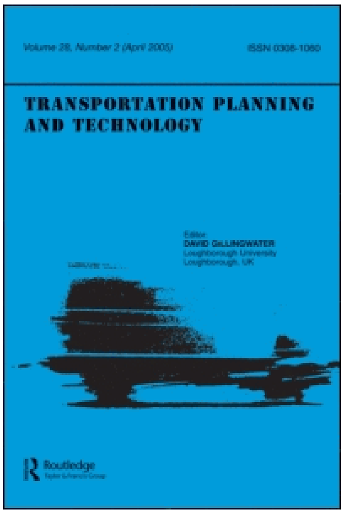

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Evaluating Locations for Intermodal Transport Terminals

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ARTICE

Evaluating Locations for Intermodal Transport Terminals

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ABSTRACT The choice of location for an intermodal transport terminal is an important component in a regional logistics system and a paramount decision for the investor as well as the community affected. The investor needs a realistic estimation of traffic potentials and incorporated cost-estimates of a location, since it serves as an important input to the investment decision process. Policy makers need instruments and tools to analyse the effect of intermodal terminals on the surrounding environment, which also enables a comparison between several possible locations in order to ensure sustainability and long-term competitiveness. The model in this paper allows a comparative evaluation of a set of possible intermodal terminal locations based on considerations by relevant actors. Furthermore, it presents a process of retrieving data and effectively communicating results. Considerations and interests of stakeholders are incorporated into the approach by means of evaluative criteria. The approach aims at facilitating the planning process of regional logistics systems in general and the evaluation process of intermodal terminal locations in particular by considering both public and private interests focusing on economic and environmental aspects.

KEY WORDS: Terminal location; transport geography; GIS; external effects; noise effects

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Introduction

Evaluating locations for intermodal terminals is a crucial part in the development of sustainable transportation systems, since they facilitate the use of intermodal transport. As part of the development of sustainable transport taking place in Sweden and Europe, this paper sets out to develop an approach for evaluating potential intermodal terminal locations on the basis of economic and quality-related considerations, e.g. lead-time and sustainability. There are both positive and negative consequences of using transportation; these are addressed in the sustainability of the transportation system. Sustainability has many definitions. Richardson (2005) bases her definition on the Brundtland Commission (United Nations, 1987) – 'the ability to meet today's transportation needs without comprising the ability of future generations to meet their transportation needs'. The approach developed in this paper operationalises the consideration of sustainability by evaluating environmental impacts of different terminal locations in terms of emissions and noise effects. Other external domains affecting sustainability include land use, safety, health and congestion (Himanen *et al.*, 2005). Although the approach developed in this paper can cope with congestion and land use, these are not primary considerations, since the regions under study here are peripheral. Safety and health are not considered, with the exception of health issues related to emissions, since they are aspects mainly associated with technological specifications and requirements of vehicles and thus left outside the scope of this study.

Due to private actors' (i.e. investors' and operators') interests and involvement concerning terminal development and transport system designs, there are obvious economic considerations when locating a terminal. The social and environmental considerations for the affected surroundings, however, are mostly represented by public actors (McKinnon, 1998). Public actors thus have a somewhat different perspective and approach for the evaluation of possible and desirable intermodal terminal locations.

Traditionally, methods for evaluating intermodal terminal locations focus on either economic, environmental or quality aspects, often in exclusion of each other. Weber's theory of location is an example of lowest costs optimisation based on minimising transport cost. Hoover's cost analysis is another example of a cost-oriented analysis, which focuses on transport and production cost factors (Ekenstedt, 2004). Economic oriented approaches can often be extended to imply costs of environmental and quality aspects. However, such cost estimations introduce the need for assumptions and a shift towards cost translation of environmental and quality impacts. Such approaches produce a great risk of arriving at a debate of the translated assumptions used and shift the focus from the core issue of terminal locations.

An evaluation method that can consider economic, environmental and quality aspects simultaneously with few cost translations as possible would facilitate a shared perception and joint platform for decision makers. Consequently, evaluation methods that focus on a narrow scope of aspects may delay the process of developing intermodal terminals.

The field of transport geography offers an opportunity for such a shared point of departure. Geography is something easily understood and agreed by actors and by combining regional geographical information with the regional logistics system, a common platform for regional analyses of intermodal terminal locations is possible. The fact alone that an evaluation method originates from geography is not sufficient. The evaluation method should consider all interests that are important to private and public actors and relevant issues concerning the transportation system. On the basis of geography, a geographic information system (GIS) is the arena for which the evaluation method has been developed.

The aim of this paper is to develop a geographic approach for evaluating locations for intermodal terminals on the basis of economic, environmental and quality considerations with support of GIS. This is explored in a study that concerns the logistics systems in the Skaraborg and Sjuhärad region, located in the western part of Sweden. The approach presented in this paper is developed within this study and tested for the above mentioned regions. The location issue for Skaraborg and Sjuhärad concerns intermodal terminals incorporating rail/road connections. Besides evaluations based on goods volumes and distances, opportunities for evaluating noise effects of different terminal locations are explored as an attempt to include social aspects into analyses of terminal locations and regional logistics systems.

This paper is intended to be descriptive and suggestive rather than formal and rigid. The approach developed presents a 'beginning to end' process that is practical and useful for both private and public actors. Unlike approaches such as that typified by Schniederjans *et al.* (1982), based on goal programming to resolve a site location problem, this paper does not consider quantifiable personal preferences. The approach here is developed to provide as much and accurate information as possible without personal judgements and preferences to enhance the notion of an impartial and factual platform for discussions and decisions about intermodal transport terminals.

