seen in many different ways, it is suggested that, for the purposes of testing alternative transport and land use arrangements, it should as far as possible be defined so as to require only the use of data which is readily available, robust and able to be predicted with maximum confidence.

The following definition fulfils these requirements:

$$X_i = \sum_j S_j f(C_{ij}) \qquad \ldots.(1)$$

where X_i = accessibility at zone i

S_j = a measure of activity at zone j

C_{ij} = the perceived cost to the traveller of travel between zones i and j

f = a travel impedance function designed to reflect known travel characteristics, e.g. a gravity model

It will be seen that this definition allows the accessibility measure to reflect both the pattern of land use through the activity variable S and the quality of the whole transport system through the travel cost variable C. Because accessibility here is a summation of products of activity and an inverse function of the cost of getting to them, nearby activities will figure far more prominently than distant ones. However in principle, any change to either land use or transport will be reflected in a change in every zone's accessibility measure, again closer changes having the greatest effect.

Isolation: a measure of the utility of location

The author showed that a particular transformation of this definition of accessibility is a measure of utility and hence may be used directly in evaluation. This transformation is called Isolation and is defined so that it is the travel cost from zone i to a hypothetical zone with the same total number of activities as the whole urban area and which produced the same value of accessibility:

$$X_i = \sum_j S_j f(C_{ij}) = (\sum_j S_j).f(Y_i) \qquad \text{....(2)}$$

where Y_i = Isolation at zone i

$(\sum_j S_j)$ = total study area activities = S_T

hence
$$Y_i = f^{-1}\left(\frac{X_i}{S_T}\right) \qquad \text{....(2a)}$$

and it may be thought of as a properly weighted average travel cost for all travel in the area included in all zones (i.e. with total activities S_T) which takes full account of the perceived impedance to travel reflected in the travel impedance function.

Isolation then is a proper measure of the perceived impedance of gaining access to all the activities the region has to offer so it can be thought of as a disutility attached to that location and is thus referred to as location disutility. It will be noted that it is a function of the pattern of land use, the quality of the transport system and the size of the city; it is therefore as rational as it is simple.

This is not to say of course that it comprehends all the factors which give a location value - intrinsic environmental merit is not included at all. Furthermore different activities or opportunities will be perceived in quite different ways and individuals will respond differently to particular patterns of activities and opportunities. Nevertheless it is contended that the measure is capable of representing those aspects of value or utility which will change with changes in the transport system or the land use pattern, so that changes in the location disutility which will result from them are proper bases for their evaluation. Furthermore, although individuals will respond differently, the effect on the community as a whole will be properly reflected since value depends on average rather than specific responses and in any case is the result of the pattern of individual choices where individuals presumably act to maximise their own utility.

Every transport/land use combination will have its own characteristic pattern of locational disutility distribution. Comparing the patterns for alternative combinations thus gives a basis for evaluation of the alternatives. This can be done both on the basis of metropolitan averages and on the basis of the effect on a certain region or socio-economic group. Thus if an appropriate transport strategy for a particular problem region is being sought, the pattern of location disutility changes within that region can be determined for each alternative and a scheme formulated which distributes the benefits in the most desired way. Alternative strategies can be evaluated on the basis of finding the largest increase in utility (decrease in disutility) per dollar spent or finding the strategy which maximises the increase in utility for a given budget.

Isolation as an indicator of land use intensity

The above concepts give a way of evaluating specific transport and/or land use proposals in terms of movement efficiency. They do not address another major difficulty in transport planning, that of predicting the likely effect of transport changes on the pattern of land use. This requires a further extension of the accessibility concept.

If, as stated above, a determinant of location is accessibility, then it would be expected that highly accessible locations would have the more intensive development, or at least that property values would, other things being equal, be higher with higher values of accessibility. Of course in the long term, this amounts to the same thing: high property values lead eventually to more intensive development because of a desire to maximise returns on investment.

Many researchers have found relationships between residential density and distance from the city centre. There are two problems with these relationships - they do not take account of land uses other than residential and they do not hold for multi-centred cities or those with dispersed activity patterns. However since these relationships have a certain respectability and intuitive logic, it may be possible to build on them in such a way as to overcome the difficulties mentioned; initially by ensuring they reflect the quality of the transport system rather than just the distance to the city centre (thus making them sensitive to transport changes).

Presumably these relationships worked because most activity was concentrated at the city centre and they were reflecting the utility of being close to activities. The same concept should therefore be applied by relating density to Isolation. It can easily be shown that if all activity was in the city centre Isolation would equal travel cost to the city centre. Hence replacing distance to the city centre with Isolation would not change the nature of the relationship but would allow it to cope with modern dispersed cities, to be based on travel cost rather than distance and therefore to be able to reflect transport network changes.

The relationship would also be more useful if it took account of employment as well as residential density. A combined density measure was therefore developed which attempted to reflect the relative density perception effect of one worker compared to one resident.

Typical relationships involving distance to the city centre show that it has a negative exponential relationship with density and the same formulation has been proposed for Isolation. This means the logarithm of density is linearly related to Isolation.

Data from a number of cities have been used to validate the linearity of the relationship. They also suggest that it may be universal in the sense that the same parameters of the linear equation may apply to all cities. The consistency of this relationship together with evidence that areas tend to change with time in such a way as to move towards the line suggest that it represents an equilibrium condition.

An equilibrium between accessibility and land use would clearly be a long term phenomenon and one which would be affected by many other factors including intrinsic environmental merit and, in the short term, by planning controls. Cities generally change more quickly than the adjustments towards equilibrium can occur so the existence of an equilibrium condition is not likely to be demonstrated frequently. It must therefore be a somewhat ephemeral concept which is hard to define but that difficulty should not detract from its importance. In calibrating the relationship it was encouraging to note that London, an old stable city, corresponded very closely to it whereas more rapidly changing Australian cities had a lower conformance but in expected ways.

If the equilibrium exists then there must be some financial mechanism for bringing it about. An area which is not in equilibrium would have, by virtue of that condition, a utility or disutility the capitalisation of which would tend to move the area towards the equilibrium. Hence an area with too low a density for its accessibility should have a premium on property values which, over time, will tend to generate more intensive land use. Conversely, an area with a density too high for its accessibility will have depressed property values which may then be manifest in the problems of a socially disadvantaged area or in eventual depopulation or blight if other factors or initiatives do not correct the disequilibrium in the meantime. This utility has been called density utility or disutility and is calculated as the difference between actual Isolation and the Isolation suggested by the equilibrium line for the area's actual density.

Mathematically this is expressed as:

$$Z = Y - \frac{K - \log D}{\rho} \qquad \text{.... (3)}$$

where Z = density disutility

K = the intercept of the equilibrium line

ρ = the slope of the equilibrium line.

Density utility (negative Z) would therefore suggest that an area is ripe for more intensive development. Density disutility suggests overdevelopment and possibly the need for transport improvements or increased local employment to correct the situation.

A conclusion of this approach is that the greater the value of Z, either positive or negative, the greater will be the pressure on the area to change (to decay or develop). While this is generally true, there are often other reasons why an area is more or less highly developed than its accessibility would suggest. This is because there is some other element selectively adding to or detracting from an area's locational value. If this element has a value sufficient to cancel out the density disutility, the area could be in development equilibrium.

Density disutility will be affected by changes in transport and/or land use. It may therefore be appropriate to check proposals for their effect on equilibrium: with proposals which tended to reduce disequilibrium generally regarded as preferable in this context. An increase in disequilibrium will lead to more rapid change (independent of growth) with all the public infrastructure and private costs which that entails. It also has equity effects in that those with the greatest command of resources are able to act to take advantage of the disequilibrium at the expense of those with little or no command of resources.

Following through these concepts highlights the conclusion that changes in transport or land use certainly change patterns of accessibility but those changes are in effect capitalised by existing property owners. Thus expenditure of public funds on transport improvement results in a transfer of value to those property owners whose accessibility is increased and little else. Transport proposals should therefore be tested to determine the distribution of these benefits so that, over time, they are distributed fairly. This of course is a political matter and the value of analysis based on these concepts is that it allows the distribution of benefits from proposals to be clearly identified by decision makers.

This approach suggests what the equilibrium land use intensity should be for any level of Isolation and provides a measure of the utility or disutility conferred by any transport or land use change. This is all that is needed for evaluation. To create a model to predict land use changes over time which result from transport change requires an allocation model. Golding's intervening opportunities model (referenced as Golding & Davidson 1970 in both attached papers) would provide this. This would allow any level of population increase to be allocated according to the pressures for growth and decay suggested to be created by the magnitude of density utility or disutility.

APPLICATIONS & EXAMPLES

1. General Appropriateness of a transport network

See Isolation diagrams in Figures 1 (Queensland major roads network), 2 (Brisbane 1986 network), and 6.1 (Adelaide 1977 network).

