TRADE DEVELOPMENT, COMPETITION AND MODELLING INTERMODAL TRANSPORT SYSTEMS

Glen D'ESTE
Senior Research Fellow
Transport Systems Centre
University of South Australia
The Levels SA 5095
AUSTRALIA
Fax: +61-8-302-3972

Ross ROBINSON
Associate Professor
Centre for Transport Policy Analysis
University of Wollongong
Wollongong NSW 2522
AUSTRALIA
Fax: +61-42-26-4257

abstract: In many parts of eastern Asia, there is a wealth of resources and productive capacity but the resulting potential for economic development is not being realised due to inadequate transport links. This paper examines the nexus between trade and transport development, with an emphasis on shipping services to comparatively remote and less developed areas. The paper introduces a conceptual framework and discusses the use of an intermodal transport network model as an instrument for investigating the relationships between improved access to markets, competitiveness, trade volumes and transport service viability. Transport and economic development in northern Australia is presented as a case study.

1. INTRODUCTION

In many parts of eastern Asia, there is a wealth of resources and productive capacity but the resulting potential for significant economic development is not being realised due to inadequate transport links to markets. Regional and international trade development is being retarded by a lack of access to regular, reliable and cost-effective transport services. This is especially evident in less developed and comparatively remote regions, such as eastern Indonesia, southern Philippines and northern Australia which have poorly developed transport infrastructure and are not on the major regional shipping lanes. The solution would appear to be straightforward - develop better transport links - but it is difficult to justify investment in transport infrastructure and development of services if it is not warranted by the current volume of trade. On the other hand, it is difficult for trade to grow without access to transport, so we are caught in a circular argument.

In some cases the circle is broken by major industrial investment with large transport requirements, such as the establishment of a mine or major processing plant. This provides a baseload cargo that underwrites transport services and provides flow-on benefits to other traders in terms of access to quality transport services. However in many cases, the circle remains unbroken. This is especially evident where the regional economy consists of a large number of comparatively small producers each of which does not produce sufficient cargo to support a transport service.

This paper examines the nexus between trade and transport development. It introduces a conceptual framework for the link between trade and transport and discusses the use of an intermodal transport network model as an instrument for investigating the relationships between improved access to markets, competitiveness, trade volumes and transport service viability. The aim of the paper is to present an integrated modelling framework that can provide an insight into the interdependence between transport and trade development, and serve as the basis for evaluating the viability of transport services to developing regional economies.

The discussion will focus on the proactive establishment of improved transport services as a stimulus for regional economic development and, in particular, general cargo shipping services to comparatively remote and less developed areas with mixed economies. The scenario is illustrated in Figure 1. Trade from a hinterland is centralised in a regional centre (or "hub") which becomes the gateway for trade from the region. The cargo is then moved

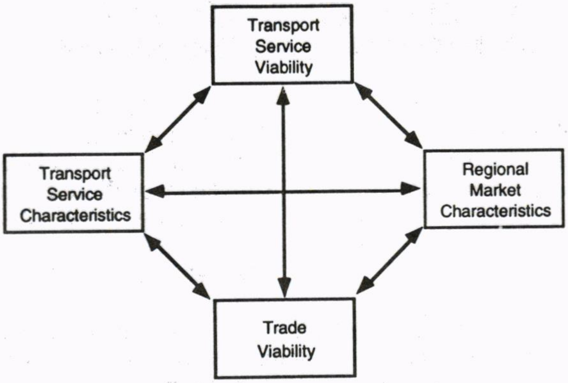

Figure 2 Trade and Transport Relationships

The challenge for many regions, particularly those in more remote locations which are not on major transport corridors, is to break the circle of poor transport and stagnating local economy. The trade-transport circle can be broken by entrepreneurial investment by a producer or transport operator, or by Government intervention to facilitate regional economic development. This paper is mainly concerned with proactive investment in transport which means that an essential task will be to evaluate the viability of improved transport links in the context of existing trade plus opportunities for additional demand generated by access to the transport service. The relationships shown in Figure 2 define the basic links between trade and transport but do not provide any insight into an evaluation methodology. Figure 3 provides additional details of the processes underlying the basic relationships and in so doing provides a conceptual framework for evaluating intervention options.