Research Settings

The location of a terminal directly affects both regional business and the surrounding environment. The regional logistic system involves many decision makers that are affected by a terminal location. The model developed in OECD (1992) provides an elementary conceptualisation of a transportation system and an opportunity to structure public and private actors' roles. From the actors' perspective, the OECD model captures the most important parts of the logistics system despite the focus on transportation. The model describes the transportation system as consisting of five layers: material flow, transport operation, information operation, transport infrastructure and telecommunication infrastructure. The model has been used (cf. Wandel & Ruijgrok, 1993; Hansen, 2002) as a framework for analysing logistics structures and functions. The layers in the model interact and are the prerequisites for any transport movement. In short, the material flow is consolidated and operated by appropriate means of transportation. The traffic market is where connection is made between vehicle flows generated by transport operations and logistics service providers, and infrastructure capacity, in order to enable transport movements. The coordination and operation of material flows are supported by information exchange using telecommunication infrastructure. The efficiency of the transport system is determined by the efficiency of layers and the effectiveness of the interconnections between layers (Figure 1).

According to McKinnon (1998), there is a diversification of private and public involvement and roles in a logistics system; private interests exist primarily at four levels: logistics structures, patterns of trading links, scheduling of product flows and management of transport resources. Translated into the structure of the transportation system, private organisations traditionally focus on the layers of material flows and transport operation. In short, the private sector generates competition and efficiency at the layers of material flow and transport operation and the public sector can best manage infrastructure due to the scope and scale of investments and responsibilities. Hence, a generalised interface between the private and the public sectors can be identified, today characterised as the traffic market.

In general, close cooperation between private and public actors would improve the interconnections of layers in the transportation system, but in particular the planning processes of terminals would benefit, since a larger scope of interests would be considered and, consequently, friction between actors in the transportation system could reduce. Private actors could benefit from public actor involvement in transport operations through their long-term planning horizon

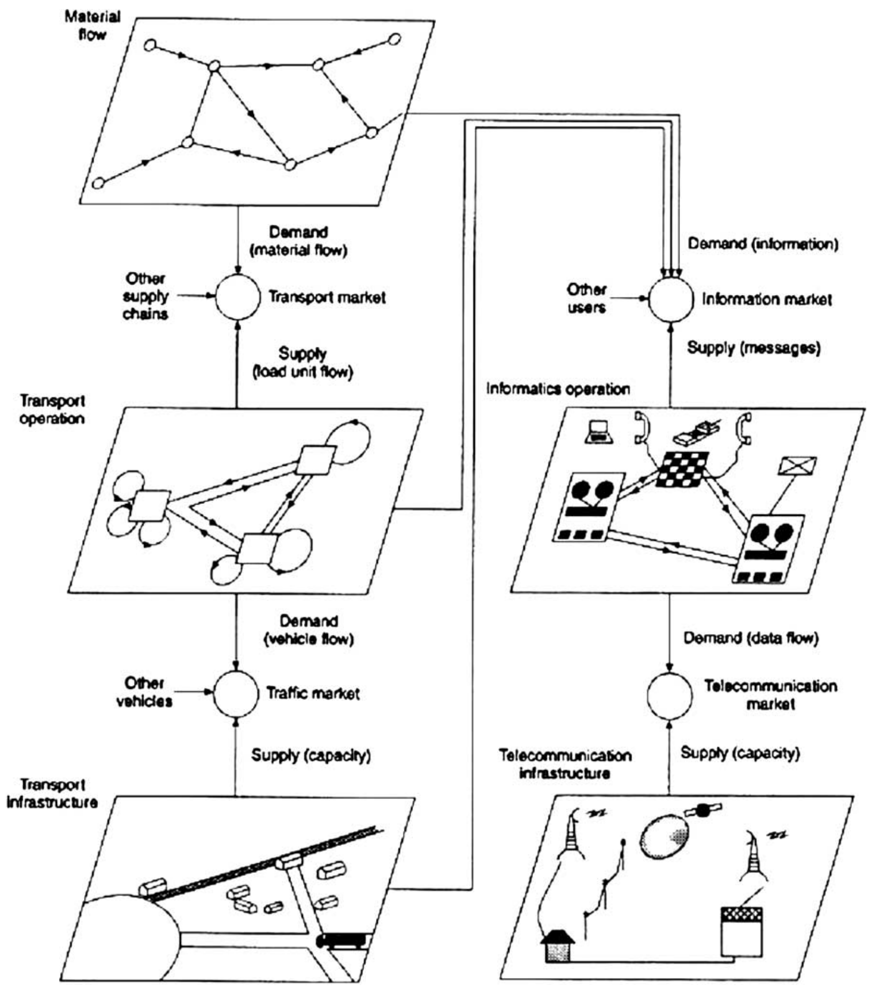

Figure 1. The five-layer model of a transportation system (modified from OECD, 1992)

and social considerations. The community as such, including both public and private actors, would benefit if infrastructure would correspond better to private needs and market development at the same time as sustainability is ensured.

Method

The ambition to evaluate locations on the basis of private and public interests through the combination of material flows and infrastructure puts high stress on the ability to manage data effectively.