Figure 1: Queensland Isolation to Population with Existing major Roads Network n = 2

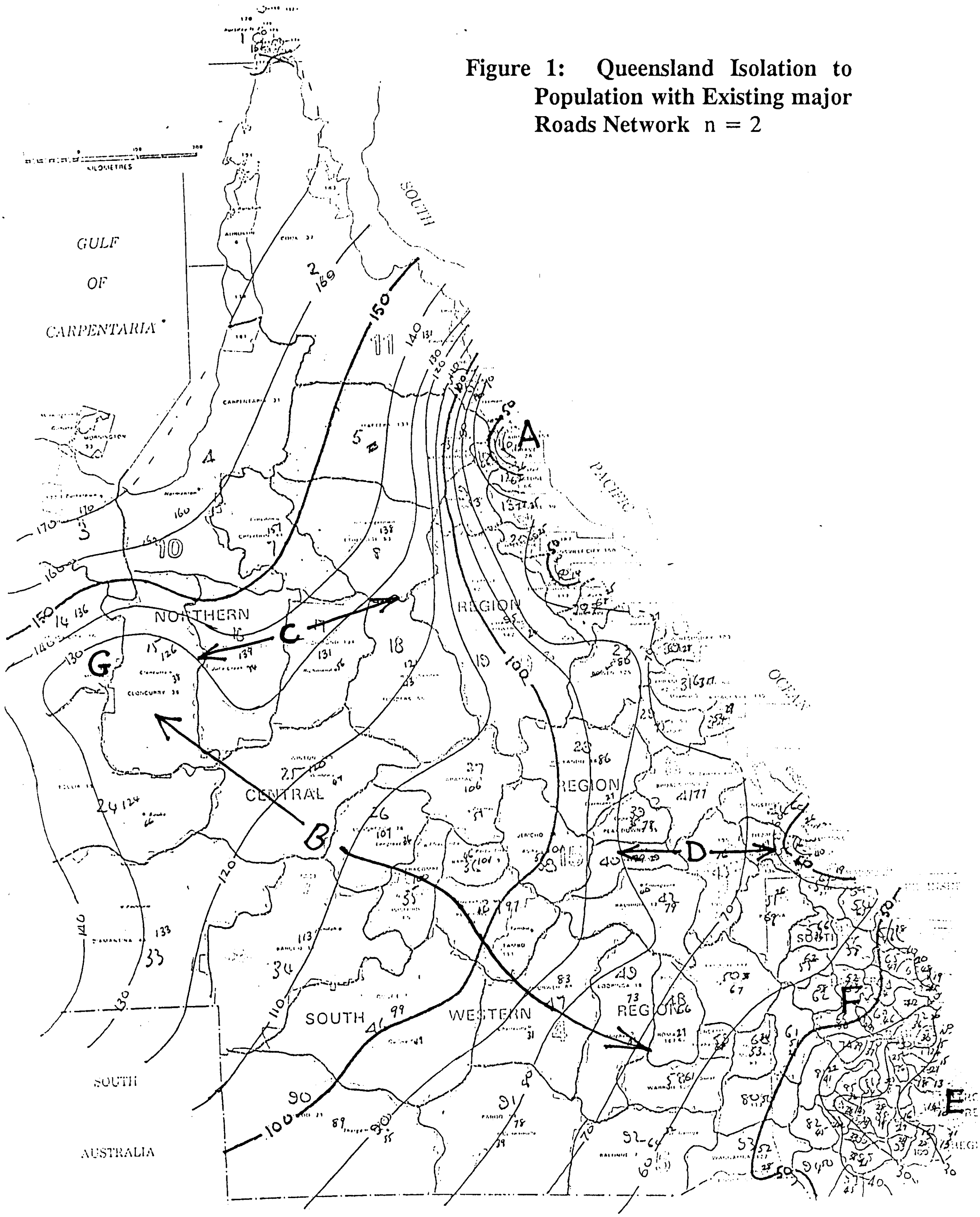


Figure 1 shows the profile of Isolation to population created over Queensland by its existing major road network using a power impedance function with an exponent value of 2.

The pattern takes into account all of Australia's population and reasonable linkages to it. In interpreting the pattern it should be remembered that orientation tends to be perpendicular to contours facing lower values. Thus "valleys" are corridors, "ridges" are areas of poor relative accessibility, "cliffs" are either major physical barriers, a point where a new link would make a major difference or places where development drops very dramatically.

The Queensland pattern reveals:

- a generally reasonable pattern across the state with sharp fall-offs limited to the Cairns and Townsville hinterlands (marked A) and some areas in the south east
- there is a strong Brisbane - Mt Isa corridor (B) but no indication of a Townsville - Mt Isa one (C)
- there is also little evidence of a corridor west from Rockhampton, certainly beyond Emerald (D)
- the southern inland has remarkable smooth contours but there is a growing orientation towards major interstate cities to the south further west away from the immediate influence of Brisbane (at E)
- the North and South Burnett are the only populated areas relatively inaccessible for their location (F)
- Queensland's coastal cities, particularly Cairns, are remarkably successful in providing quite high local levels of accessibility but the effect of Cairns drops off dramatically to the north and west (A).

These effects are the product of both the road network and the settlement pattern so, in assessing the road network implications, one needs to bear in mind whether there is population in place or in potential to benefit from new links that might be put in place to overcome accessibility deficiencies. For example, an improved road west from Cairns (A) would certainly spread the contours and reduce the location disutility but that would only be valuable if there was already population there to benefit or if the new link would be likely to generate a significant increase in population. The only other areas which are on a Isolation "ridge" and which could beneficially be reduced by road network improvements are the Burnett (F), north from Mt Isa (at G), locally south west and north west of Brisbane (at E), south west of Cairns (A) and, possibly, north west of Mackay (H). The diagram suggests it would be worth examining the network in these areas.

This interpretation suggests there is not too much wrong with the state-wide road network but more detailed analyses of specific areas including local roads would be needed to come to more local conclusions.

Interpretations for urban areas are similar. Figure 2 shows Isolation to employment for Brisbane in 1986 with a power impedance function with an exponent of 2.5.