As shown in Figure 3, there is a complex web of linkages between trade and transport components of the system so to evaluate a hypothetical or proposed service it is necessary to break into the circle of interdependencies at some point. The standard approach to evaluating the trade impact and viability of a new transport service is to start by making a series of judgements about future trade volumes. In general, this involves identifying marketable commodities within an assumed hinterland, then assuming a market share that can be captured by the transport service. The total volume of trade is then calculated by multiplying available volume by market share for each commodity then summing across the hinterland. There are several problem with this approach. Firstly there is little analytical basis for either the assumed hinterland or market shares which usually means that the assumptions tend to be optimistic. Secondly there is little or no link between the characteristics of the transport service and the commodities that are assumed to be carried. Sensitivity testing can compensate for the lack of a firm basis for many of the assumptions but this approach is largely subjective.

An alternative is to start by proposing the characteristics of a transport service. In general this is a much easier starting point since there are observable indicators that can be used to construct the profile of the hypothetical service;

- market requirements and competitive demands will determine service frequency
- freight rates being paid by competitors trading into the same market will provide a starting point for setting rates
- transit time is determined by distance to market and speeds achieved by appropriate transport technology for the service, and
- current trade volumes can provide a basis for scoping total likely demand, then the combination of total demand, frequency and transit time will determine the appropriate capacity for vehicles (trucks, trains, ships, planes) used to provide the service.

by sea to market or for further transhipment to distant markets. This situation is common throughout the archipelagos of SE Asia.

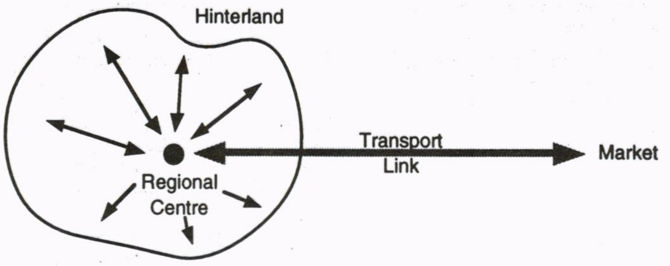

Figure 1 Regional Trade and Transport

To illustrate the way that the proposed conceptual framework can be applied to real world situations, the paper introduces a case study of the transport and economic development problems facing the northern Australian region centred on Darwin. The case study also includes a discussion of the use of an intermodal transport system model of the northern Australia-Indonesia-Singapore corridor to investigate the changes in competitiveness and trade hinterlands that would result from various transport development scenarios and improved access to markets. It is then shown that the results can be used to project trade volumes, assess the financial viability of proposed transport investment and complete the feedback loop between trade development and transport infrastructure investment.

The "chicken and egg" situation faced by Darwin - that is, trade cannot develop without transport but transport cannot develop without trade - has many counterparts throughout eastern Asia. Further the general principles are applicable all modes and a wide range of local conditions. Therefore this paper will have relevance to the economic development problems faced by many regions of Asia, especially those whose trade prospects are disadvantaged by inadequate transport.

2. TRADE AND TRANSPORT

Since inter-regional trade is inherently involved with adding value to goods by moving them to distant markets, trade and transport are inseparable. The fundamental relationships between trade and transport are summarised in Figure 2.

The basic features of the trade-transport system are transport service characteristics (frequency, transit time, capacity, freight rates, technology, etc), and regional market characteristics (commodities, prices, volumes, etc). These factors directly determine the financial viability of trade and of transport services through complex linkages between all components of the system. A transport service cannot be viable without adequate demand for movement of suitable cargos (viable trade), and equally trade cannot be viable without access to transport services with suitable service characteristics. For example, trade in perishable cargos cannot be viable without fast and reliable transport at a price that allows a reasonable profit for the producer. Further, the characteristics of a transport service are largely determined by the type and volume of cargos and the level of sustainable freight rates. Equally the type of goods traded to and from a region is influenced by the characteristics of transport services. Good, cheap transport will enable and create markets while expensive, slow and unreliable transport will stifle trade opportunities. There are many examples in eastern Asia where regional economies with poor transport links have stagnated while other areas have boomed.

