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Q-ANALYSIS AND TRANSPORT: A FALSE START?

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Introduction

In a recent paper in this Journal Johnson (1984) introduced Q-analysis as a fundamentally new and useful methodological approach for transport research. The paper is one of a number by that author aiming to demonstrate the applicability of Q-analysis to researchers in this field (see also Johnson 1976-A, 1976-B, 1977, 1981-A, 1981-B, 1983-A). The purpose of the present paper is to identify and critically to evaluate the utility of some of the key ideas being introduced in this literature, focussing mainly on the Transportation Research paper (referred to below as the TRb paper), Johnson (1984), this being the most accessible to transport researchers, but also noting and citing material in others. It will be argued that although there may be some benefit from invoking Q-analysis in transport research, there are serious shortcomings in Johnson's presentation of the approach. In particular; some of the implied claims of the utility of the approach are unsubstantiated; existing methods that in some cases could achieve similar ends are neglected; and elements of ambiguity and of unduly cumbersome notational conventions cloud the meaning and significance of various features.

The relatively widespread publication of Q-analysis material in the transport field (see papers cited above) in itself invites a published response and appraisal. Although this appraisal is critical, looking beyond the series of papers cited below, such criticism should not necessarily be interpreted negatively as a basis for rejecting Q-analysis as a potentially useful basis for opening up particular lines of inquiry: there are a number of relatively simple features that can be usefully invoked to give insights in particular contexts, and a potential basis for developing original new theory. The methodology of Q-analysis was originally developed by Atkin (1974) and is enthusiastically appraised in Gould (1980). A partial re-specification is suggested in Macgill (1984).

Some basic ideas

In the TRb paper road systems are considered as collections of routes composed of a series of links, with intersections represented as identifiable links, not as points (see, for example, Figure 1a, where L_2 represents the intersection of links L_1 L_4 L_3 and L_5). Such a representation of routes is clearly favoured by Johnson over that more commonly used in transport research, remarking of the latter that "the representation of road intersections as points is a serious distortion of reality" (Johnson, 1984 p.93). The style of representation of routes as given in Figure 1a in other transport literature could also well be acknowledged (Allsop, 1979; Charlesworth, 1979; Road Research Laboratory, 1969).

On the basis of representations of the kind given in Figure 1 some of the standard concepts and conventions of Q-analysis are worked through to lead to the first set of "findings" in the paper: given congestion on any particular link (L_6 on route AD, say) it can affect traffic not only on other routes that contain that link (self-evident) but also on other routes (AB, say) that do not contain that particular link (note that route AB does not contain link L_6). The latter can occur because the congestion on L_6 can affect traffic on L_5 and in turn on L_2 and this in its turn can affect traffic on L_3. The extent to which routes will affect each other is suggested to be "proportional to the number of links they share". We call this claim (a), Johnson (1984, p.90). Then, "Consider two routes which are q-connected but not q-near, and in which at least n intermediate routes are necessary to establish connectivity. The greater the value of n, the 'further apart' are the two routes and intuitively one would expect less mutual interference". In other words the extent to which a congested route affects others is asserted to depend (inversely) on the remoteness of the congested route from other routes, remoteness being defined in terms of the number (n) of intervening <u>routes</u> lying on the "shortest path" between them (we call this claim (b)). "Similarly, for a given value of n, the greater the value of q the more one would expect the routes' flows to interfere with each other <u>through combinatorially more connections</u>" (we call this claim (c), though cannot easily provide an alternative wording because the underlined words do not appear to be logically consistent with the earlier part of the sentence).

We consider all three claims to be of doubtful utility. Concerning (a), although <u>ceteris paribus</u> it may be reasonable to assert in the context of Figure 1(a) that congestion on L_6 on route AD will affect routes AB and CB equally, because they both share the same number of links with AD, it becomes unreasonable in the context of Figure 1(b): here AD has more links in common with AB than it does with CB, but there is no basis whatever for suggesting that AB will be more affected than CB by congestion on L_6 of AD. We conclude that claim (a) is open to arbitrary distortion and cannot be taken as a useful or accurate generalisation. The root of the difficulty would appear to lie in the fact that congestion is link-specific more than it is route-specific, though Johnson (1984) has attempted to fashion a result in terms of routes, not links. A related criticism over an arbitrariness in the number of links shared by different routes can be made in the context of the discussion of Figure 13 in Johnson (1981-B).