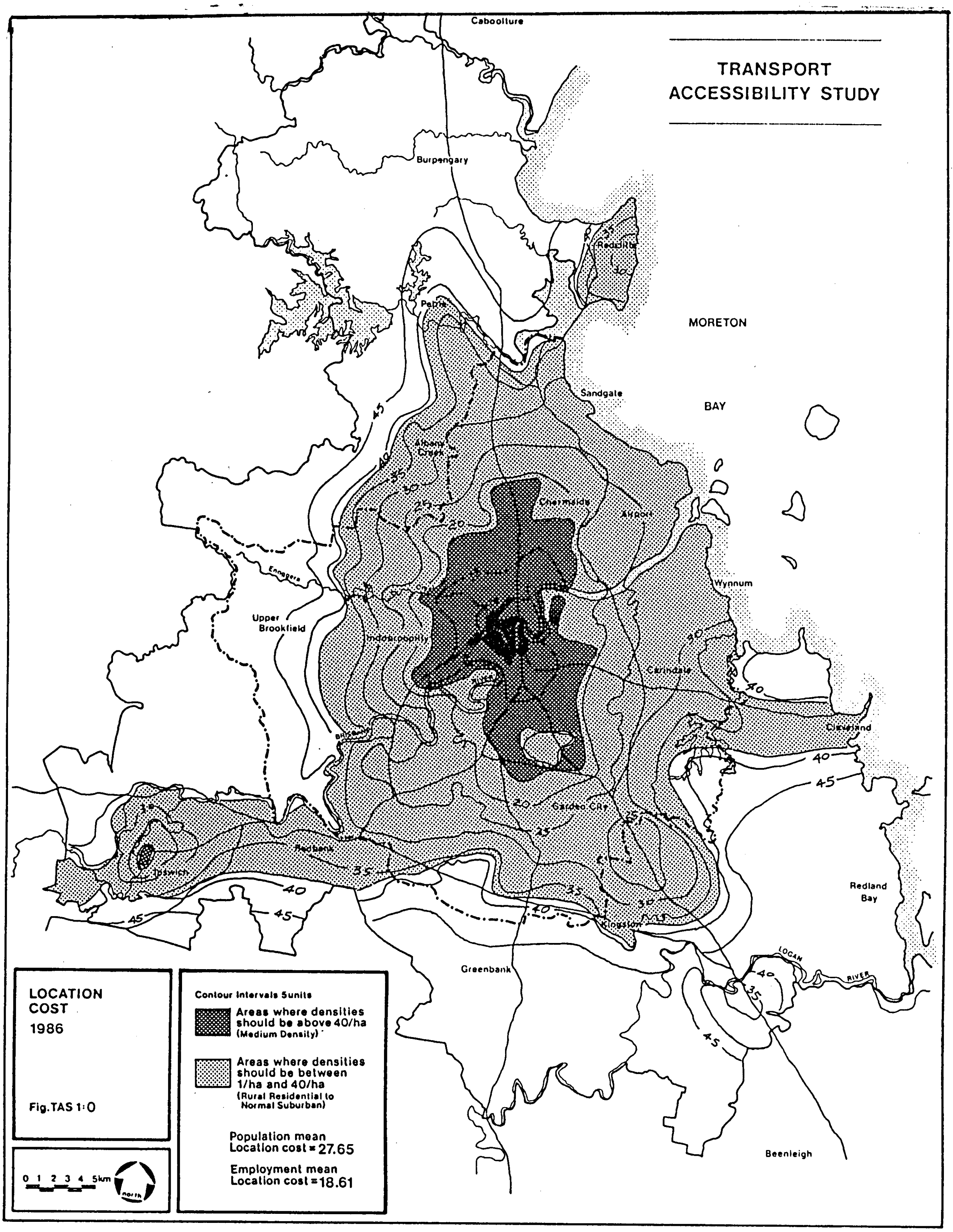
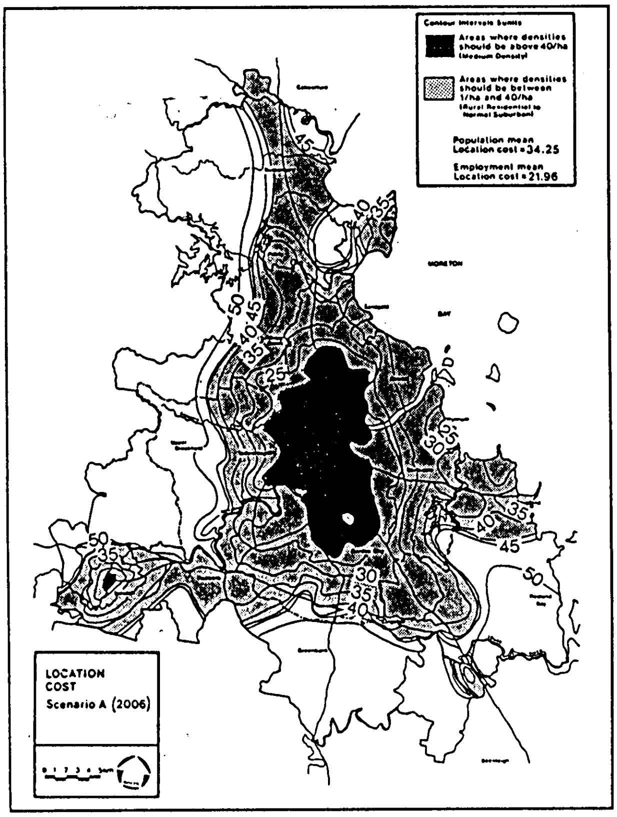
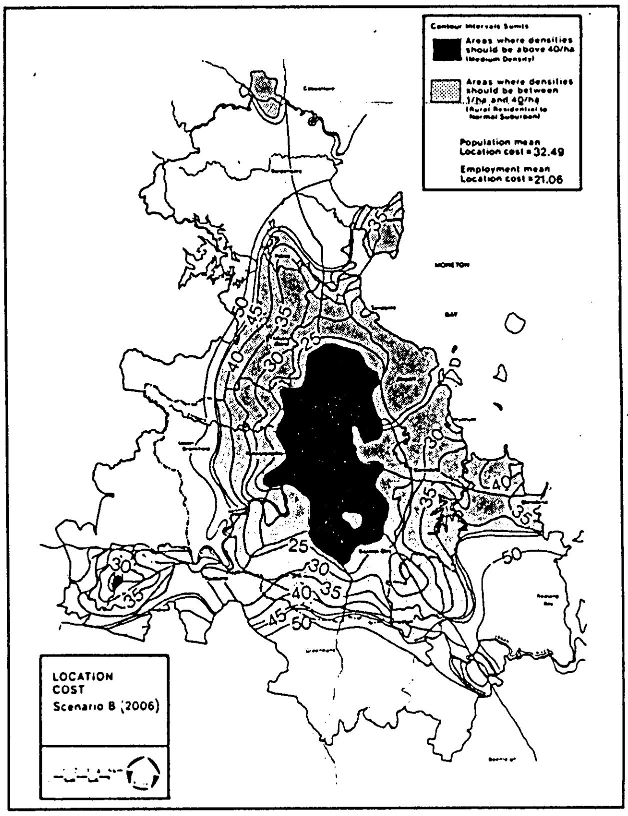


Figure 2: Brisbane Isolation to Employment in 1986 n = 2.5

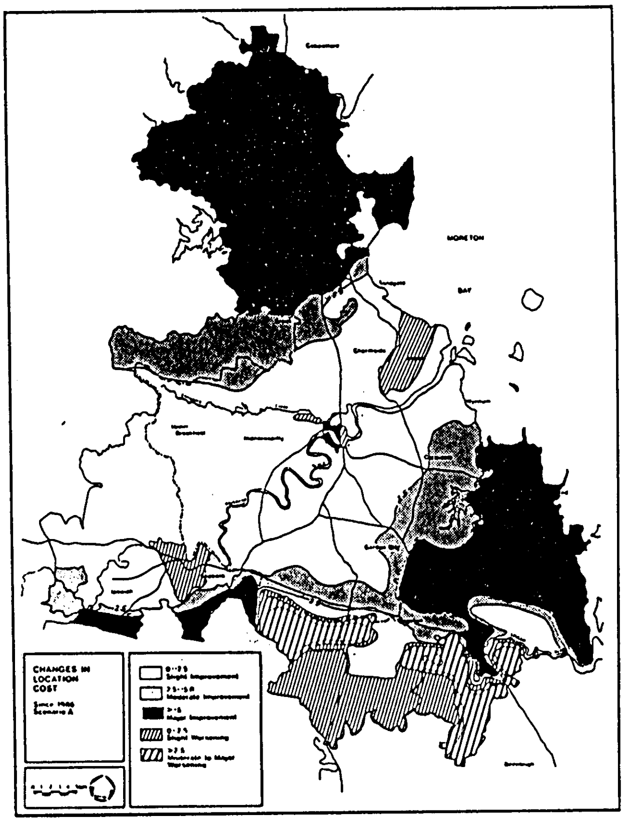
BRISBANE TRAFFIC STUDY



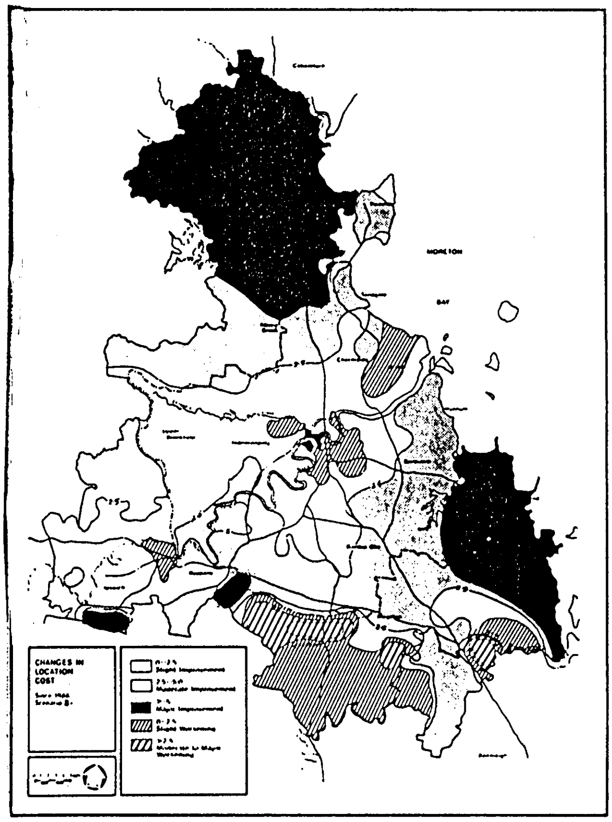
Locational Cost Scenario A



Locational Cost Scenario B



Changes in Locational Cost Since 1986 — Scenario A



Changes in Locational Cost Since 1986 — Scenario B

Figure 3: Brisbane 2006 Isolation to Employment for Different Land Use and Network Scenarios and the Distribution of Changes from 1986

A highlight of the Brisbane pattern is the way the river causes pockets of reduced accessibility. At such places, a new river bridge would overcome the deficiency, so such locations could create significant local benefits for a new bridge. Bulimba (A in Fig. 2) and Kenmore-Moggill (B in Fig. 2) are outstanding examples.

2. Spatial and Economic Performance of Urban or Regional Networks

The Isolation diagrams described above can be prepared for alternative proposed networks as well as the existing one. The total location disutility or location cost produced by a network can be determined by multiplying the Isolation for each zone by the size measure for the zone and summing. Dividing by the total of the size measure gives a value per size unit which allows broader comparisons.

In the Brisbane Traffic study for example, mean location costs were calculated for both population with its accessibility to employment and employment with its accessibility to population. Values of these corrected for changed total size values were then compared with different future network/land use combinations as one performance measure. See Figure 3. Similar calculations can be done for network alternatives for a fixed land use. Comparing these gives a direct measure of a network's general economic performance. If economic performance with respect to certain activities, e.g. industry or a particular industry, is required for policy reasons, the calculations can be done just using size measures relevant to those particular activities. The Adelaide work, examples of which are shown in Figure group 6, exemplifies this approach where location cost plots were done for a wide range of industry and activity groups (e.g. Figures 6.4 and 6.5).

3. Modelling the Urban Land Use effects of Transport Network Changes

The relationship between density and accessibility is shown for 1986 Brisbane in Figure 4. Other examples are in the attached papers.