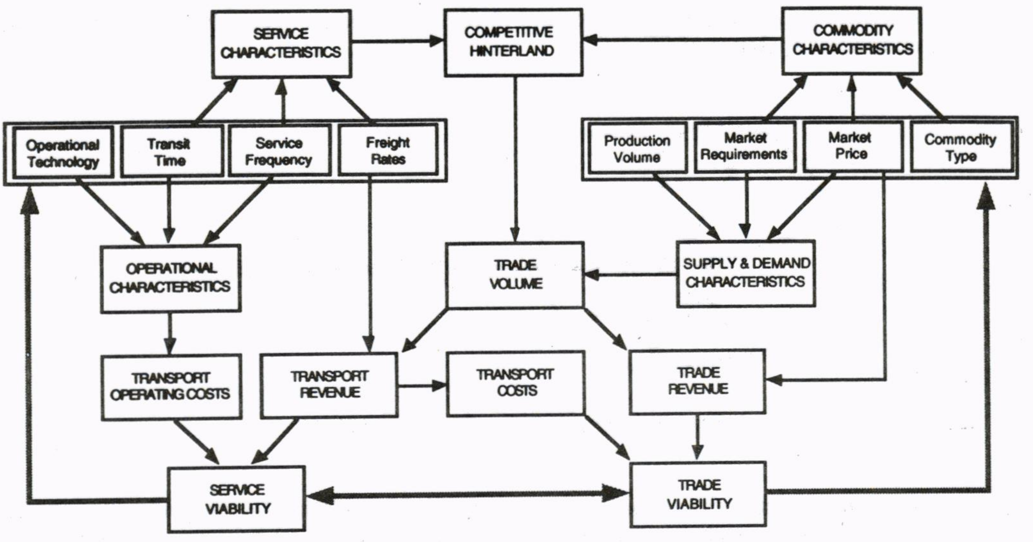

Figure 3 Conceptual Framework for Trade-Transport Evaluation

Using this approach it is a relatively straightforward procedure to define the characteristics of a transport service that is appropriate to the situation under consideration.

Having constructed a transport service scenario (or scenarios), two important features of the market follow; firstly the financial performance of the transport service as a function of trade volume, and secondly the competitive hinterland for the service. The financial performance of the service can be calculated using a spreadsheet cost model for the transport service. Many such models have been developed and the cost structures and relationships for all modes are well understood. Locating the hinterlands for which the regional centre will be a competitive trade gateway, is a somewhat more difficult task. Each commodity has different transport requirements in terms of maximum transit time, minimum service frequency and maximum door-to-door price. Therefore the hinterland will be different for each category of commodity and will depend on the characteristics of the proposed transport service. For example, a transport service that has been tailored to the needs of time-sensitive cargo may not be competitive for price-sensitive cargo, and vice versa. The identification of hinterlands is further complicated by the need to consider alternative trade gateways and the full door-to-door journey rather than simply the transport service being evaluated. The use of an intermodal transport network model to construct hinterlands is discussed in Sections 3 and 4 of this paper.

Having determined hinterlands in which the combination of trade gateway and transport service is competitive for a selection of representative commodities, it is reasonable to assume that the majority of the traded volume of each commodity will be captured by the service. The total demand for the service can then be calculated by summing the available supply (or demand) for each commodity in its hinterland. Note that this is the starting point for the standard method mentioned above and that the methodology proposed in this paper develops a firm conceptual and analytical basis for estimating volumes and market shares.