Claim (b) suffers from a different sort of criticism though it is again rooted in the attempt to generalise in terms of routes, not links. Although it is intuitively reasonable that the effects on a given route of congestion elsewhere will be less severe the more remotely the congestion occurs, it is misleading to mould the crux of this point into a result about the remoteness of <u>routes</u> from each other. This can be seen in more detail with reference to the Q-analysis for a selection of possible routes from Figure 1(a): see Table 1 and Figure 2. According to claim (b) in the context of $q = 1$ in that figure, congestion on route CD should affect routes ED and CF more than route EF, because there are direct connections between routes CD ED and CD CF, but only indirect connections between routes CD EF (CD and EF are q-connected but not q-near at $q = 1$, as seen in Figure 2). This is doubtful reasoning, for if we refer back to Figure 1(a) we note that for congestion on link L_6 the most reasonable assumption, in the absence of further information, is that it would affect ED and EF to the same extent. Alternatively, for congestion on L_4 or L_2, it would appear tenuous to conclude that it would affect route ED more than route EF. Thus, contrary to claim (b), the number of intermediate routes does not necessarily seem to be a crucial factor in determining the effect of one route of congestion on another. A very crucial aspect, overlooked in Johnson's analysis would appear to lie in the position (link) on a route where congestion occurs, and how remote that link is from other routes in terms of the number of intervening links. This seems to be far more important than the remoteness of routes from each other in terms of other intervening routes. Certainly, in the absence of any convincing example of the assertion that the number of intermediate <u>routes</u> that forge the connectivity is of key importance, we cannot accept the utility of claim (b).

Claim (c) would also appear to be misconceived: in itself the quoted remark suggests that there will be combinatorially more connections between routes the greater the value of q at which they are q-connected. In <u>our</u> understanding of Q-analysis, this is not necessarily so, however: the value of q at which routes are q-connected is determined simply by the number of links shared by different routes. The number of combinatorial connections on the other hand, refers to something different - the number of edges through which routes are (indirectly) joined in the q-nearness graphs. Thus a "greater value of q" does not necessarily occur through "combinationally more connections". It is not possible to salvage the first part of claim (c) (i.e. ignoring the underlined words) because this would be open to the same arbitrary distortion as was found for claim (a). The second part of the result, turning on the number of combinatorial connections between routes may be a more fruitful avenue to pursue in determining the extent to which routes mutually interfere, but as with claim (b), of key importance will be the position on a route at which congestion occurs - a factor not mentioned in the TRb paper, and not readily accommodated as long as "routes" are used as the metric. (Congestion on link L_7 of route AD in Figure 1(c) will have far less effect on route A'B' than would congestion on L_1, a feature that Johnson's framework cannot accommodate.)

As remarked above the key root of our criticisms about Johnson's claims is what we regard to be a misplaced emphasis on routes at the expense of links. What the focus on routes appears to give are rather coarse aggregate rules of thumb at some higher level of resolution. We do not accept the general utility of this becuase of the aggregation over possibly interesting and potentially important intermediate detail.

In addition to the specific criticisms made above, we add two further remarks: (i) there is unduly little attention given to whether the "effect" of the congestion on one route is advantageous or detrimental to other routes (whether it eases or inhibits flows elsewhere); again a feature of fundamental significance. Congestion at L_2 on route AD in Figure 1(b) could ease the flow on route EF, but at L_7 it would be inhibiting. In the case of route systems with combinatorially more interconnections, there could be a complex series of both positive and negative feedback effects in transmitting the effect of the congestion. Although this possibility is noted by Johnson, the fact that it is not pursued operationally further undermines the utility of "results" established in the TRb paper. Further significance of this remark will arise below in the context of whether or not it is advantageous to disconnect routes from each other; (ii) changing the number of allowable routes in a given system can introduce a further degree of arbitrariness to which the reader has not been alerted in the TRb paper; although a comment about this is made in Johnson (1981-B) it is not indicated in the TRb paper. (It is also not clear how the representation would handle the situation depicted in Figure 1(d), where there are alternative routes between origin A and destination F, though we do not at this stage raise this as a fundamental point.

The TRb paper next refers to the concept of q-transmission (see also Johnson, 1982), remarking that the kind of feedback mechanisms this picks up are "not unrelated to those of network theory and systems theory". We regard this as a significant understatement (i) because q-transmission for $q = 0$ __is__ conventional feedback, (ii) because of the absence so far in the TRb paper of examples for $q > 0$ and (iii) due to remarks elsewhere (Johnson, 1983-B) that convincing examples of q-transmission for $q > 0$ are difficult to find.

Complementing our criticisms so far, then, is a belief that other methods can pick up the key results being sought through Q-analysis less cumbersomely, more accurately and with greater precision. Roberts' (1976) simple signed digraph models would seem to be very appropriate tools, representing links as nodes, joining them whenever they represent adjacent links in the transport network and signing them (+ or -) according to whether a positive impulse (eg. congestion) at one will be transmitted to others as a corresponding positive or a negative effect. The signed digraph for Figure 1(d) is given in Figure 3 (readily incorporating the existence of alternative routes between, for example, A and F). The effect of congestion on any given link can then be picked up via a pulse process, explicit formulae for which can be given. The specific routes thereby being affected can be identified from the route x link incidence matrix that is associated with this road system, and the formulation of the pulse process would automatically specify whether or not the effect is augmenting or diminishing. The use of weighted digraphs could refine such an approach, incorporating information on how the magnitude of an incoming pulse at a node is distributed between the outgoing edges. This simple network theory can more than accommodate the sought features.