The geographical perspective combined with the demand for effective data management was the reason for choosing GIS-T (Geographic Information Systems for Transportation) as the method for modelling. GIS-T emerged in the 1990s (Dueker & Ton, 2000) and is proving to be effective in integrating the data needed for transport modelling and data management (Hesse & Rodrigue, 2004; Bergqvist & Tornberg, 2005). The method has the capability to combine complex transportation systems with special attention to infrastructural prerequisites and it offers great opportunities for visual representation through the use of maps and animations (Barnett & Okoruwa, 1993; Bergqvist & Tornberg, 2005). Mendes and Themido (2004) evaluated different techniques and methods for the purpose of retail site location and found that the unique ability of desktop GIS lies in the integration of spatially related information and performing spatial analysis combined with the ability to produce attractive and informative maps easily.

Since, the research behind this paper is conducted in close collaboration with public and private decision makers in the Skaraborg and Sjuhärad regions, the pedagogical aspects of the approach were important. One important ambition, based on the practical usefulness of the approach, was that is should not only support fractions of an evaluation process but facilitate all stages of the process. The process is here defined by three main stages: data collection, modelling and evaluation (Figure 2).

The stage of *Data collection* concerns the collection and management of data. The stage of *Modelling* focuses on the actual method used for combining variables in order to make comparisons and evaluations. Validation is incorporated as the last activity at the stage of Modelling, with the purpose of spotting the needs of recollecting and remodelling data. Finally, the stage of *Evaluation* deals with the evaluation of different location alternatives according to costs, environmental impact and quality aspects.

Data Collection

The model platform is constructed based on the three components of a transportation system, i.e. material flows, operations and infrastructure, corresponding to three of the layers in Figure 1. Analyses and descriptions of regional logistics systems may require extensive data collection, especially concerning *Operations,* since it consists of numerous qualitative aspects of logistics service providers' behaviours and system designs and logics. To absorb such aspects, multi-sectoral reference committees in both Skaraborg and Sjuhärad were formed. The committees consisted of decision makers that have a substantial part and interest in the regional logistics system, e.g. large

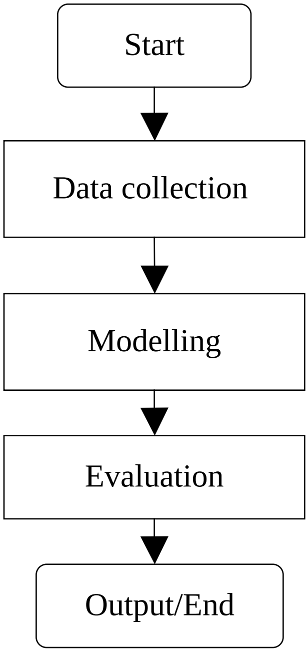

Figure 2. The three-stages of the approach

manufacturing firms, regional governments, etc. The members of the committees assisted in data-retrieval, analyses and they have valuable knowledge of the regional logistics system. Furthermore, the members were an important source for validation and verification. The data collection was based upon variables identified as necessary for describing and analysing the transportation system from a terminal perspective, therefore, it was essential that members from the committee were involved at this stage of the process.

Descriptive Variables

Hesse and Rodrigue (2004) identify two geographical dimension of logistics – time and space. The model developed in this paper has two types of input data – material flow and data related to infrastructure. Besides these geographical dimensions, material flows have physical dimensions that are important from an intermodal transport perspective. The terminal function of interest is intermodal and, therefore, material flows have to be loaded into standardised load units. Since all material flows cannot be loaded into standardised load units, 'type of material' is an important physical dimension. Another physical dimension that is important for the evaluation of terminal locations is size.

The size of material flows makes it possible to combine different workplaces with alternative terminal locations by the use of a distance and volume based measurement, e.g. tonne-kilometers (tonkm). The model presented in this paper evaluates location alternatives on the basis of tonkm and noise effects. The element of time is a variable not included in this approach but it may facilitate evaluations where model logic concerns 'fastest route' or 'cheapest route' instead of 'shortest route'. This paper considers a path principle based on 'fastest signed speed limit'.

The time element also contains many variables derived by shippers' logistics requirements. The time element can be divided into two categories – 'length of time' and 'variation of time'. Transportation lead-time is a typical 'length of time' variable, whereas variables of time-windows are of 'variation of time' character. The 'variation of time' variable seldom takes on a particular value; rather it is measured in terms of intervals, since it is often a tolerance parameter expressed by the shipper. The model developed here only considers inputs in terms of material flows and infrastructure and the chance to reach a near equilibrium of workplaces surrounding the possible terminal locations; therefore, the model intentionally neglects the physical mobile resources necessary for transport as well as aspects of variation in time and length of time.

Data Collection Method

Material Flows

The prerequisite for evaluating intermodal terminal locations in a regional setting is comprehensive and representative regional data of the descriptive variables. The empirical data of descriptive variables is retrieved from a 'mapping' questionnaire. The mapping questionnaire was distributed to actors in the regions perceived as having substantial material flows that could also be co-loaded. This restriction is based upon the assumption that an intermodal solution based on road/rail transport would benefit from large quantities suitable for loading in standardised load units.

The mapping questionnaire population consisted of workplaces with five or more employees in industries with SNI-codes (branch codes) 15–37 (manufacturers) and 51 (wholesaling). These are the industries believed to be of interest for intermodal transport solutions over relatively long distances, i.e. interregional flows. Industries were chosen in such a way that the risk of duplicating material flows is minimised as much as possible. If for example retailers would be included, there would be a risk of material flow duplication between retailers and wholesalers. The choice between wholesalers and retailers was based on the fact that the population of wholesalers is smaller and that wholesalers often manage the interregional flows for retailers. Furthermore, by choosing wholesalers, data will display consolidated material flows instead of material flows that originate from single retailers, which is an advantage for the evaluation, since it only concerns interregional flows.