The equation for the relationship between Isolation to employment and density is

$$\ln(D_P + \alpha.D_E) = K - (\beta/E_{TOT}^{1/n}).Y \qquad .... (4)$$

where D_P and D_E = population and employment density respectively

E_{TOT} = total employment

α, K and β = parameters to be set (in Eq. 3, $\rho = \beta/E_{TOT}^{1/n}$) .... (5)

Using the apparent universal value of these parameters, developed initially for London :

$$\ln(D_P + 0.6.D_E) = 7.1 - (27/E_{TOT}^{1/2.5}).Y \qquad ....(6)$$

when density is number per km^2, and Y in terms of time (minutes) and is calculated with respect to total employment using a power impedance function with an n value of 2.5. A typical plot is shown in Figure 4. Others are in the attached papers. See particularly page 1408 of the first paper.

Note that total employment is an element of the slope parameter, and that the universal value is the β rather than the ρ. [A corollary of this is that when comparing across time periods when an area has changed its size, Y values must be similarly adjusted to make them comparable.]

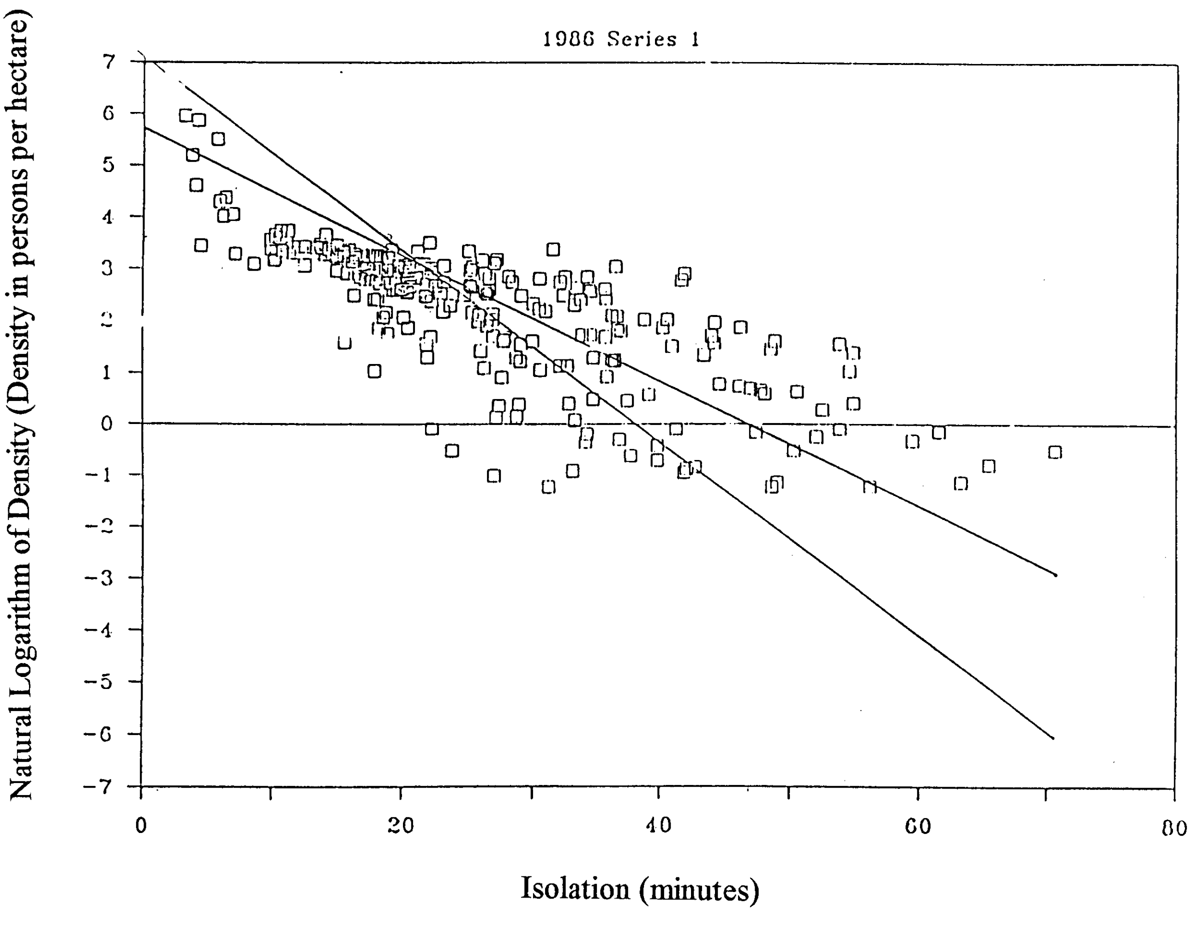


Figure 4: Density - Isolation Relationship for Brisbane 1986 showing universal and locally fitted relationship

Alternative lower values of K and b are sometimes applied for Australian cities to produce a better fit of existing data. Such substitutions should be applied with care since the line seeks to represent equilibrium rather than the existing transitory state. This matter needs careful review in each application.

From these, profiles of density utility or disutility can be determined for each network/land use combination and total values of density utility calculated. This total value of density utility is an economic performance measure of sorts but it could be argued that a network which minimised density disequilibrium (i.e. minimised the absolute sum of positive and negative values of density utility) is preferable because that most reinforces existing development patterns and presumably makes best use of existing infrastructure. Of course, for equity reasons the objective might be to minimise density disutility and if development is sought density utility should be maximised. There is thus plenty of scope to use this technique to produce indicators of performance of a wide range of different urban development and social justice policies.

The distribution of density utility and disutility and the way network alternatives change those distributions can similarly be used as an indicator of the network's performance in furthering a wide range of possible social justice or equity or urban development policies. Examples of these plots for Adelaide networks are shown in Figures 6.3, for the existing network, and 6.8 for a trial network with a proposed freeway. Thus the effects of the freeway on land use equilibrium could be assessed. This was particularly relevant because at the time there was a large region of over-development in the far south and it was important to determine the extent to which the proposed freeway would relieve it.

4. Assessing the Regional Development Effects of Network Changes

There is no relationship between density and Isolation in rural areas to correspond to the urban case because rural density is determined more by the type of activity than by location. Nevertheless it is still generally true that improving accessibility will enhance development prospects for a range of reasons. [Its effect on reducing transport costs overall is included in the type of analyses described in Section 2 above.] Thus plots of changes in location disutility consequent upon transport network changes are important indicators of performance for regional development policies or goals. Areas targeted for regional development should record reductions in Isolation with network improvements resulting from investment. Similarly areas of social disadvantage can be helped by investment programs which result in network improvements which deliver to such areas relative improvements in accessibility.

5. Land use Modelling

Modelling the land use effects of transport system changes requires first an estimate of the changed development potential caused by the transport change, then a method to estimate the total growth of the area over a given time period and finally a means to allocate that growth into areas with potential.

The Isolation-density relationship gives a value of potential and its strength (by the size of the density utility measure). It also gives values of negative potential where decay or loss of development is likely. An estimate of total growth over the area will be made externally but it could in turn be influenced by accessibility analyses over a larger area. Intervening opportunities concepts like that developed by Golding and Davidson (op cit) would appear to offer a suitable allocation model.

6. Activity Location

Figures 6.4, 6.5 and 6.6 show Isolation profiles for various employment groups and community services in Adelaide. These reveal, for example, in Figure 6.5, areas with poor access to schools. This information should be useful to authorities responsible for planning school location. Alternative new school location patterns (including proposed school closures) could be postulated and Isolation profiles for those patterns prepared. Comparing the impacts of these different patterns on the school population allows their effectiveness in serving that population to be assessed.

7. Relative Public Transport Quality Distribution

By comparing Isolation provided by car with that provided by public transport, the relative overall quality of public transport service can be seen. Since public transport is rarely used for very short journeys, a more representative result is obtained by leaving out intrazonal accessibility effects. Figure 6.2 gives an example.

8. Normalisation of Volumes for Strategic Comparison of Rural Networks

This area has not been researched but it appears that accessibility may produce a volume normalising factor which would allow the comparison for strategic significance of rural roads in widely different areas. Figure 5 shows initial calculation of the factor for Queensland. With this the reader can make comparisons among known volumes and draw independent conclusions.

COMPUTATION & PRESENTATION

Techniques for computing accessibility values and presenting results are dependent on rapidly changing computer technology. Basically, accessibility values are calculable from outputs of network analysis programs. How such computation relates to the program depends on the program and the format of other data to which the accessibility values are to be related.

Determining Intrazonal Accessibility

Because most interactions resulting in movement occur at short distances, and because typical travel impedance functions show very low impedance between close origins and destinations, accessibility of a zone to itself is usually very high. It thus will be a major component in the calculation of Isolation. Incorrect calculation will therefore lead to significant errors.

Whether or not the process of calculation is difficult mathematically will depend on the impedance function. For power functions of the gravity model type, used in all the examples in this paper, the equations are particularly messy with special cases for $n=1$ and $n=2$.

The approach for car travel is to assume that there is a terminal time for use of a car, the time taken to go to where it is parked and move it to the door. In dense areas, some places could be accessed on foot in a shorter period and are assumed to be so accessed. All other parts of the zone are assumed accessed by car. To calculate this the zone is assumed circular and distances radial at a fixed nominated speed. Density is clearly an important determinant of intrazonal accessibility. It determines how close the nearest destination is, how many, if any are accessed on foot and the number of destinations in each annulus of distance from the zone centroid. A full discussion and derivation is reported in the Appendix to the first attached paper. If other impedance functions are used, a separate derivation will be required for each. Short-cutting this process for the car mode by using a simple value needs to be done with great care because of its significance in the total Isolation value. However, for public transport modes, a short-cut approach will generally cause a lower value of error.