It would appear relevant at this stage to comment on a remark by Gould (1983) in advocating the utility of Q-analysis for transport research: "Not long ago, the Mianus Bridge collapsed on the main New York to Boston thruway. Here was a dramatic example of structural change in the backcloth changing patterns of traffic and altering transmissions . . . A Q-analytic description would tell you that you had to start redirecting trucks fifty miles away to alleviate the 'shock waves' working out from the break". We simply note that the type of graphical approach suggested in Figure 3 is specifically conceived to pick up such shock waves, and it would as yet appear to have been developed to a considerably more mature and reliable extent than Q-analysis for such a purpose.

More formal propositions

Whereas the ideas from the TRb paper reviewed so far refer only to hypothetical road systems, they are followed in that paper by a more formal proposition which is illustrated for more realistic systems. The proposition asserts that a road system will be better if its routes traverse fewer links (lower $\hat{q}$ for routes*) and share fewer links with some other route (i.e. are more disconnected - lower $\check{q}$ for routes), and correspondingly, if individual links are used by fewer routes (lower $\hat{q}$ for links) and there are fewer cases of different links being used by the same routes (lower $\check{q}$ for links). The main illustration given is that of the Plough Roundabout, Hemel Hempstead, an illustration used also in earlier papers (Johnson, 1976-B; 1977; 1981-A; 1981-B; 1983-A). The same idea is also illustrated in earlier papers in the context of a motorway intersection.

The idea being expressed in the proposition is intuitively sensible - that "good" road systems tend to have short paths, with as little opportunity as feasible for routes to interfere detrimentally with each other. This is often exemplified in the introduction of more links (e.g. a by-pass). There may be considerable merit in formalising this intuitively sensible idea rigorously as a basis for making traffic management better understood and better applied. However, the specific formalisation given in the TRb paper would not appear to be sufficiently precise. In particular although reduction in $\hat{q}$ and $\check{q}$ for links seems a desirable aim, a corresponding reduction in $\hat{q}$ and $\check{q}$ for routes is not necessarily so. In the specific case of altering the system in Figure 1(a) to produce that in Figure 1(e) the new route between E and F actually increases the number of links on routes AF and CF (i.e. increases q for routes) though we would hesitate to suggest that the new route would not constitute an improvement to the road system as a whole. A different kind of reservation about the propositions lies in the same soil as our criticism of earlier claims

* In standard Q-analysis notation $\hat{q}$ and $\check{q}$ stand for top-q and bottom-q, respectively.

a, b and c, namely that the value of $\check{q}$ is only a crude indicator of the extent to which routes can interfere with each other and not an indicator of whether the interference will be beneficial or detrimental: $\check{q}$ for a given route is determined by the number of links it shares with <u>one</u> other route, whereas of significance in determining the extent to which routes mutually interfere (and the sentiment expressed though not carried through in more informal discussion in the TRb paper (eg. mid p. 92)) would seem to be the <u>number</u> of other routes that are inter-connected for given values of q. To express this point another way, in the TRb paper it is suggested that more disconnection of routes means lower values of $\check{q}$. What we are suggesting is that routes can be more disconnected without having any effect on $\check{q}$, and $\check{q}$ is therefore not a reliable indicator of the connectedness of the road system. Moreover, it does not pick up any significance in - <u>where</u> on a route shared links may occur. In our view a more crucial factor is the density of shared links between routes (as reflected in q-nearness graphs) and not only whether any shared links occur (as reflected in the values of q in the structure vector). Moreover, again no account is taken of whether the effect of connectivity is advantageous or detrimental: <u>more</u> (not less) connectivity can be very desirable in dissipating congestion in offering alternative ways of getting between different places. Again we would prefer simpler graph-based methods.

It would appear, in fact, that use of the indicator $\check{q}$ to pick up the degree of q-connectivity between routes destroys what others have seen as a key appeal of Q-analysis (an approach that ensures a particularly close familiarity with data representing particular contexts under study (Gould, 1983; Beaumont and Gatrell, 1982)). The same can be said about the use of eccentricity. Again we suspect that there are other, more effective, ways of picking up key structural features of different road systems: a simple count of the number of routes a link has to support will be a good indicator, these numbers being "smaller" for "better" road systems (with one obvious modification needed where there are alternative routes between different locations). We remain to be convinced that we cannot get more precision from this simpler and more direct approach than from the additional material introduced in the TRb paper.