The response-rate for the population in Skaraborg was 22.0 and 24.1% in Sjuhärad. Intuitively, this data was perceived as not being sufficient for the evaluation of terminal locations. In the falling off analysis of the material flows, there were indications of a correlation between material flow quantities and the size of workplaces. For each workplace, some initial data was available through the general business registry database managed by Statistics Sweden (SCB). To test a regression model between the dependent variable *quantity of material flows* with some initial data such as *number of employees* and *branch* from the database, an imputation model for material flows was developed. A total of four regression models were developed and tested, i.e. two models for each region concerning material flows to and from workplaces. The regression models were tested within intervals of $\pm 2\sigma$ for the dependent variable, i.e. *quantity of material flows*. The same independent variables had to be applied to the model in both regions to support a logical connection and facilitate verification and validation. There were some indications that the workplace's branch affected the quantity of material flows. The dummy variable of the branch *wholesalers* showed significance. However, it did not improve the adjusted R square value that indicates the explanation rate of the model. Furthermore, workplaces within branches 221, 222 (publishers, printing houses, bookbinding) showed significance. These branch related observations were pulled out of the regression model and analysed within the respective branch related sample, i.e. wholesalers and 221, 222, since this branch has unusually small material flows in proportion to the number of people employed. The relatively small amount of material flows was probably also the reason why the population of 221, 222 showed great homogeneity in the amount of material flows. For workplaces in branches 221 and 222, a model based on arithmetic means was applied.

The population of *wholesalers* was categorised into *heavy* and *light* types of sub-branches. A linear regression model could be useful for this sample. However, the number of observations was too small. Instead, a model based on mean values for the two categories was adopted.

The linear regression model analyses for the remaining workplaces had the following results (Table 1).

Table 1. Regression analysis of material flows to and from workplaces in Skaraborg and Sjuhärad

Regression statistics						
	Outgoing goods			*Incoming goods*		
Skaraborg						
Multiple *R*	0.9543477			0.9369964		
R square	0.9107796			0.8779623		
Adjusted *R* square	0.9098502			0.876664		
Standard error	4666.6788			5539.2846		
Observations	98			96		
ANOVA						
Regression	1			1		
Significance F	3.563E-52			1.016E-44		
Coefficiants	*Coefficiants*	*t Stat*	*P-value*	*Coefficiants*	*t Stat*	3.563E-52
Intercept	−246.2471	−0.496350388	0.62078182	−81.123129	−0.1362206	0.8919382
X Variable 1 (employees)	41.418966	31.30473952	3.563E-52	40.877984	26.004875	1.016E-44
Sjuhärad						
Multiple *R*	0.7218473			0.6928467		
R Square	0.5210636			0.4800366		
Adjusted *R* Square	0.5130813			0.4713705		
Standard error	1730.9968			2161.7071		
Observations	62			62		
ANOVA						
Regression	1			1		
Significance F	3.587E-11			4.388E-10		
Coefficients	*Coefficients*	*t Stat*	*P-value*	*Coefficients*	*t Stat*	3.563E-52
Intercept	−141.4343	−0.492959216	0.62384076	−102.91083	−0.2872214	0.7749324
X Variable 1 (employees)	25.412885	8.079454833	3.5869E-11	29.23472	7.4426298	4.388E-10

The regression results were perceived as sufficiently satisfactory for the purpose of supplying imputation of material flow to the workplaces that did not answer the questionnaire. After the regression models were developed, a random sampling analysis was conducted based on the response missing workplaces to ensure that there was no divergent connection between number of employees and the quantity of material flows. From the interviews with and the analysis of about 20 workplaces, the results indicated that there was no divergence compared to the sample used in the regression model. Another important observation from the regression analysis is that the intercept in all four models was negative. This is, of course, impossible in reality. However, the population only consists of workplaces with more than five employees and because those workplaces had a mean value of seven employees, if they are in the category of 5–9 employees, the model behaves realistically in the sense that it does not produce negative material flows after imputations. It is possible to 'freeze' the regression analysis by setting the intercept at zero. This could be a good idea if the absolute value of the observed *t*-value for the constant is less than the critical *t*-value (for Skaraborg and Sjuhärad critical $t = 12{,}7$ with 95% confidence interval). Since the observed *t*-value for the constant is less than the critical *t*-value in this case, one may conclude that, statistically speaking, the constant is zero. However, if we force the constant to be zero, the value of material flows for workplaces in the interval of 5–9 employees would create too large an amount of material flows, since the independent variable of employees is an interval based variable. Thus, forcing the constant to be zero would have undesirable effects on the logical quality of the model. Once more we would like to stress the fact that the regression models are only tested and validated for five or more employees.

After imputation to the missing population, the total amount of material flow quantity for the Skaraborg region increased from 3.7 million tons to 5.3 million tons. The increase for Sjuhärad was from 2.6 million tons to 3.7 million tons. The initial material flow quantities in both regions were about 70% of the total material flow quantity after imputations. An interesting observation is that the response rate was 22 and 24%, respectively. However, in terms of material flow quantity, the coverage was 70.0 and 70.3%, respectively – the explanation being that larger workplaces were more willing to participate by completing the mapping questionnaire. As an illustration, the response rate for workplaces with 100–199 employees was 36.7% for Skaraborg and 40.0% for Sjuhärad, whereas the response rate for workplaces with 5–9 employees was 17.4% for Skaraborg and 13.9% for Sjuhärad.