Finally, the projected viability of the transport scenario is obtained by substituting the trade volume into the cost model. The result will either be that the scenario is viable or not. If the transport service is shown to be viable then it is probable that the required trade volumes will be greater than that presently existing in the market (otherwise it could be argued that the service should already exist in a contestable market). The increased trade volume indicates two things; firstly that the proposed transport service may not be financially viable in the short term and secondly that the transport service can act as a stimulus for regional economic development with long term growth in demand for transport services. It follows that the establishment of the improved transport service will require either an entrepreneurial operator willing to absorb short term loses in pursuit of long term market dominance, or a government willing to underwrite the establishment of the service in the short term in pursuit of long term regional benefits. Alternatively if the results suggest that the proposed transport service is not viable then the characteristics of the service can be redefined and the process repeated until a viable scenario is obtained. It may be that the characteristics of the viable service are such that they indicate limited potential for major economic development under currently foreseeable market conditions and technologies. In this case, it is difficult to justify any investment.

3. CASE STUDY : NORTHERN AUSTRALIA

The major elements of the methodology and evaluation procedure can be demonstrated by considering a case study of trade and transport development in northern Australia. Australia is generally seen as a developed country but there are areas of northern Australia that are less developed as a result of their remoteness and lack of access to adequate transport services. The region centred on Darwin is a prime example and will be employed as a case study for illustrating the use of the conceptual framework described above.

Darwin is the centre of a region that is isolated in a transport sense both by distance and by a shortage of regular, reliable and cost-effective transport links to markets in east Asia and beyond, as well as to the rest of Australia. Darwin is not connected to the Australian rail network, indeed, it is some 1,500 km from the nearest railhead. It is some 3,200 km by road from Darwin to the nearest major population centre (Adelaide) and by sea, it is some 1,850 nautical miles to the nearest major Australian port (Fremantle). Further no major international container services call at Darwin. The only shipping services calling at Darwin are regional operators who provide a general cargo services that island-hops around the eastern Indonesian region and include infrequent calls at Singapore. In addition, the current volume of international trade from the region is small; the population of the Darwin region is less than 200,000 persons and the current annual port trade is only some 8,500 TEU.

Despite its low trade volume, remote location and restricted transport links, Darwin has been proposed as a major growth region because there is significant potential for agricultural, mineral and manufacturing production in the region. Further, Darwin has been proposed as a potential gateway for Australian exports into Asia, because looking north and east into Indonesia and beyond, Darwin is much closer to Asian ports than it is to other Australian ports.

Table 1 Sea Distances from Darwin to Asian Ports

	Distance (nautical miles)
Surabaya	1200
Jakarta	1532
Singapore	1887
Davao	1240

Several steps have been taken to facilitate regional economic development. A Trade Development Zone (TDZ) has been established at Darwin, a new container port is being constructed at Darwin and the feasibility of linking Darwin to the Australian railway network is being investigated by both government and private studies. However the major market opportunities lie in Asia to the north and west so the ultimate success of major economic development in northern Australia will depend on the establishment of regular, reliable and cost-effective shipping services to Singapore and ports in Indonesia and southern Philippines. But shipping services will not be viable without trade and trade cannot commence without transport, so we come back to the trade-transport circle.

The viability of breaking the trade-transport circle by the proactive establishment of a new shipping service to Singapore was investigated using the methodology described above. Port calls at Surubaya and Tanjung Priok (Jakarta) were also considered but the main focus of the investigation was on links between the Darwin region and Singapore. The details of the analysis are confidential but the technique can be described in general terms. Briefly, the steps in the analysis were

1. Define the characteristics (transit time, frequency, capacity, freight rates) of several alternatives configurations of the proposed shipping service

2. Develop a cost model for an archetypal shipping service and calculate the financial performance (volume-profitability curves, break-even point, etc) of each configuration

3. For each set of shipping service characteristics, determine the extent of the hinterland for which Darwin is the preferred trade gateway

4. Determine the current or potential production of each commodity within the hinterland and calculate the likely volume of trade between the region and Singapore

5. Using the results of Steps 2 and 4, assess the viability of each shipping service scenario

Characteristics for the proposed shipping service were defined by comparison with services with operating between Singapore and other Australian ports, and on the basis of perceived market requirements. It was assumed that freight rates should be comparable with those available from other Australian ports and that a weekly calls at Darwin was a reasonable minimum level of service. With current trade volumes that are low and expected to continue to be relatively small under any reasonable scenario, it was assumed that a small modern container vessel (say 500 TEU maximum) was appropriate. Finally, assuming a typical speed (say 14 knots) for a small container vessel gives a 6 day transit time between Darwin and Singapore so that 2 vessels would be needed to deliver a weekly service. With the characteristics of the service established, its cost structure was calculated using a standard spreadsheet cost model appropriate for a small regional shipping operation.