Commutation rules for Isolation

Isolation at a point cannot be determined by addition of components (e.g. interzonal and intrazonal Isolation cannot be added to give the composite value. Component accessibility values can however be added. To produce composite Isolation values, go back to the accessibility values, add them and then re-convert to Isolation.

Comparing Isolation values as an area grows

A component of Isolation is total number of activities in the study area (e.g. population). As the area grows, equivalent Isolation values will increase. To compare Isolation values from different periods, it is therefor necessary to adjust for changing area population. The adjustment derives form the impedance function used. For a gravity model with a power function, the equivalence adjustment is simply the inverse ratio of the populations (or other activity measure) raised to the power used in the impedance function. Again, accessibility itself is comparable across different population totals without the correction necessary for Isolation.

CONCLUSION

The proven and potential uses of accessibility and Isolation concepts are extensive. They range from measures of transport network performance through measures of efficiency of land use/transport patterns to land use prediction and service activity location. Computation is becoming ever easier as computers improve. Once understood, use of the concept provides remarkable understanding of the transport network, its relationship to the area it serves and the effects on the area of transport changes.

On a more general note, transport network modelling capability tends to be used mostly for traffic forecasting. This paper gives examples of how the network model outputs can be applied to derive much more general indicators of network performance and network quality. There are others, some of which use Isolation plots or values in conjunction with other model products to produce yet more abstract indicators of network performance. Despite their abstraction, they are often much more valuable than traffic volume forecasts in evaluating networks. Whilst the traffic volume forecasts are essential for network element design, these abstractions offer more insight into higher order network functions and provide indicators of performance against higher order goals which Governments are increasingly setting for transport investment.