For descriptive variables of 'type' character, the mean values were applied since there is less diversification of responses, and hence no logical connection on which to conduct a regression analysis.

The last step in the process of collecting data concerning material flows was to transfer the data of workplaces to a geographic position. This was made by geocoding individual addresses of workplaces to a map. Geocoding is a method for applying geographic coordinates to data based on geographic land records, e.g. zip codes and addresses.

Infrastructure

Concerning infrastructure, GIS effectively stores and manages topologically structured geographic data such as transportation networks, which is an advantage when calculating, for example, route-systems. The ability to manage a topologically oriented database is a capacity to structure data hierarchically, which is a necessity, since we combine different transport infrastructure networks in the model, i.e. road and rail.

There are software packages available for managing topologically structured data, e.g. ArcInfo Workstation from ESRI Inc. The transportation networks, later transferred into the model, are based on the commercial transport infrastructural database TeleAtlas, constructing the geometric network with links and nodes and the logical description of link directions (Zeller, 1999).

TeleAtlas contains impedance information, such as link travel time and bearing capacity of infrastructure on each link, thus, enabling calculation of the maximum flow capacity of specific links. This information can be connected to the Swedish Road Administration's (Vägverket) 24-hour data of vehicles utilising specific links, thus creating time-related impedances. When impedances reach predetermined levels, the model logic can modify either the speed limit on infrastructure or change the speed capabilities of the mobile resources that utilise the affected link. For example, the number of vehicles on a specific link and time can determine the level of impedance and through predetermined levels in the model logic, the speed limit of those specific vehicles can be adjusted accordingly. Since the studied regions have relatively low-density traffic systems, the noise analysis indicated that at worst only a few, about a dozen inhabitants, would be affected. With that small numbers, specific landscape features and natural barriers have greater impact. Therefore, those results are not accounted for in detail.

With data being as comprehensive and representative as desired, an integrated approach for evaluating terminal locations can be used. The layer of *Operations* has not been dealt with in this section, since it is regarded as the interconnection between *Material flows* and *Infrastructure* and, therefore, it is represented by model logic, and hence, the next section deals with the aspect of interconnection, i.e. *Modelling*.

Modelling

In each region, there are a number of available locations for an intermodal terminal, which the approach evaluates on the basis of costs, environmental impact and quality. Initially, areas in connection with rail infrastructure are divided into cells of 600×600 meters. These cells are constructed so that they have a large enough area to contain an intermodal terminal. The exclusion of cells is based on the presence of buildings and the absence of road infrastructure in the cell. The existence of building is checked by investigating the existence of day and night population in cells. Figure 3 displays the possible location alternatives for the Sjuhärad region. As can be seen from the map, the region is located near the city of Göteborg. The distance between the city of Göteborg and the largest city in the Sjuhärad region, Borås, is about 65 km.

After the exclusion, evaluation of goal variables for the different cells is carried out. For the cost estimate, a weight-distance calculation is made, i.e. tonkm. Distance is one dependent variable in routing but there may be several, for example, shortest (length), fastest (time) and/or cheapest routes (Barnett & Okoruwa, 1993). There are several algorithms that can find the least-cost path through a network. One of the best known algorithms is generally credited to Djikstra (1959), and it was used as a solver in this analysis. The Djikstra algorithm is a so-called greedy algorithm, which means that the choice of a mathematical local solution also results in a global solution (cf. Grimaldi, 1994). Material flow paths are created in the model using the Djikstra algorithm and a principle of effective time, i.e. fastest signed speed limit on a link.

The issue of environmental impact consists of two components: emissions and noise. Emissions are almost linear to transported distances and transport time. Noise is an environmental impact not measured in scale but in scope, i.e. it is not only the amount of noise that is of utmost importance, but rather the extent of noise impact during a certain period of time. The scale aspect of noise is typically managed by vehicle-construction regulations and is not regarded in this study. The extent of noise in the model is managed by tracking the amount of vehicles, the speed limits, distances to inhabitants from roads and the number of inhabitants passed on the way to and from a terminal. Different location alternatives can thereby be evaluated on the basis of noise impact on inhabitants in the region. This analysis is possible by the use of a detailed database from SCB (Statistics Sweden) containing information on population density and property notation combined with a table of decibel values developed by the Swedish Road Administration (Vägverket) for noise analysis purposes. The table combines impedances, speed limits, share of heavy traffic and distances from road centre to inhabitant. The algorithm developed for calculating noise effects is similar to that of Upchurch *et al.* (2003). The algorithm developed here calculates straight line distances between the traffic links in the transport network and inhabitants by constructing buffers. Buffering is a technique that permits a designated area along a link, e.g. road to be added spatially to a map (cf. Barnett & Okoruwa, 1993). Buffers combined with the impedances of nearby links create a platform for retrieving a measurement of the sound level from the table developed by the Swedish Road Administration. If the sound level for an inhabitant exceeds 65 dBA, the sound is believed to be disturbing according to Swedish standards. This algorithm enables an evaluation of the number of inhabitants affected by noise for different terminal locations. This particular algorithm was developed using ArcInfo, but it