The next step was to identify competitive hinterlands for a Darwin-Singapore shipping service. That is, the extent of the region in which Darwin is a competitive gateway for Australian trade into Asia. Three categories of commodity were considered - extremely price sensitive cargo, extremely time sensitive cargo and cargo with a balance of time and price sensitivity. In addition, the impact of several hypothetical land transport improvements were considered. The analysis of hinterlands was undertaken using the Multi-Modal Freight Flow Model (MFFM) developed by the Centre for Transport Policy Analysis. The MFFM model is described in detail in Section 4 of this paper.

The hinterlands for the three commodity types were quite different. Due to the high cost of land transport relative to shipping, the hinterland for price sensitive cargo was simply the immediate geographic region centred on Darwin. The hinterland for time sensitive cargo being traded in Asia was much larger because Darwin is closer to Asian markets and can offer shorter transit times. The hinterlands for each of the commodity types were then used to estimate the likely volume of trade that could be captured by a Darwin-Singapore shipping service with a given set of service characteristics. For example, fruit is a time sensitive cargo so using the hinterland for time sensitive commodities, volumes of current (or potential) production and estimates of market demand, it is possible to estimate the likely volume of trade in fruit to be carried by a Darwin-Singapore shipping service. The exercise is then repeated for a range of commodities to create a picture of the overall potential trade market.

Finally, total revenue for the service can be calculated using the trade volumes and proposed freight rates, and total costs follow from the trade volume and operating cost model. This provides an estimate of the likely short and long-term financial viability of a service with the assumed operating characteristics. Decisions can then be made about long term commercial prospects for the service, about the need for government intervention to underwrite the service in the short term or about the need to redefine the service and re-evaluate its viability.

4. MODELLING DARWIN TRADE HINTERLANDS

A key requirement of the methodology described in this paper is the identification of hinterland in which the regional centre and transport link are potentially competitive. As noted above, the hinterlands for Darwin were calculated using the MFFM model. MFFM is a sophisticated logistical model that focuses on ports and shipping but recognises that the maritime component cannot be considered in isolation from the overall transport task. The model tracks freight flows from origin to destination including land links at either end, port handling, and options for transhipment of cargo at intermediate ports. Therefore it is well suited to the investigation of issues such as port competition, landbridging and the development of hub and feeder operations. In essence, the model calculates the expected pattern of cargo movements for a given state of the transport system and pattern of demand.

MFFM provides a tool for the user to systematically compare and evaluate the implications of different states of the logistical system. The model imposes consistent rules to predict the distribution of cargos moving in a logistical network. It is fundamentally a network-based, cargo assignment model in which route choice is determined by a combination of cost, time and service factors. The fundamental objective is to identify the path (or paths) through the network that minimises some prescribed measure of the penalty associated with transporting the freight consignment. The model does not purport to predict what the future will be like or what it should be like. Instead the model is an exploratory tool that allows the user to manage large amounts of information, and systematically investigate the likely impact of possible transport scenarios in a consistent manner. It is a "what-if" model in which the user specifies and controls the scenarios to be evaluated. These scenarios can differ in the strategies adopted by shippers, and/or in the characteristics of the supply side of the transport market. Examples of issues that can be addressed using MFFM include

- the effect of changes in the pattern of shipping services, including changes in schedules, port calls, and vessels
- the impact of new entrants and the viability of existing shipping services
- the effect of changes in relative sea and land transport freight rates
- port competition
- the impact of new industries and patterns of industrial development
- the land transport implications of changes in shipping patterns

Figure 4 shows the type of intermodal transport system that MFFM has been designed to model. In practice, intermodal networks tend to be much more complicated that this example, however the example captures the essential elements of a competitive intermodal system.

