Economic loss estimation along transportation corridors

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Unscheduled events may have sudden and significant impacts on the economy of a region (see figure 1). The damage to the production facilities and lifelines may spread across boundaries of regions or even countries via inter-industry relationships and can have serious economic impacts on other regions. The estimation of the damage of a disaster plays a role in risk assessment and it is necessary that all damage is included to provide a complete analysis of the consequences of a disaster. My master thesis gives an overview of existing loss estimation models and presents a method to estimate the economic loss of a temporary disruption of the infrastructure.

Damage incurred as a result of an unscheduled event can be classified in tangible loss (monetary terms) and intangible loss (relative value). Tangible damage can be further classified in direct and the indirect damage. Direct damage may be thought of as a loss in asset value, whereas indirect damage can be considered to be the loss of income and/or production and impacts on the environment that cannot be readily stated in monetary terms (see figure 2). In this research, economic loss is refers to

Figure 1.

"The economic loss as a result of the disruption of the infrastructure is 4,3 million Euro per day"

1) the direct losses of the increase in transport costs due to damage to infrastructure
2) the indirect losses of the loss of trade through inter-industry links.

Theoretical framework

This research defines a method that combines the transport and economic system in order to estimate economic loss as a result of an unexpected event. The approach is based on the Input-Output approach and the classic four-step transport model.

Transport system

The transport model is useful in forecasting the load of the flow, both passenger and freight, on the network and in estimating changes in the network or transport modes. The freight and passenger transport will be modelled with the classic four-step model. The major advantage of this model is that it classifies the four main decisions 1)will I make the trip 2) where do I go 3) Which transport mode will I use and 4) which route will I take, in sub models. The answers of these questions are given in trip generation, distribution, modal split and assignment, respectively. The classic four-step model will be used in loss estimation, because it provides the load on the network and gives insight in the importance of a road in the network.

Economic system

The basis of the economy of a region is the circular flow, which represents the relationship between the households and firms in an economy. The literature describes several methods that describe the economy of a region, examples are the Input-Output (I-O) and the Computable General Equilibrium (CGE) approaches. The I-O approach is a commonly used method that quantifies systematically the interrelationships between the sectors of an economic system. The method quantifies systematically the interrelationships between the various sectors of an economy system. The system may be as large as a nation or even the world economy, or as small as the economy of a region or even an enterprise. The size of the economic system does not affect the approach. It is a recognised tool to reflect the circularity of flows within an econo-