The subsequent use in the TRb paper of the structure vector to summarise the thrust of the cited proposition, although apparently effective in the roundabout case, we regard as no more than a coarse descriptor of the system "before" and "after" the given change (and similarly, we would suggest, for the motor-way intersection case in Johnson, 1981-B, does not ameliorate our criticism). We agree that it may be beneficial to seek to establish generic results on structural form and structural change. However specific form of results put forward by Johnson cannot be taken to have general validity.

A similar analysis of road systems appeared in previous papers (1976-B; 1977; 1981-B) aiming to use standard (and some non-standard) conventions of Q-analysis to demonstrate why some configurations for road intersections can be expected to perform better than others. Due to the relative simplicity (as a road system) of even the most complex case considered, our reservations hold less strongly in these cases, but correspondingly the simplicity also severely weakens the rationale for needing the formalisation, and such an extent of cumbersome notation. The related conclusion (Johnson 1981-B, p.159) that "link dimension and connectivity structure are particularly relevant in the design of junctions" is tautological: they are the design.

We would suggest that the key feature differentiating each of the intersections is the number of routes which individual links have to support: the intersections that perform better are always those whose links have to support the fewest routes, this decreasing from seven in the worst case to between four and one in the best. It is not necessary to perform a Q-analysis to elicit these observations; they can be elicited simply from the original routes x links incidence matrices. The complex notation clothing subsequent observations (Johnson, 1976-B; 1981-B) about flow patterns accommodated at a junction , flipover values and new links needing to be faces of existing links make their validity and utility difficult to assess.

Larger scale systems

In the next part of the TRb paper the ideas encapsulated in the proposition discussed above are considered in the context of the route system of a town, Bedford. It is observed from the structure vectors that the route-link and link-route structures are relatively disconnected, and therefore that Bedford's through traffic routes do not interfere with each other to a great degree. We would suggest that basic connectedness properties of a more standard graph-based approach could pick up such observations more simply and with greater precision. (The slicing that is invoked in this connection is not unique to Q-analysis.)

Moreover, on the basis of our earlier argument that $\check{q}$ is rather a crude indicator of connectivity, neglecting <u>how many</u> routes are involved, we would question the utility of the skyscraper diagram that is given to summarise the structure of the system, and of eccentricity for identifying where routes interact which do not interact elsewhere. Both are of more limited applicability than is made apparent in the TRb paper. The other concept introduced in this part of the paper is that of a t-path - contiguous links used by a specified number (t) of routes. Although these may be of some interest as key features in the structure of the system, their identification can be made in the absence of general familiarity with Q-analysis, and we cannot identify any particular useful feature about t-paths that is pursued in this paper.

There follows the link-face theorem. This asserts that the global structure of a road system is contained entirely within the route-junction structure: "the connectivity structure of the link-route structure is unaffected by the removal of all the non-junction links". This is an intriguing result, and we cannot accept its claimed significance having been unconvinced (as suggested earlier in this paper) about the utility of exploring what Johnson refers to as the "connectivity structure". It is ironical to note that not only does the relative structural unimportance of non-intersection links (L_1, L_3, L_4, L_7, L_8, L_9) stand out immediately from a simple graphical representation of the road system (i.e. again we do not need Q-analysis to make the observation - see Figure 4), but that the removal of non-intersection links then actually reduces this representation to one in which intersections are given by dots and roads between them by edges - a representation described earlier as "a serious distortion of reality" Johnson (1984 p. 93). (We suspect that the advised removal of non-junction links may contradict advice in Johnson, 1981-B, about the desirability of adding links to intersections that are faces of existing links.)

<u>Other material</u>

For a degree of completeness we comment briefly on additional material from other papers aiming to draw transportation researchers towards Q-analysis.

(i) Accessibility for pedestrians.

Johnson (1976-A; 1981-A; 1981-B; 1983-A) rejects the method of representation of road systems in conventional transport theory, and recommends that town maps be divided into <u>plots</u> of land, each possessing one or more land uses. In this representation, a 'road' would become a landuse. The accessibility of pedestrians in a part of Southend-on-Sea is used to illustrate the utility of this representation, showing that different intensities of road traffic flows constrain pedestrian accessibility to certain parts of the town. A listing of q-connected components at different dimensional levels is given, but their significance is not explained beyond noting that they can pick up the "isolation" of individual geographical areas at the 1-dimensional level. (We are not convinced of any practical significance in transport planning in identifying their dimensionality at other dimensional levels.) Utilisation of more conventional graph theory, defining geographical areas as nodes, with adjacent pairs linked if they are mutually accessible could have achieved this.

(ii) Space time paths

In various papers (Johnson, 1976-A; 1981-A) it is proposed that Hagerstrand's (1970) space-time model be rewritten in terms of Q-analysis in order to give "a richer picture of the relative advantage of the mobile over the immobile" (1981-A, p.322). Individuals' paths through space and over time would be defined as sets of simplices to show, for example, that motorists have available more simplices and ways of combining them than pedestrians. We simply draw attention to this as one of a number of suggested adaptations of the conventional space-time model in transport in recent years (see Jones et al, 1983, for a summary of others). Some long-standing problems of space-time modelling - very heavy data requirements and consequent utility only for general policy issues at the national level and not at the local level for which they were designed (Pickup and Town, 1981) will need more serious consideration in future developments.