The sample network illustrates intermodal options available for transport between a particular origin and destination. From the origin, the consignment can travel by road or rail to one of two competing ports for loading onto a shipping service. The shipping service can then travel direct to a port near the destination or it can travel to a transhipment port for transfer to a second shipping service. Having arrived at the port of unloading, the consignment can then travel to its final destination by road or rail.

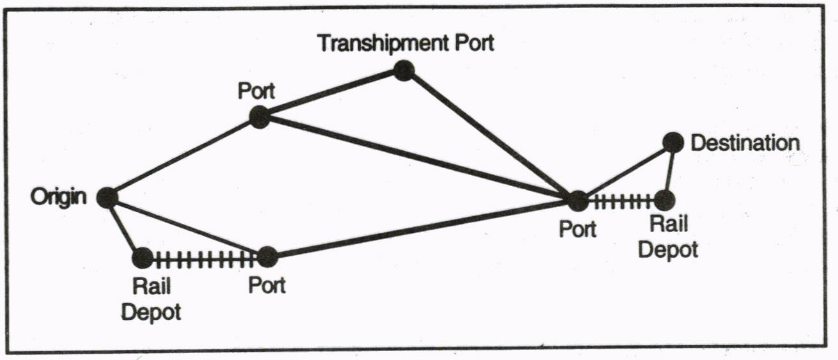

Figure 4 MFFM Transport network

The information required to build an MFFM network is basically a description of the supply side of the intermodal transport system, including

- details of operational characteristics of shipping services
- land transport links and costs
- details of cargo handling costs and options
- shipping freight rates and relative quality of service
- transhipment options
- commodity details

For full details of the way that an actual intermodal system is represented in terms of MFFM nodes and links, see D'Este and Meyrick (1991).

The route choice process and hence choice of trade gateway is implemented in MFFM by associating a service frequency and a generalised transit cost with each link in the network. The generalised cost is a combination of time cost and dollar cost with a facility for also including estimates of relative service quality to differentiate between competing services with the same schedule and price. Each of the factors (time, cost, quality) that comprise the generalised cost is given a weight so that the outcome of different shipper strategies, such as least cost, shortest transit time or balanced strategies, can be simulated by adjusting the relative weights.

It follows that shipper choice and hence assignment of freight flows to paths and through specific nodes in the network is based on a combination of service frequency, transit time, cost and other service quality factors as suggested by survey results, see D'Este and Meyrick (1992). To implement the choice process, MFFM uses a new network assignment algorithm that combines the stability and rich use of information of the Gallagher-Meyrick (GM) algorithm, see Gallagher and Meyrick (1984), with the computational efficiency of the algorithm developed by Spiess and Florian (1989). The Spiess algorithm was initially developed for analysing transit networks and is implemented as part of the EMME/2 software package, which is used for transit planning by many agencies in Australia, United States, Canada and Europe. The key elements of the MFFM solution algorithm are

- the objective is to minimise the total generalised cost of the trip from origin to destination.

- the algorithm is akin to standard "shortest path" network algorithms but differs in that it accommodates situations in which links are only available at certain times according to the service frequency on the link, or equivalently, that link trips involve a constant transit time plus a distribution of waiting times.

- the probability that a particular path (shipping option) is chosen is equal to the probability that it is the path with the lowest generalised cost, remembering that generalised cost is a combination of cost, time and service factors.

- where there are competing options and time is a decision factor, the option that is the "cheapest" can vary with the pattern of service arrivals. Therefore the algorithm is not an "all-or-nothing" algorithm - several shipping options can have a non-zero probability. The behavioural interpretation is that the shipper will sometimes use one service and sometimes another depending on which is the "cheapest" on that occasion.