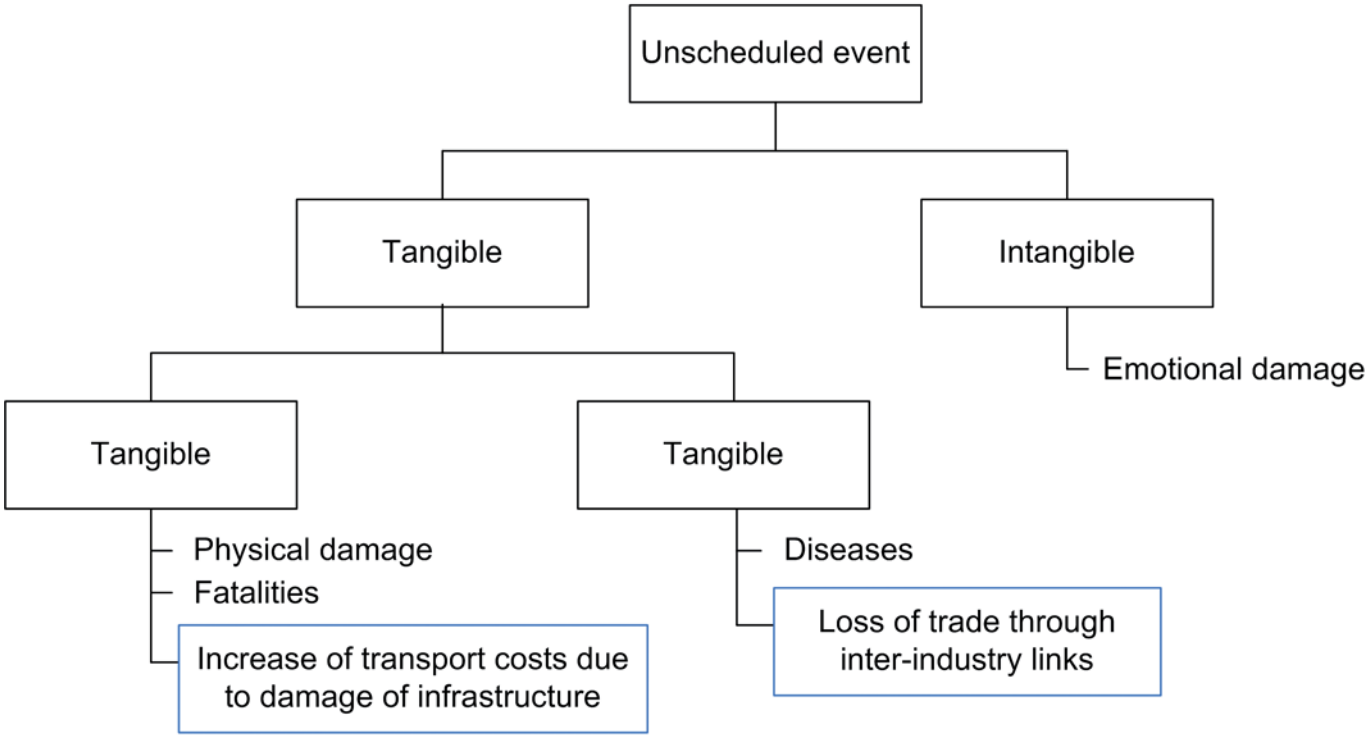

Figure 2.

my. In this system, each industry (denoted A, B, and C in figure 3) produces some amount of output. Part of this output will be used by the same industry for its own needs. Another part of the output will be trade between the other industries for their production needs. This flow of intermediate goods between the industries can stream in both directions. The final part of the output produced by each sector is allocated to the final demand categories, such as consumption, investments or exports. Last, the final demand categories are supplying labour and capital back to the productive industries, which closes the input-output circle of flows.

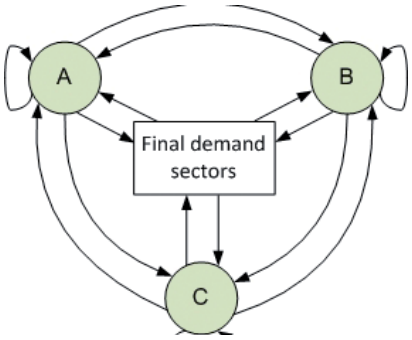

Figure 3

Transport costs

The transport costs play a role in both the economic and the transport system. The transport costs can account for 20% of the total costs of a product, which means that an increase of these costs will cause an increase in the total costs. Empirical evidence underlines that a rise of 10 percent of the transport costs causes a reduction of the trade volumes of more than 20 percent. Within the transport model the transport costs play a role in trip distribution and modal split. Trip distribution is based on the distribution function, which is a cost function and represents the willingness to pay for a certain distance. Modal split is based on

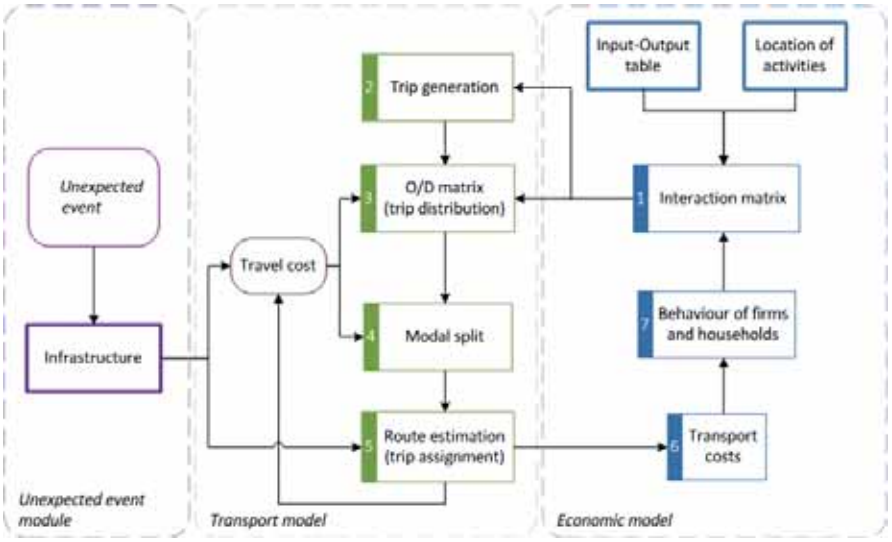

Figure 4.

the utility function of a transport mode which included the transport costs of that mode as well.
The main causes of a variation in transport costs can be divided in variations in transport demand and in (capacity) supply. A second distinction can be made between generic and specific factors. In case of generic factors, the influence of these factors is stretched over a large network (e.g. country), specific factors have a local influence (e.g. around one destination or road). A variation in transport demand can cause more traffic on the roads and this can result in another route for the trip with a longer trip length, but that will go faster than go via the congested route. A variation in the capacity of the roads can result from a closure of a road because of the weather (e.g. mountain passes because of snow) or because of an accident (e.g. tunnel). An unscheduled event can be classified as a specific factor that affects the capacity of the roads and will cause a variation in the transport costs. The variation in transport costs of a product can cause a shift in the supply or demand of the product.