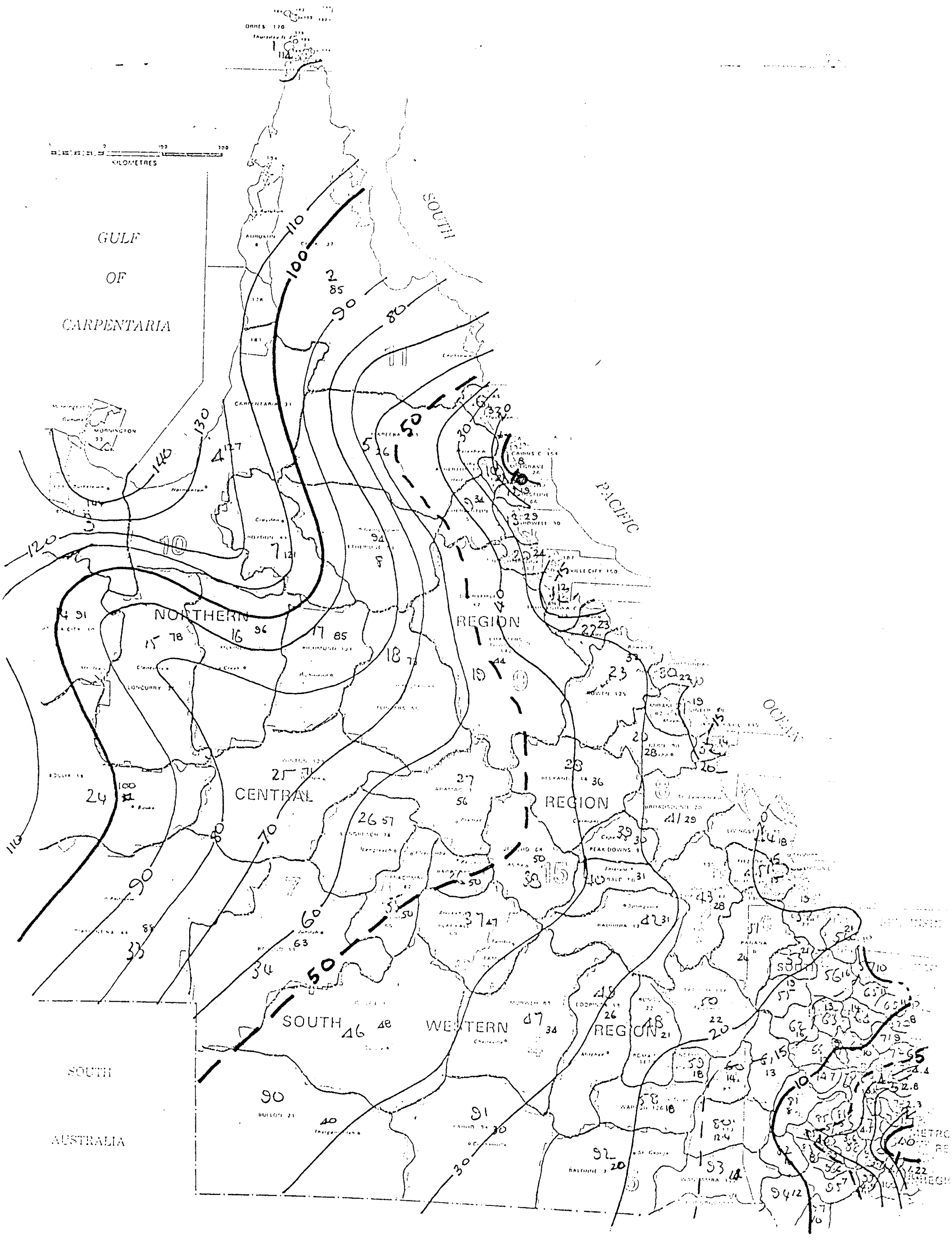


Figure 5. Volume Normalising Factor

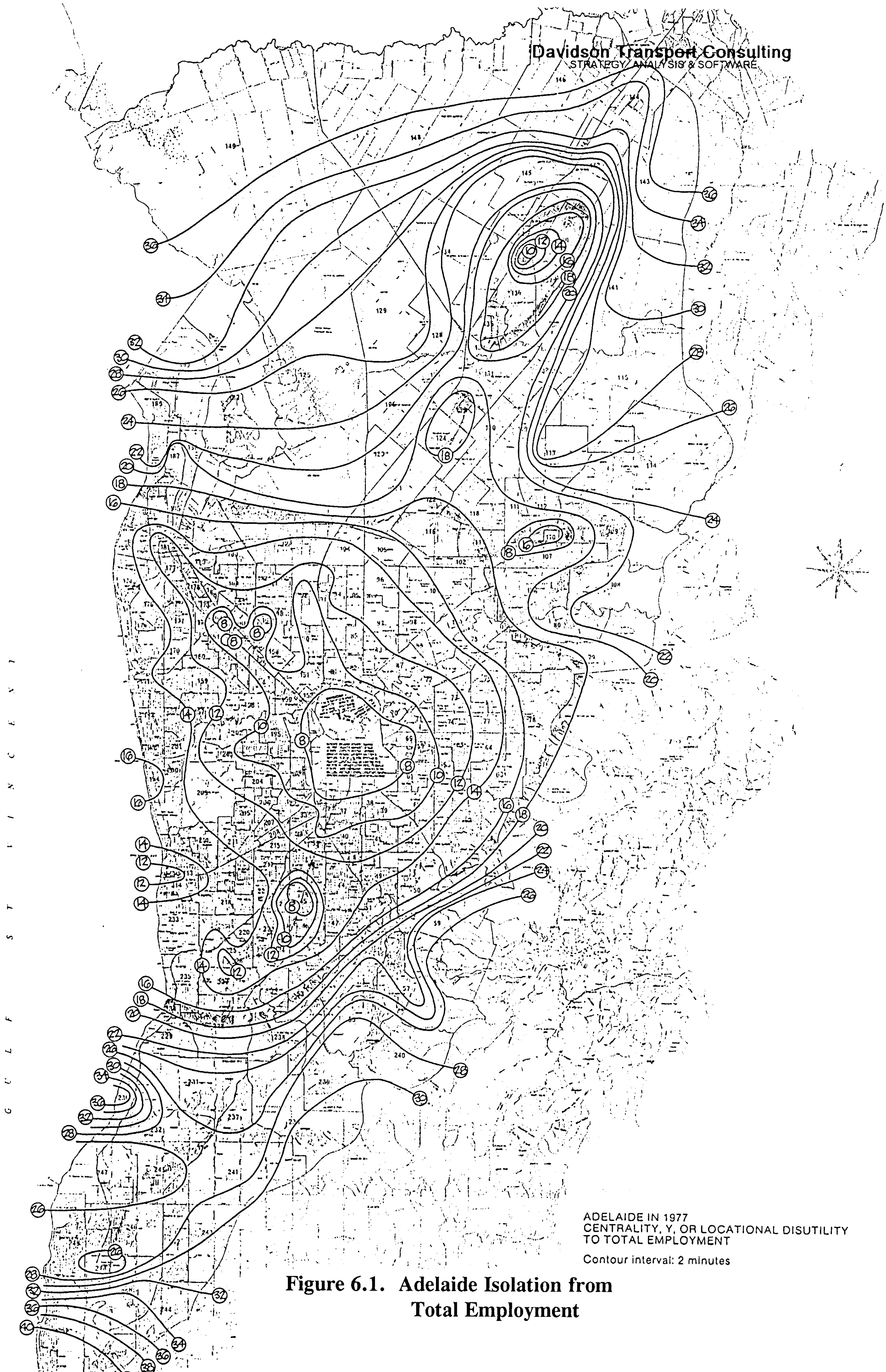


Figure 6.1. Adelaide Isolation from Total Employment

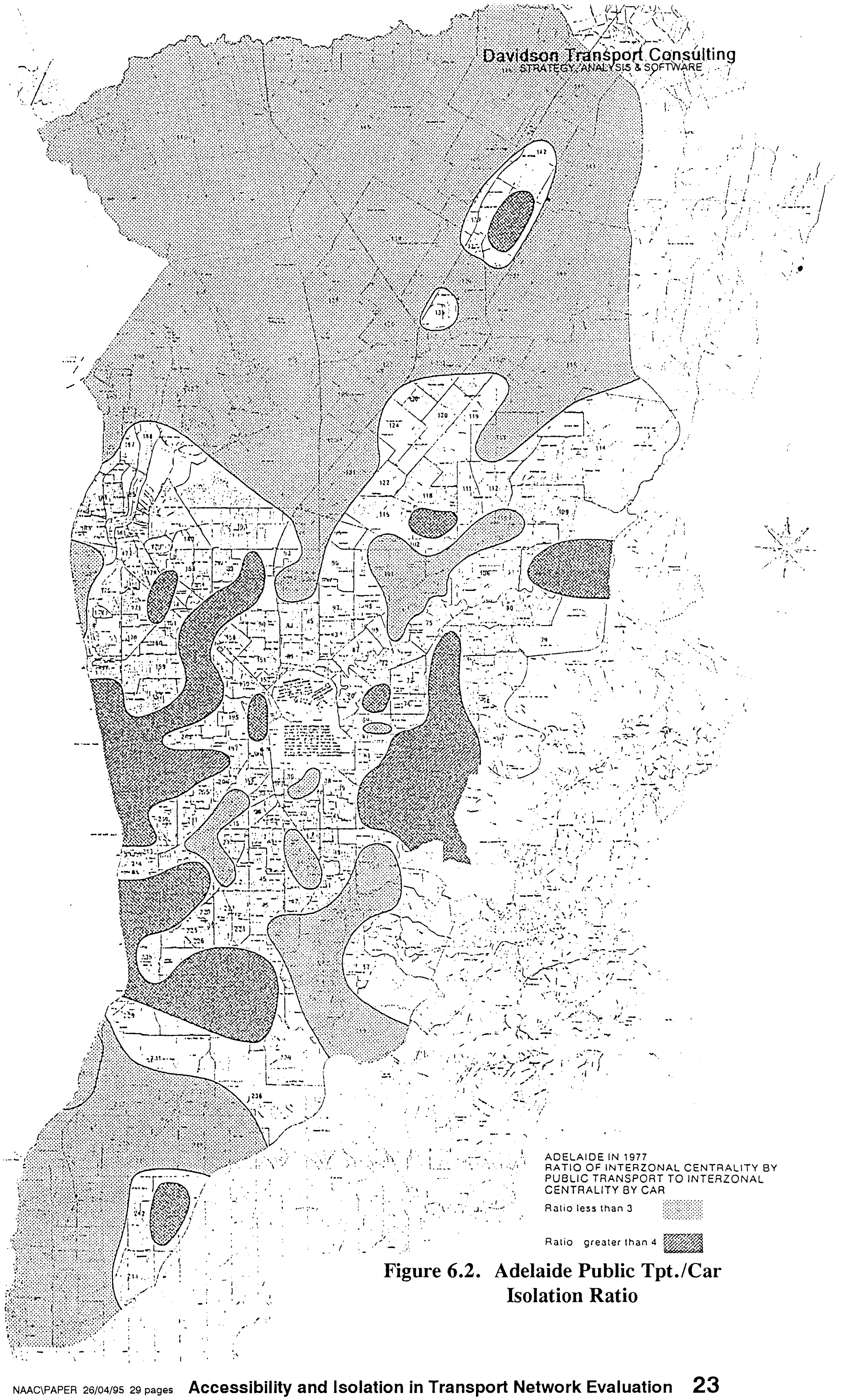


Figure 6.2. Adelaide Public Tpt./Car Isolation Ratio

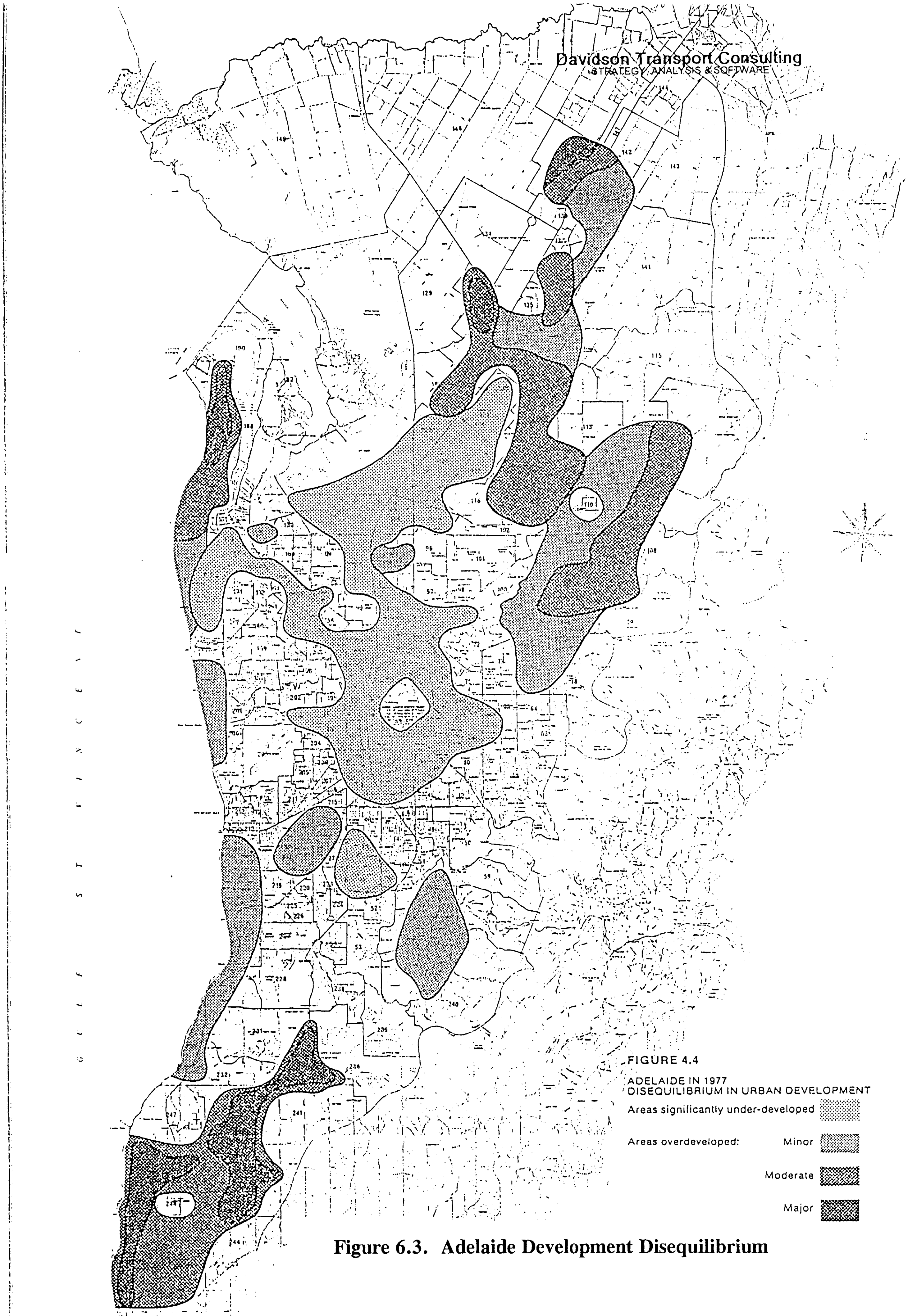