(iii) Changing social trends

Johnson (1981-A) notes that telecommunications can make spatially distant homes and offices very highly connected because: "if I have a teletype in my house attached by telephone to a computer, I effectively have a computer in my house, and I do not need to make a trip to access the computer" (p.324). Thus, defining the flow of information and ideas as "traffic" on a location-activity structure, the reduced need for some trips can be reflected in a Q-analysis since this "computer age" structure can be highly connected unlike the relatively disconnected "physical space structure". It is agreed that emerging technologies of waveguides and optical fibres will reduce transmission costs which will influence different trip purposes and the choice of workplace and residential location (Walters, 1983). However, what is absent from Johnson's remarks is an explicit discussion of the way in which Q-analysis can provide important new insights into this subject. Again more conventional graph-based adaptations might be more obvious alternatives. Similar sentiments hold for suggestions to site workers close to their work place, removing the need for roads and long trips, in turn eliminating the need to plan for traffic, Johnson (1981-A). Although this seems intuitively obvious, experience suggests that it does not work in practice.

(iv) Dynamic micro with macro-hierarchical system

Johnson's (1977, 1981-A, 1981-B, 1983-B) main criticisms of transport theory under this heading are (a) that it falls into two incompatible parts - a dynamic micro-theory (based on shock-wave theory) and a static macro-theory (based on Wardrop's "equilibrium principle"), and (b) that it has failed to establish a framework within which to analyse structural relations between transport and the urban environment.

To overcome these difficulties, an alternative representation is suggested which

> "makes the aggregation from the minutae of the road system to regional and national level both natural and practical. In other words, it is possible to have holistic transportation planning at the national level which does not ignore the human reality of, for example, heavy traffic flows through small residential streets or conflict between local and through traffic. This representation is based on hierarchical sets of zones and the points at which roads cross boundaries. A 'link' at level N+2, for example, might traverse an N+2 zone representing a small town. It would be made up of a set of N+1 links themselves traversing N+1 zones which represent parts of the town, its centre for example. Each N+1 link is made up of a set of N routes between its endpoints. Finally, each of these level N routes is made up of level N links, where these correspond to the street that are links in the conventional network representation. In this representation road intersections become N links of the same geometric status as roads."
>
> (Johnson, 1983-C, p.)

We find this conceptually interesting, though in contrast with Johnson's suggestions we would hesitate to explore the utility of this conceptual representation in the context of the type of Q-analysis "results" reviewed earlier in this paper, in view of the reservations we have expressed. Again we would suggest that other methodological perspectives (notably more conventional graph-based methods) would be more profitable, affording more precise and operational analyses. We do not, however, necessarily share Johnson's view of the desirability of using a single methodology at all levels of spatial resolution: the differing significance of different types of feature at different levels of resolution suggests a desirability of invoking different styles of approach, and more subtle and powerful procedures for aggregation and disaggregation between different hierarchical levels.

Conclusions

1. We have questioned the utility of Q-analysis as presented in recent papers by Johnson (1984), noting elements of ambiguity and unduly cumbersome notational convention, some unsubstantiated claims and an absence of convincing evidence of the potential utility of the method. The use of routes as a measure of "distance" between different parts of a network introduces an undue degree of arbitrariness, and reliance on the concepts of q and structure vector conceals important detail. Although our criticisms have been based largely on material in a single paper we cannot find adequate compensation for them in other papers in other available literature.

2. Our criticisms can be interpreted as a plea for a more telling and convincing demonstration of the utility of Q-analysis as a new methodological perspective in transport research. Until this is forthcoming we would hesitate to recommend to others in the transport field to spend long penetrating its unfamiliar terminology and conventions in the hope of finding new operational tools. Theoreticians may find greater reward.

3. Although the general tenor of the present paper is critical, in the material we have read there are undoubtedly a number of simple ideas that are perhaps undeservedly underemphasised in mainstream transport research ($\hat{\sigma}$ for links, paths, junctions as areas, some consistency in hierarchical schemes, the idea of a latent route-link structure and the very evocative metaphor of traffic on a backcloth). We suggest however, that

these at present would be more profitably re-emphasised within more traditional paradigms than by taking Q-analysis on board. In other words we suggest being very selective in which of the many facets of Q-analysis are used and being very catholic in combining them with other methods.

4. The empirical illustrations of Q-analysis given in Johnson's papers do not in our view, adequately convey the advantage of analysing a data set using the algorithm and conventions of Q-analysis, and the great benefit thereby afforded in terms of such close familiarity with data. This very basic aspect, an antecedent to the kind of theoretical results reviewed in this paper, is something to be experienced perhaps only at first hand, and not readily grasped through observation of someone else's structure vectors, q's or q-listings, but the desire to establish a number of theoretical results may have further diminished the prominence of this aspect in the papers reviewed.