The economic loss estimation method

The framework for estimating economic loss due to a temporary disruption of the infrastructure is based on the classic four-step transport model and the economic Input-Output approach (see figure 4). The input for the model is the Input-Output table, the geographical dispersion of the activities, and the existing infrastructure in the region. During the steps of the model, the original Input-Output table is distributed over the network and the routes between the activities are estimated. The aim of this is to obtain the value of each road in the network, i.e. the importance of the road. If the infrastructure is temporary disrupted as a result of an unscheduled event, the method makes it possible to estimate the economic loss of the region. If alls steps of the method are executed, the system is in its long-run equilibrium. The disruption of the infrastructure creates a change in behaviour of households and firms and will cause a change in the transport model and therefore on the transport costs. It is assumed that the geographical location of the activities remains the same during the disruption of the infrastructure, and that migration of people does not depend on the disruption, i.e. the land-use does not change.
Travel costs given in distance are represented on two places in the framework, in the transport model and in the economic model. In the transport model, travel costs are the input for the distribution function to estimate the Origin-Destination matrix, and for the utility function to estimate the modal split of the trips. The trip

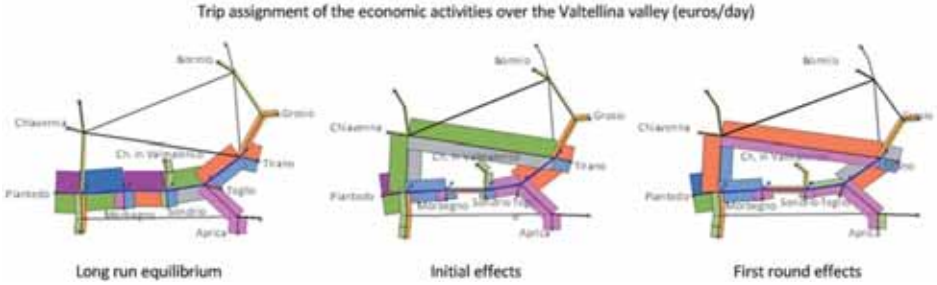

Figure 5.

assignment results in travel costs for each trip over the network and is equal to the variable part of the total transport costs of a product or person. These transport costs exists of fixed costs (e.g. depreciation of the vehicle, insurance, maintenance) and variable costs depending on the distance a person of product is transported (travel costs).
Equilibrium is reached when the Input-Output table is geographically distributed over the region, the steps of the transport model are executed and the value of the transport and production costs is estimated. The households and firms will not react on the production cost, because these are connected to the data of the Input-Output table of the region. From the long-run situation, the distribution of the outputs of the agglomerations of the activities is estimated and the value of road in the network is known. The corresponding transport costs of the trips are known and serve as the reference value for the situation during the temporarily disruption.

Economic loss estimation of a temporary disruption of the infrastructure

The basis of the estimation of initial effects is the situation before the unexpected event. As a result of the event the infrastructure will be temporary disrupted, to what extent depends on the resilience factor of the infrastructure. The disruption has two initial effects on the transport system:
1) The infrastructure of a transport mode (e.g. road, rail track) is damaged, which means trips need to be made with other modes that are still intact.
2) Trip makers need to choose another route, because a link in the route is not available as a result of the unscheduled event.
The initial effects assumes that the Origin-Destination remains the same as before the event, which means that the economic activities will be assigned to the available transport modes and routes. The value of the effects depends on the location of the disruption and the seriousness of the disruption. Because of a shift in the route assignment and transport mode, transport and production costs of the activities will change as well.
The firms and households will react on the change in transport costs and change their behaviour. The effects of an unexpected event can have influence on their final demand function. In the case of a disruption of a lifeline it is likely that the consumption will decrease as a result of an increase of the transport costs, which means that the final demand function decreases. The decrease of the final demand function means that the gross output of the region will decline and will affect the interaction table which was estimated in step 1 of the method. To estimate the economic loss of the first round effects of the disruption of the lifeline, the seven steps from the method need be followed again with the new interaction matrix. After the first round, the economic system will react again on the change in transport costs, which means that the households and firms will react on the new transport costs and the effects will work through the system until they are negligible. The total economic loss equals the increase of the transport costs and the decrease of the gross output of the region.
The method has been applied to analyse the economic loss of a landslide, with hypothetical scenarios in the Valtellina valley in Italy. A scenario is a landslide between Morbegno and Sondrio which causes a temporary disruption of the road, but does not disrupt the rail track (see figure 5). The economic loss as a result of this disruption of the infrastructure is 4,3 million (see figure 6).

Million Euro/day	Direct	Indirect	**Total**
Business	1,4	0	**1,4**
Wages	0,3	0,4	**0,7**
Consumption/Tourism	0,9	1,3	**2,2**
Total loss			**4,3**

Figure 6.

Conclusion

The proposed method gives more insight in damage estimation because it distinguishes economic loss in direct loss which is the increase of the transport costs and indirect loss which is the decrease of final demand and gross output of the economic sectors in the region. Furthermore it can be used as a tool for risk analysis and prevention efforts for unscheduled events. Examples are the assignment of vulnerable spots in the region and the prevention of the economic vulnerable infrastructure in the region.