Figure 6.3. Adelaide Development Disequilibrium

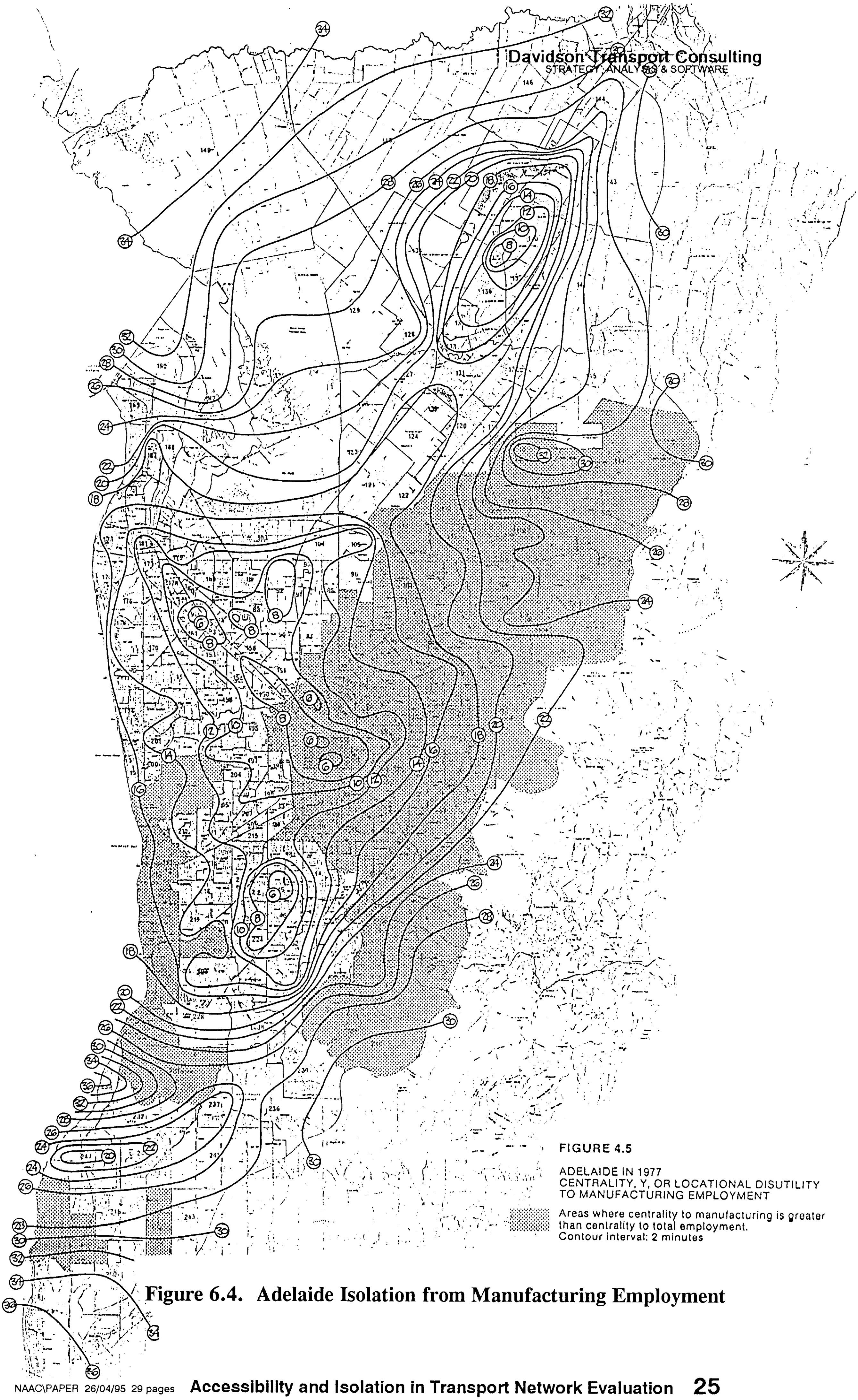


Figure 6.4. Adelaide Isolation from Manufacturing Employment

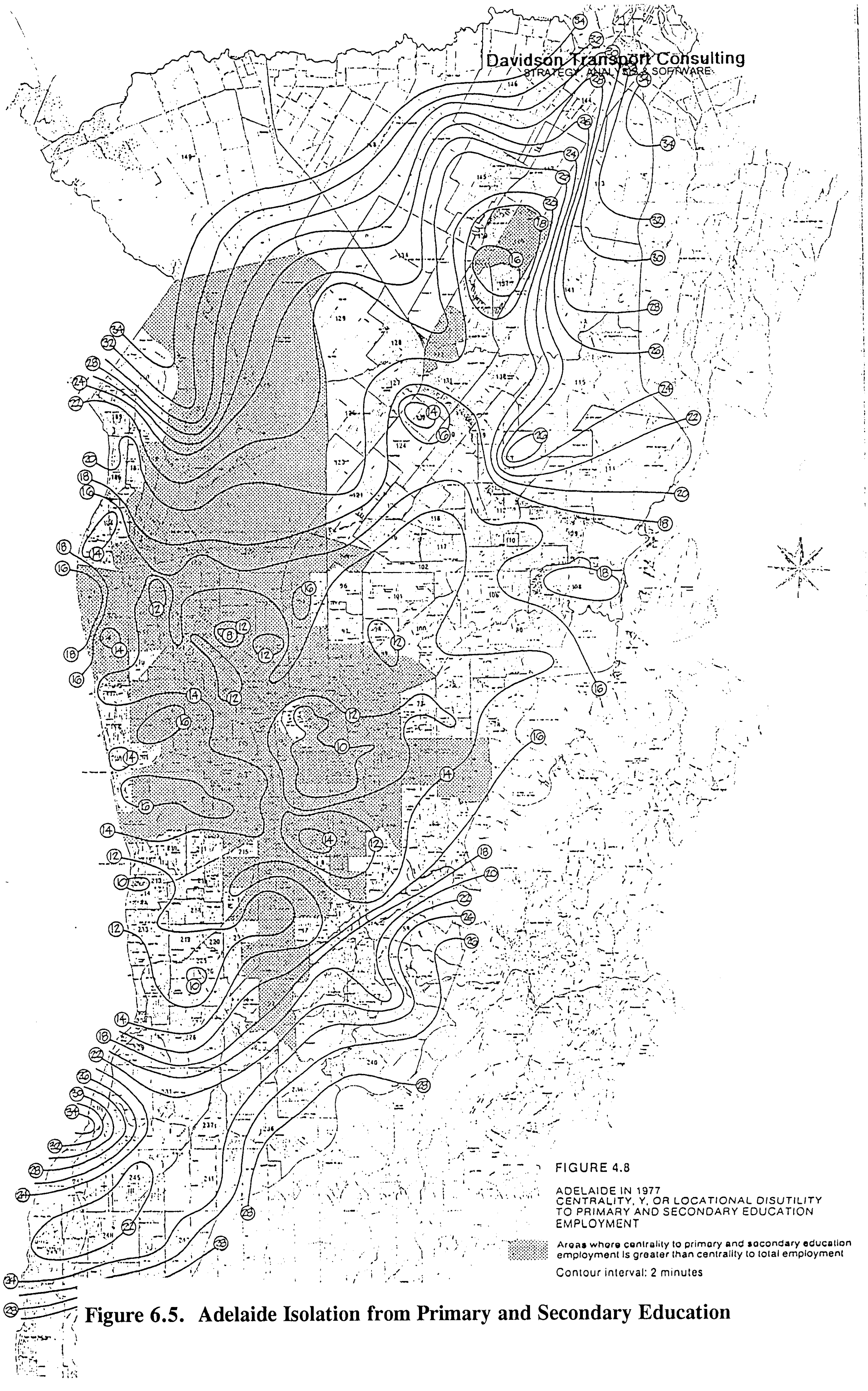


Figure 6.5. Adelaide Isolation from Primary and Secondary Education