5. An indepth illustration in a single empirical context may have provided a more convincing basis for demonstrating the utility of Q-analysis as a new approach in the transport field than the rather bitty and necessarily superficial use of a range of different illustrations by Johnson seems to have given.

6. We believe that more conventional graph-based methods could be adapted to capture more successfully the type of results or connectivity sought so far in the Q-analysis papers reviewed. This suspicion would appear to be endorsed - though perhaps not strongly enough - by a remark made by Johnson and a colleague in a different context (Earl and Johnson, 1981, p. 381): "It is clear from the startling advances in electronics that graph theory has been very successful in these applications, and although Q-analysts might find a multi-dimensional description of electrical systems more natural it could be that they would just replace the well-known and tried methods of electrical network theory with something less familiar but not inherently new".

7. Until a convincing example is given of the need for the representation of multi-dimensional connectivity in transport research, rather than the layers of uni-dimensional connectivity that graph-based methods can already supply, then we would prefer to stick to the latter for operational work (though we still see a conceptual and mathematical appeal in the former). In other words we recognise a unique characteristic of the methodology of Q-analysis in modelling a relation via a complex instead of via a graph. Its vindication as

an operational methodology will only arise in contexts that <u>need</u> this characterist (i.e. where representation would otherwise be unduly impoverished). As currently developed in the transport field, Q-analysis can make a distinction between 8-traffic, 5-traffic and 13-traffic but has failed to provide a telling interpretation of these distinctions or to suggest operational applicability of them.

8. We believe that Johnson's dismissal of the utility of network or graph based methods is misconceived. Quoting further from Earl and Johnson (1981, p. 382) "In as much as network theory replaces areas of roads by lines and areas of junctions by points it is by definition unable to represent the two-dimensional geometry. When network theory ignores explicity routes through the network, it is unable to represent the multi-dimensional geometry of road traffic systems". As regards the second point here we do not consider it a shortcoming of the operational aspects of network <u>theory</u> (connectivity, feedback) that routes are ignored and the structural importance of areas of roads and junctions distorted; rather it is at most a shortcoming of the way the system is defined and represented, this preceding the invocation of such theory. Moreover, we do not even then regard it as a serious weakness, because although it requires roads to be represented as 0 and 1 dimensional structures (rather than the 2 dimensional real entities that they are) we do not share Johnson's apparently serious reservation of accommodationg 3 dimensional (in the real world) vehicles adequately, because they too are represented as 0 and 1 dimensional entities. All representations require some corruption of reality and this does not appear unduly detrimental simplification.

9. The focus on routes X links for eliciting latent structure in road systems and in particular the use of routes as a fundamental metric does not appear to have provided a basis for generating useful new results and in some cases has obscured important structural features for the type of road transport systems. Johnson's approach as developed so far may prove to be more successful in the more limited context of bus-route planning, for here the use of routes as a metric could have some real importance. Meanwhile we raise the question of whether structural features deemed to be important in other contexts elsewhere in the Q-analysis literature are what they seem. We also suggest the possibility of reformulationg the Q-analysis material in order to exclude the unsuccessful focus on routes as a metric.

References

Allsop, R.E. (1979) Some mathematical aspects of the management and control of traffic in urban road networks, Bulletin of the Institute of Mathematics and its Applications, 15, 283-286.

Atkin, R.H. (1974) Mathematical Structure in Human Affairs, Heinemann Educational Books, London.

Beaumont, J.R. and Gatrell, A.C. (1982) An introduction to Q-analysis, CATMOG 34, Geo. Abstracts, Norwich.

Charlesworth, J.A. (1979) Control and routeing of traffic in a road network, Traffic Engineering and Control, 20, 460-466.

Earl, C.F. and Johnson, J.H. (1981) Graph theory and Q-analysis, Environment and Planning B, 367-391.

Gould, P. (1980) Q-analysis, or a language of structure for social scientists, geographers and planners, International Journal of Man-Machine Studies, 13, 169-199.

Gould, P. (1983) Reflective distanciation through a meta-methodological perspective, Environment and Planning B: Planning and Design, 10, 381-392.

Hagerstrand, T. (1970) What about people in regional science? Papers of the Regional Science Association, 24, 7-21.

Johnson, J.H. (1976-A) The methodology of Q-analysis in planning and transportation, in Matzner, E. and Rusch, G. (eds.) Proceedings of the IFIP Workshop: Transport as an Instrument for Allocation Space and Time - a social science approach, Institute of Public Finance, Technical University of Vienna, Austria.

Johnson, J.H. (1976-B) The Q-analysis of road intersections, International Journal of Man-Machine Studies, 8, 531-548.