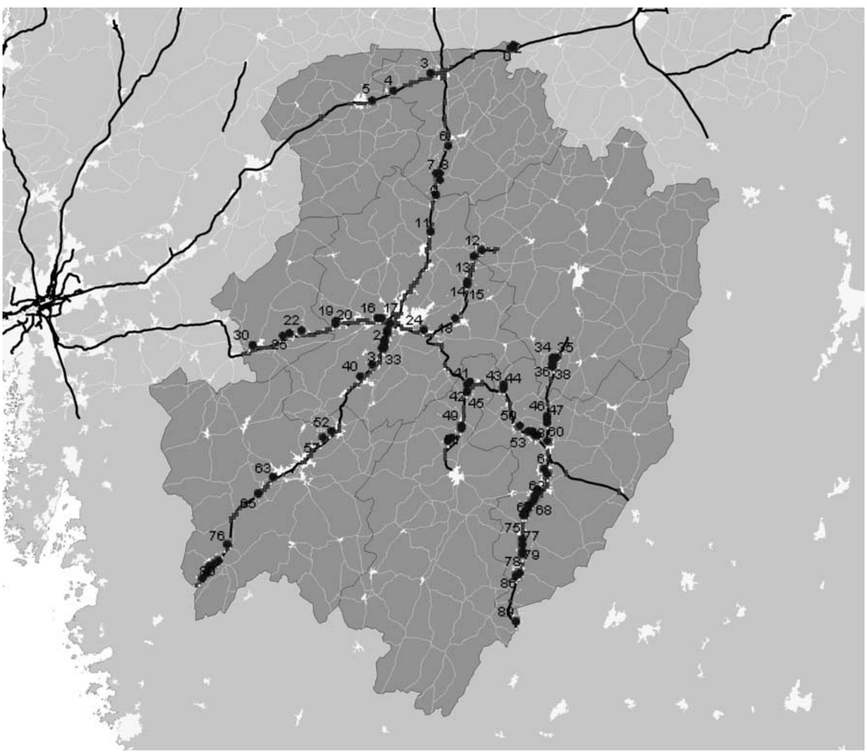

Figure 3. Possible terminal location alternatives in the Sjuhärad region

should be possible to implement the algorithm in other full-featured GIS software packages.

The element of quality in the logistics system is evaluated on the basis of throughput-time for material flows. The transport time for each material flow combined with the size of material flows offers an opportunity for evaluating the quality aspects in element of total throughput-time. Each location alternative can then be evaluated on the basis of total throughput-time for the transportation system. For the approach developed here, the location that produces the least tonkm is also assumed to provide the highest quality of service related to time considerations. This is based on the assumption that rail and road vehicles travel about the same speed.

Evaluation

An analysis of the material flows to and from workplaces in the regions with different terminal locations is not sufficient. When using a terminal, material flows will be transported using a different transport mode, namely rail transport. The rail transport can be evaluated and analysed in mainly two ways: it can be compared with the current situation of road transport operations or it can be analysed in comparison with other possible terminal locations. We chose the latter. Since the main rail infrastructure links in the regions realistically (based on capacity and status) only enable material flows to be transported either in an eastern or western direction, possible terminal locations can be compared with each other, since they will differ in distance to the destination. If material flows are divided into western and eastern destinations, terminal locations will differ in tonkm despite having the same amount of material flows utilising the terminal. However, they also differ in the tonkm produced by road transport. The difference in tonkm by rail and road cannot be directly compared, since the modes of transport have different structures in costs and environmental impact. To be able to compare tonkm of road with rail, cost estimates are required. The next sections account for the estimations made here and the result obtained from the model runs for Sjuhärad and Skaraborg.

Sjuhärad

Table 2 displays the cost calculations made in the case of Sjuhärad and the results obtained from the analyses.

The estimated cost per tonkm for rail is 0.081 EUR (1 EUR: 1.57 USD). For the Sjuhärad region, 80% of the material flows have western destinations, about two million tons. With the right circumstances and a market share of more than 10% of the western material flows, this

Table 2. Results from the analysis of the most favourable locations in the Sjuhärad region

ID	tonkm road	Difference %	Diffrence tonkm	Diffrence EUR	
6	90824589	28.1%	19932497	2022993	
11	**70892092**	**0.0%**	**0**	**0**	
18	79318494	11.9%	8426402	855214	
17	81829437	15.4%	10937345	1110055	
40	103339738	45.8%	32447647	3293183	
48	116126607	63.8%	5234515	4590951	
	Distribution	Tonkm	Difference		
West	80%	2141666			
East	20%	535417	1606250		
Comparison	Distance (km)	tonkm (west/east)	Difference tonkm (road+rail)	Difference (EUR)	
17–11	**8**	**−12849998**	**−1912653**	**51564**	
17–18	6	−9637499	−7126556		−527473
18–11	2	−3212500	5213902		579037
Comparsion	17–11	17–18	17–11		
Breakeven	**0.08**	0.03	0.26		
Rail	Road				
0.081	**0.099**				
Ton	**Units (20f)**	**Cycles/year**	**No. of wagons**	**Cycle length (or)**	**EUR/tonkm**
20,000	1312	50	13	150	0.0868
20,000	1312	100	7	150	0.1041
20,000	1312	200	3	150	0.1221
50,000	3280	50	33	150	0.0798
50,000	3280	100	17	150	0.0869
50,000	3280	100	17	150	0.0869
50,000	3280	200	9	150	0.1011
100,000	6562	100	33	150	0.0801
100,000	6562	200	17	150	0.0875
200,000	13,124	100	66	150	0.0775

may be sufficient for the construction of a 10,000 TEU rail shuttle service heading west. One effect of combining road and rail transports is that location 19 (ID) enhances its relative position towards other locations in the eastern parts, since it decreases the distance of rail transport. However, this advantage does not counterbalance the disadvantage concerning road transport that location 19 has compared with more eastern locations, such as 11, 17 and 18.