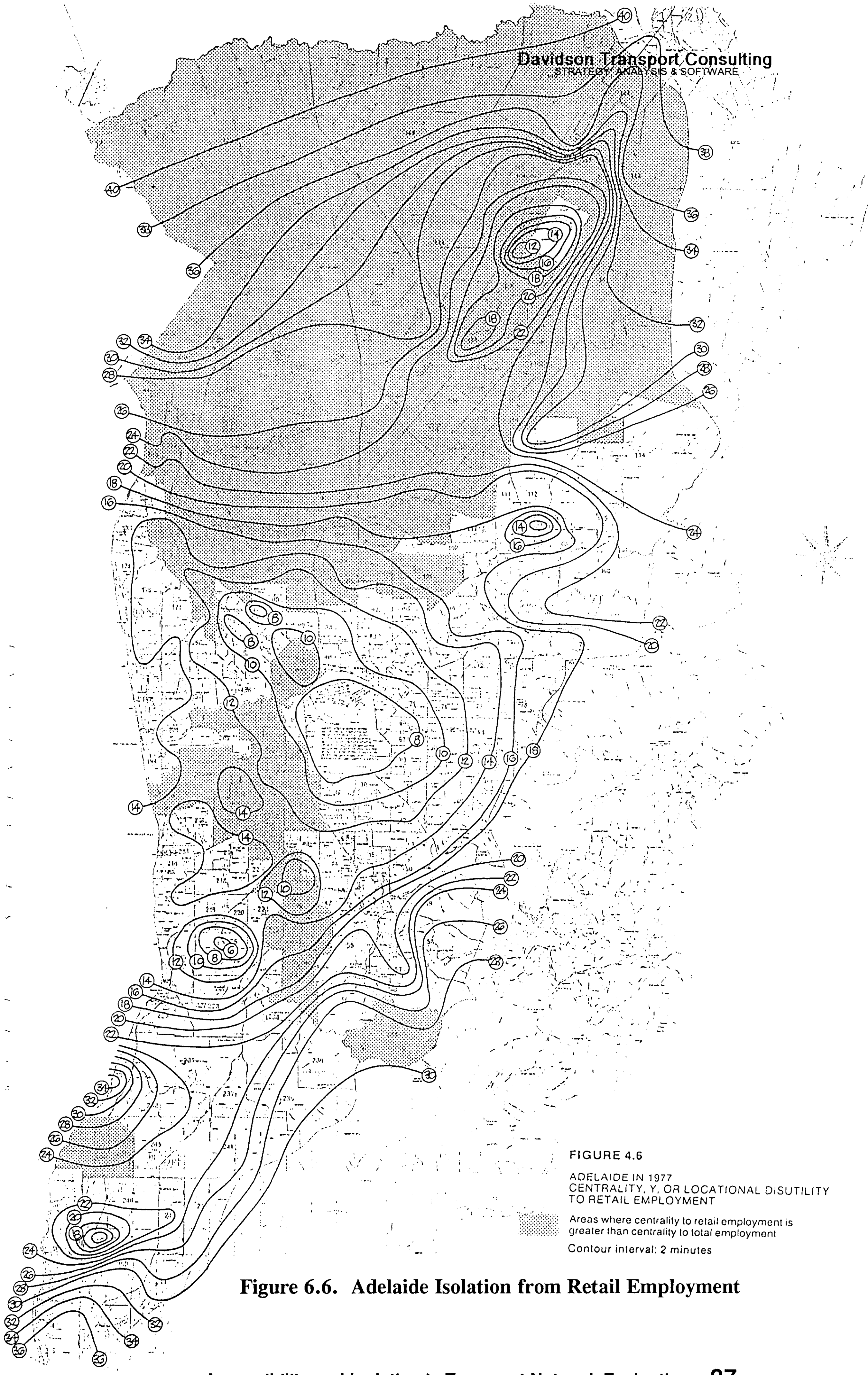


Figure 6.6. Adelaide Isolation from Retail Employment

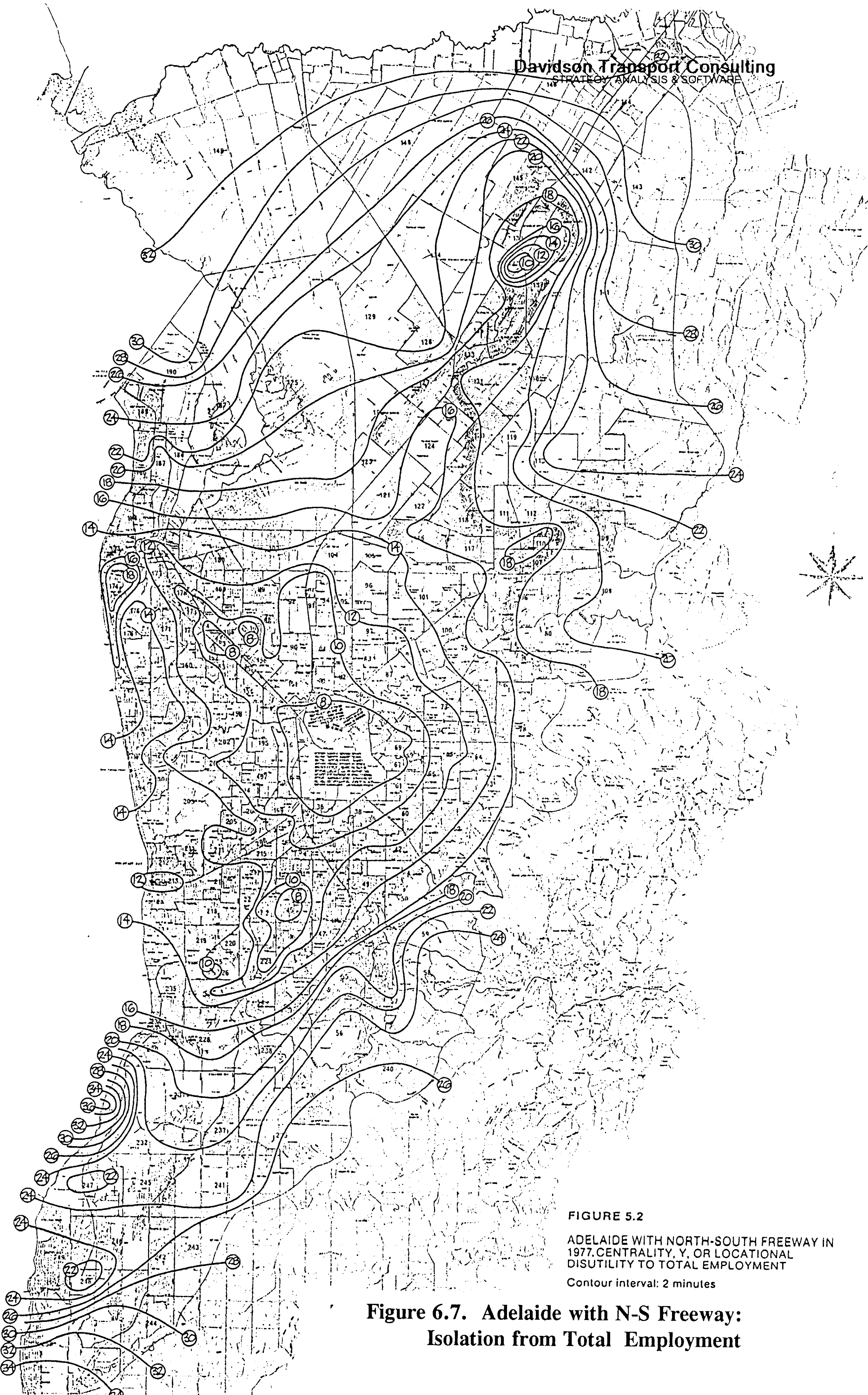


Figure 6.7. Adelaide with N-S Freeway: Isolation from Total Employment

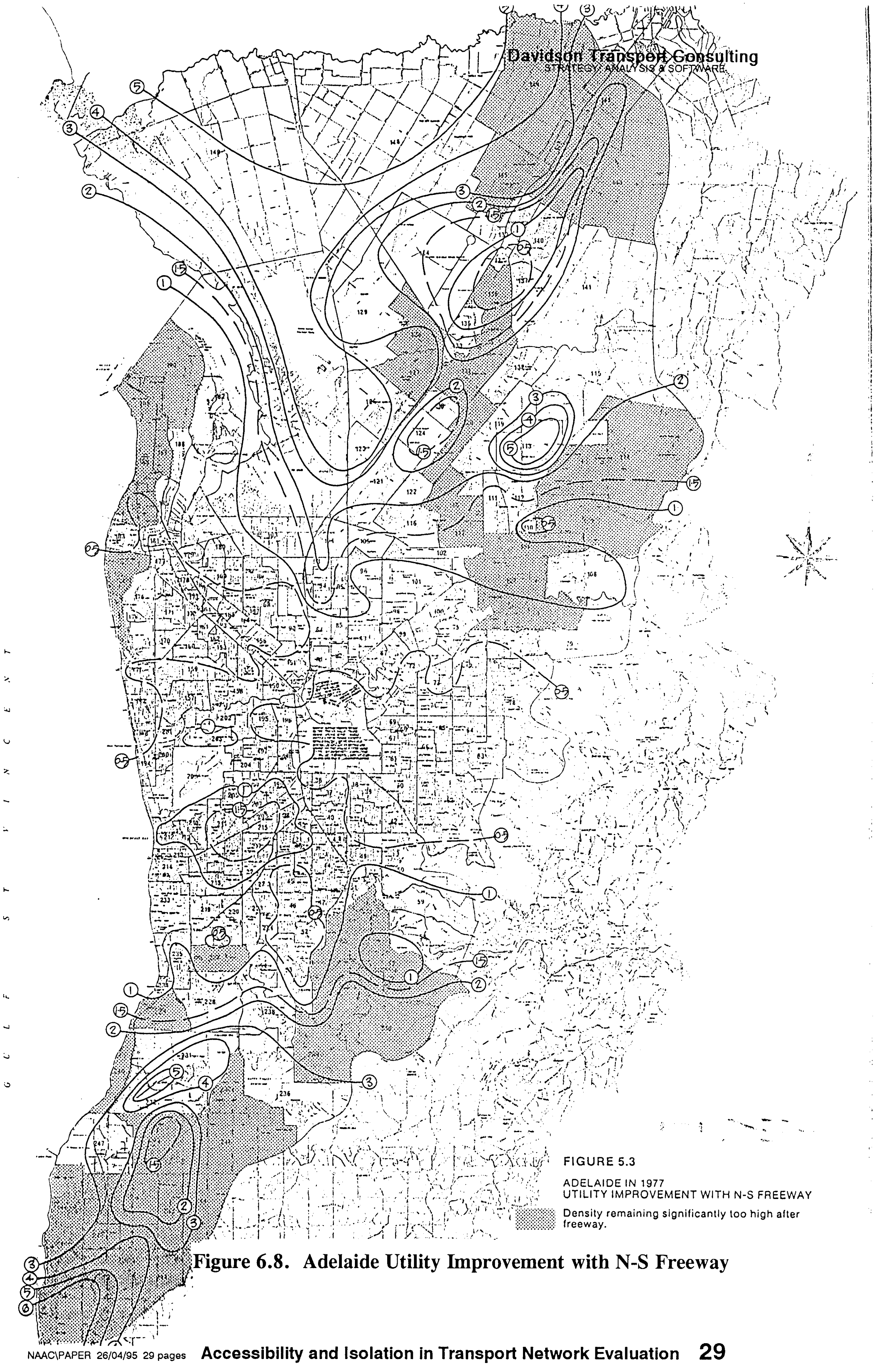


Figure 6.8. Adelaide Utility Improvement with N-S Freeway