- a good analogy is catching a bus. Consider a case where there are two bus services - one is frequent and the other is less frequent but offers the same transit time and cost. Usually you will catch the frequent service but if you arrive at the bus stop when the infrequent service is about to leave, you will catch it. Hence both have a chance of being chosen but the more frequent service has a greater probability of being chosen.

The basic output from the assignment procedure is the probability that each of the feasible intermodal transport options is the preferred route for consignments from a given origin to a given destination. Therefore it is possible to determine the likelihood that a given node, such as Darwin, is a competitive gateway for trade between two given points and hence to construct hinterlands.

Darwin's likely hinterlands for exports to Singapore and beyond were constructed using the MFFM model and the following procedure

1. construct a scenario for the state of the intermodal transport network and translate the scenario into an MFFM network. The scenario would include an improved shipping service to Singapore and possibly, some changes to land transport links to Darwin.

2. select a cargo category, such as time-sensitive cargo. The category will determine the relative weights given to factors in the MMFM generalised cost function and hence the objective function for the assignment procedure. For example, transit and waiting times will be given a high weighting for time-sensitive cargo and the objective will be to minimise the door-to-door delivery time.

3. select an origin and location destination for transport of a consignment of the commodity selected in Step 2. The origin will be somewhere in Australia and the destination will be Singapore. Steps 2 and 3 define an hypothetical test consignment for assessing the viability of Darwin as an export gateway.

4. run the MFFM model to determine the probability that the consignment will be handled through Darwin. If there is a high probability of export through Darwin then the origin is recorded as being within Darwin's hinterland for that type of commodity.

5. repeat Step 4 for a large number of trip origins within the northern Australia region and for a selection of other origins elsewhere in Australia.

6. construct the hinterland for Darwin by taking the envelope of all origins for which Darwin has a high probability of being the preferred trade gateway.

7. repeat the process for other categories of commodity; price-sensitive, and various trade-offs between time and price.

The output is a set of hinterlands for which Darwin and the proposed shipping service are competitive. The process can then be repeated for imports to build up a picture of potential markets for movement of various types of commodities through Darwin. In effect, the hinterlands constitute the region in which to look for cargo to support the improved transport service and stimulate economic development.

Note that if all trade flows are fully specified *a priori* then MFFM can also be used as a traditional freight assignment model but this mode of operation was not used in the Darwin case study. In this study MFFM was used only to construct hinterlands.

5. CONCLUSIONS

It has been argued that one of the greatest barriers to regional economic development is access to regular, reliable and cost-effective transport services. Trade volume is unlikely to grow without access to transport but it is difficult to justify investment in transport infrastructure and development of services if it is not warranted by the trade volume, so we are caught in a circular argument. Under these circumstances and in the absence of major industrial investment, regional economies are likely to stagnate and not fulfil their potential.

Proactice investment in transport links is a way of breaking the circle but it is a risky strategy since it relies on confidence in the ability of access to improved transport to stimulate long term economic growth. Trade will probably grow in response to improved transport services but by how much, what types of commodities will be involved, how far will the hinterland extend and what type of service will provide the desired stimulus to economic activity. These are questions that must be addressed in evaluating the long term viability of the service and overall value and benefits of the investment.

This paper has proposed a conceptual model that places trade development, competition and intermodal transport in a coherent framework and in so doing accounts for the feedback between transport service characteristics, production, trade viability and transport viability. It has also been shown that the framework can be translated into a practical methodology for analysing the long term viability of improved transport service and their impact on the regional economy. In particular, the methodology offers a solid theoretical basis for evaluating proactive investment in improved transport services to regions with latent productive capacity.

In many parts of eastern Asia, trade prospects and economic development are disadvantaged by inadequate transport links to major markets. Investment in transport is a possible solution but it is difficult to evaluate the investment because there are complex interactions between trade, transport and regional economic development. The conceptual framework and methodology outlined in this paper provide a solid theoretical basis for addressing these issues and would be an appropriate mechanism for evaluating trade-linked transport investment, particularly in the archipelagos of SE Asia.

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