In the case of a rail shuttle with a western connection, the result is that location 11 is the most favourable location alternative. The advantage is about 51,500 EUR on a yearly basis compared with location 17 and about 580,000 EUR compared with location 18. With such a small advantage, it is important to further point out the influence of other more qualitative aspects and factors. Figure 4 below shows a circle in which the most efficient locations are situated.

The most efficient terminal locations with regard to both road and rail transport are within the highlighted area around the region's largest city, Borås.

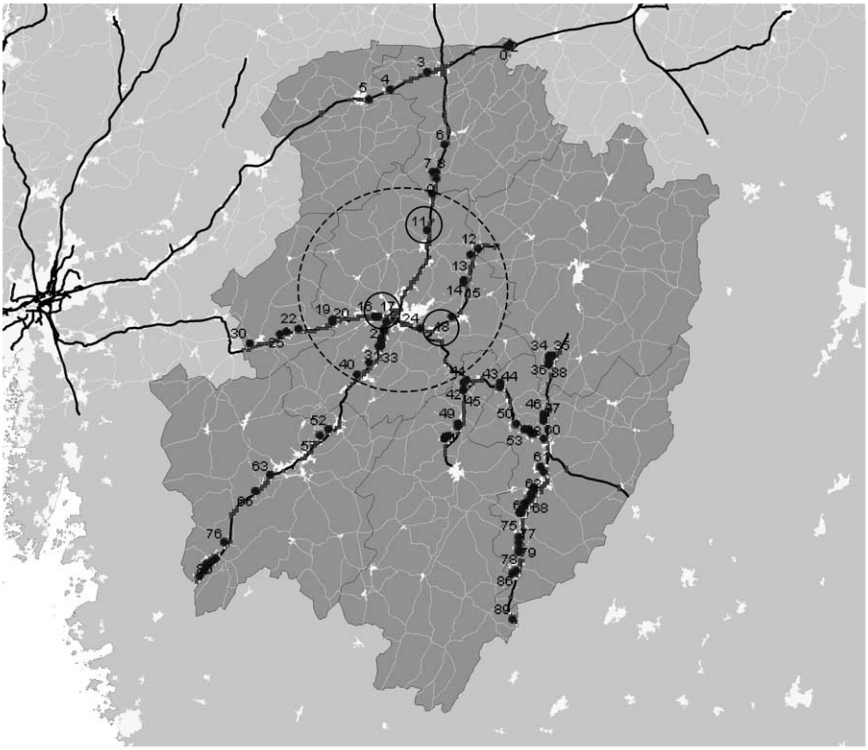

Figure 4. Visualisation of the region, rail infrastructure and the area in which the most efficient terminal locations are situated

Finally, a number of sensitivity analyses were conducted to examine how the results are affected by different courses of action and scenarios. The main scenarios tested concern the situation in which the largest workplaces in terms of material flows will not consider using an intermodal terminal solution. In the case of Sjuhärad, there is a large manufacturing company about 10 km from the city of Borås, close to location 11. They have an annual amount of material flows of about 550,000 tons. The involvement of this workplace will greatly affect the location of the terminal. Without that large manufacturing company, locations 17 and 18 would be almost five million tonkm more efficient compared with location 11. Location 17 would then be the most efficient location. In the case of Sjuhärad, there are, however, other large workplaces that, in the case of absence, would compensate in such a situation.

To sum up, the quantitative analysis suggests that the most efficient locations are close to the city of Borås when analysed in terms of costs, environmental impact and quality. The most efficient location around

Borås is difficult to decide when the differences between possible locations are so small and the fact that minor changes in the logistics system would largely affect the results. The analysis, however, indicates a circle around Borås with a radius of 10 km.

Skaraborg

The situation is similar in the Skaraborg region. However, the differences between locations are greater (Figure 5).

The same cost estimation is applied for the transportation system in Skaraborg. The most efficient location is 24,519, which is the city of Falköping. Location 24,519 is about 4.2 million EUR more efficient on an yearly basis than the next best location. The Table 3 below shows the result obtained for Skaraborg.

The sensitivity analyses mainly concerned the situation of Volvo's large vehicle manufacturing plants in Skövde. The material flows of Volvo account for about 7% of the total material flows in the region and a sensitivity analysis of those material flows being absent is valuable. The distance between the Volvo plants in Skövde and location 15,421 is about 2–5 km depending on the choice of road. In