Johnson, J.H. (1977) Methodology of Q-analysis. A study of road transport. Research Report XI, Regional Research Project, Department of Mathematics, University of Essex, Colchester.

Johnson, J.H. (1981-A) Research on transport and Q-analysis in Banister, D. and Hall, P. (eds.) Transport and Public Policy Planning, Mansell, London.

Johnson, J.H. (1981-B) The Q-analysis of road traffic systems, Environment and Planning B, 8, 141-189.

Johnson, J.H. (1982) Q-transmission in simplicial complexes, International Journal of Man-Machine Studies, 16, 351-377.

Johnson, J.H. (1983-A) Road systems have newly discovered structure which can be exploited by transportation planners, Atti Delle Giornate Di Laroro 1983, Della Associazionte Italiana Di Ricerca Operativa.

Johnson, J.H. (1983-B) Q-analysis: a theory of stars, Environment and Planning B: Planning and Design, 10, 457-470.

Johnson, J.H. (1983-C) A survey of Q-analysis, part 1: the past and present. Paper presented to Seminar on Q-analysis and the Social Sciences, University of Leeds, September 1983.

Johnson, J.H. (1984) Latent structure in road systems, Transportation Research B, 18B, 87-100.

Jones, P.M., Clarke, M.I., Dix, M.C. and Heggie, I.G. (1983) Understanding Travel Behaviour, Gower, Aldershot.

Macgill, S.M. (1984) Structural analysis of social data: a guide to Ho's Galois lattice approach and a respecification of Q-analysis, Environment and Planning, A, (forthcoming).

Pickup, L. and Town, S.W. (1981) The role of social science methodologies in transport planning, TRRL Supplementary Report SR698, Transport and Road Research Laboratory, Crowthorne.

Road Research Laboratory (1969) Representing junction delays in a restrained assignment, RRL Leaflet LF. 131, Road Research Laboratory, Crowthorne.

Roberts, F.S. (1976) Discrete Mathematical Models, Prentice Hall, Incl, Englewoo Cliffs, N.J.

Walters, J. (1983) The telecommunications impact, Papers in Planning Research 54, Department of Town Planning, University of Wales, Institute of Science and Technology.

TABLE 1: The Q-analysis calculations for Figure 2.

	AB	CD	CF	ED	EF	AD	CB
AB	3	1	1	0	0	2	2
CD		5	3	2	1	4	2
CF			5	1	2	3	2
ED				3	2	2	0
EF					3	1	0
AD						5	1
CB							3

The components at each q-level:

$q = 4$	(CD)(CF)(AD)
$q = 3$	(AD, CD)(CF)
$q = 2$	(AD, CD, CF)(AB)(ED)(EF)(CB)
$q = 1$	(AD, CD, CF, ED, CB, AB, EF)
$q = 0$	(AD, CD, CF, ED, CB, AB, EF)

Figure 1: Hypothetical road systems. (Traffic flows from left to right)

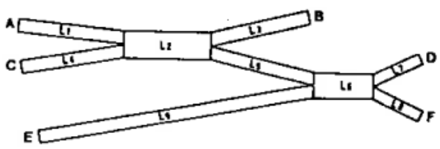

Figure 1a. With routes A → B (links $L_1 L_2 L_3$)
A → D (links $L_1 L_2 L_5 L_6 L_7$) etc.

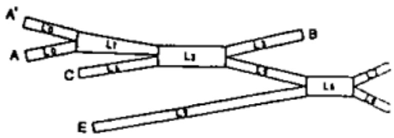

Figure 1b. Derived from fig. 1a by adding two additi
links at the front of link L_1

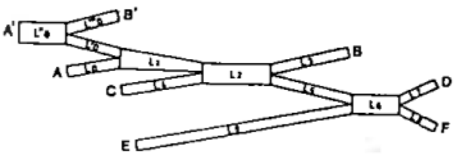

Figure 1c. Derived from fig. 1b by adding an additional short route A' B' from A

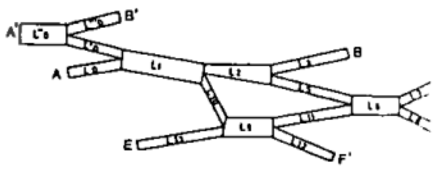

Figure 1d. Derived from fig. 1c by adding the addition
links $L_{10} L_{11} L_{12}$ & L_{13} and removing routes beginning at C (for clarity)

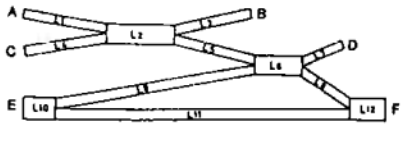

Figure 1e. Derived from fig.1a by incorporating the additional route $L_{10} L_{11}$ & L_{12} from E to F