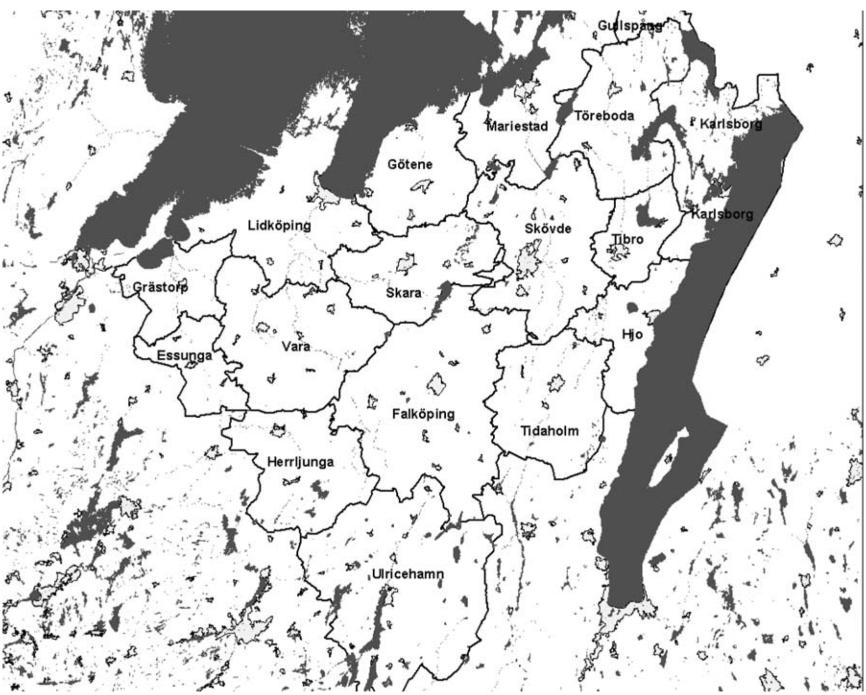

Figure 5. Visualisation of the Skaraborg region and the accounted locations

Table 3. Results from the analysis of the most favourable locations in the Skaraborg region

ID	tonkm rodad	Difference %	Difference tonkm	Difference EUR	
3937	268536015	76.1%	116030806	11778042	
15,421	152505209	0.0%	0	0	
24,519	178921417	17.3%	26416209	2681453	
	Distribution	Tonkm	Difference		
West	80%	3564047	0.0000		
East	20%	891012	2673035		
Comparison	Distance (km)	tonkm (west/east)	Difference tonkm (road + rail)	Difference (EUR)	
3937	43	114940522	230971329	31820392	
15,421	0		0	0	
24,519	**32**	**−85537133**	**−59120924**	**−4216702**	
Comparison	15,421–24,519				
Breakeven	**0.0307**				
Rail	**Road**				
0.081	**0.099**				
Ton	**Units (20f)**	**Cycles/year**	**No. of wagons**	**Cycle length (one year)**	**EUR/tonkm**
20,000	1312	50	13	150	0.0868
20,000	1312	100	7	150	0.1041
20,000	1312	200	3	150	0.1221
50,000	3280	50	33	150	0.0798
50,000	3280	100	17	150	0.0869
50,000	3280	200	9	150	0.1011
10,000	6562	50	66	150	0.0773
10,000	6562	100	33	150	0.0801
10,000	6562	200	17	150	0.0875
20,000	13,124	100	66	150	0.0775
20,000	13,124	200	33	150	0.0807

such a case, the effects of Volvo not using the terminal would lead to a decrease in road tonkm from 26 to 21 million. Since the distance going west increases for 15,421 when compared with 24,519, such absence would further enhance the advantage of 24,519, i.e. from 2.6 to 4.2 million annually. An important observation, however, is that it is unlikely that Volvo would use the intermodal terminal if it was located far from the plants and since Volvo has substantial amounts of material flows, the market for intermodal transport would decrease considerably. A possible solution, seeing that Volvo has a rail track connection to their plant, would be that a rail shuttle could begin at the plant and then continue towards the terminal. Another aspect that may affect Volvo's choice of participating is that all major logistics strategies are managed by Volvo Logistics, a subsidiary of the Volvo Group, and central negotiation may obstruct regionally oriented solutions since solutions can be considered to be unfavourable strategic bound circumstances.

Concluding Remarks and Further Research Issues

From the application of the approach to the studied region, there are some important case related conclusions. One of the most important advantages of the approach has been from a credibility perspective. A major contributor to credibility is that the approach focuses on physical prerequisites that are geographically oriented, e.g. such as source and sink. These are components in the approach that actors put great confidence in. Furthermore, demands from infrastructure planners concerning detailed data, information about traffic impacts and noise impact can be integrated into the approach successfully. This is especially useful concerning analysis of high-density areas. Despite the geographical and infrastructural focus, market oriented demands from private actors are also considered. Geographical position, material flow characteristics and market dynamics can be displayed. Material flows from workplaces are geographically positioned and analysed on the basis of intermodal transport capability. Market operations as displayed in the model of the transport system are considered on the basis of cost efficiency of transport solutions so that both intraregional and interregional material flows are taken into account in a realistic manner.

In summary, we believe that the approach developed in this paper provides an interface that constitutes an opportunity for private and public actors in the logistics system to interact and evaluate intermodal terminal investments from a more objective and integrated perspective.

Besides the evaluation process, the approach has been adjusted to a large extent to the process of retrieving data and the availability of data and, in that sense the approach is highly pragmatic.

As a logical extension of the approach, the practical implementation of a terminal, hence, is a great opportunity for further research concerning the demand for qualitative analyses of the establishing process. This issue requires knowledge about the process of locating, financing and implementing an intermodal terminal. A longitudinal study of the process in action would be of great value, because aspects of conflicts, rationality, emotions, considerations, power, and personal feelings, etc. could be identified and possible pitfalls avoided in the future.

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