Figure 2. Graphs associated with the listing of table I

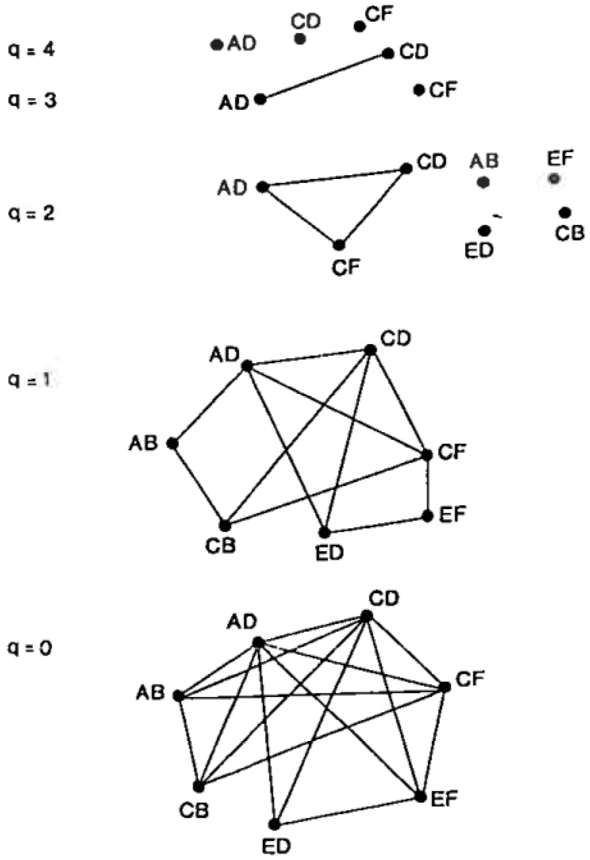

Figure 3

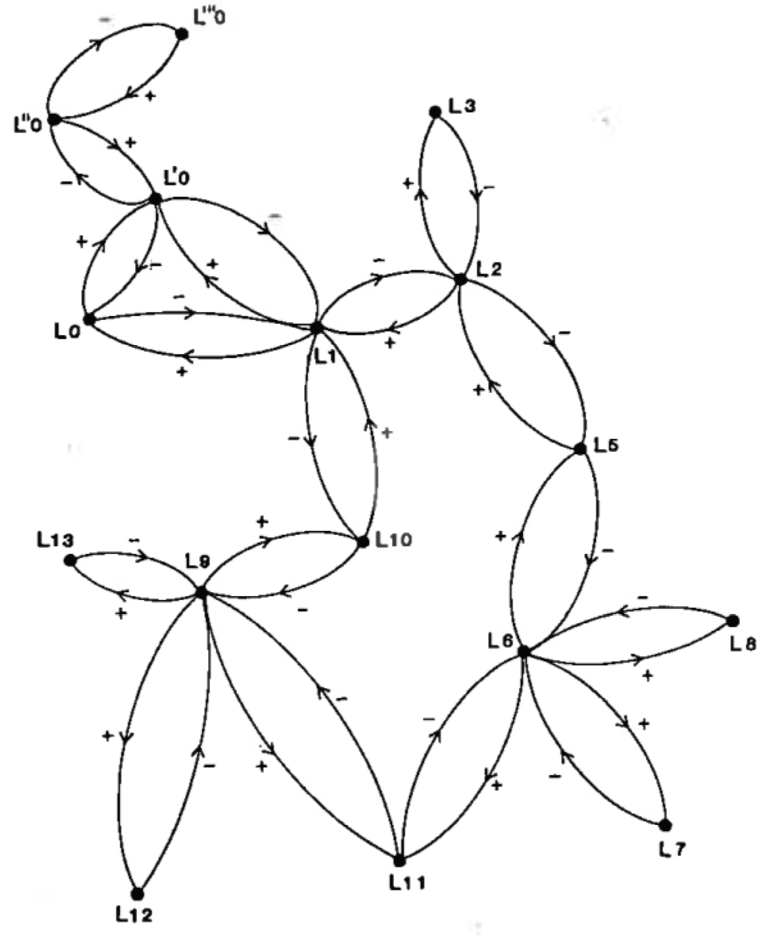

Figure 4a : A simple graph of the link structure of fig. 1a

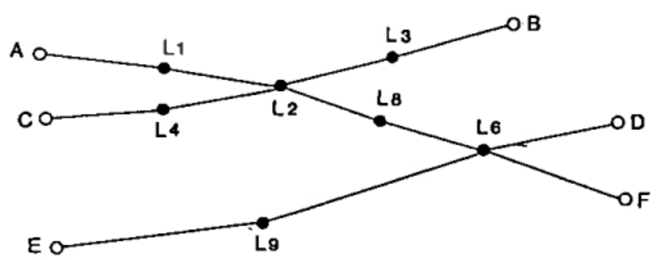

Figure 4b : The effect of removing non-junction links from fig. 4a