MEASURING TOTAL RATHER THAN PARTIAL RETURNS TO HIGHWAY INVESTMENTS: THE USE OF AN ECONOMIC EQUILIBRIUM CONCEPT

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ABSTRACT

Traditional evaluation of highway investment plans focus on measured benefits weighed against costs, with travel time saved being the primary measure of benefit. This benchmark makes intuitive sense but in practice it can lead to a bias towards areas with already high concentrations of infrastructure and economic activity and away from those with low development and transport availability. Moreover, some of the great infrastructure investments of the past, e.g., large 'greenfield' highway arterials in countries such as the US, would most likely have failed a standard benefit-cost test in advance, yet proved to be economically synergistic in their ultimate results.

This paper will take a different approach, using measurement of economic return to proposed EU TENS Corridors, with a focus on Corridor 8 running through southern Italy into the Balkans. Rather than focus merely on traditional benefit and cost measures, which, it is argued, are measures of partial returns, this study will use a framework of assessing changes in economic equilibrium which are caused by proposed investment plans, a much more general measure of impact. In fact it will be argued that traditional measures often miss, negatively and positively, impacts that an equilibrium approach will capture and thus bias investment decisions, especially those for large scale projects (Colonna et al., 2005).

One equilibrium state that may often apply in large scale investment plans, is the so-called Nash Equilibrium. Instead of treating highway investments as situations where agents react to exogenous prices ("dead variables"), their decisions can be treated as strategic reactions to other agents' actions ("live variables") and, in the Nash case, agents do better to come up jointly with cooperative solutions rather than independently arrive at competitive solutions which will be ultimately suboptimal. Such equilibria are argued to be typical in transport settings and seem to apply especially in Corridor 8.

Keywords: Transport Investments, Benefit-Cost Analysis, Nash Equilibrium, Nash solution, Nash Question, EU TENS Corridors

1. PARTIAL AND GENERAL EQUILIBRIA IN TRANSPORT PLANNING

The traditional modern method of evaluating transport investment is benefit-cost analysis. The basic idea is straightforward enough: if the social benefits of a project are larger than the social costs, then the project will add to the society's overall resources, and the project should be undertaken. If the reverse holds, then the project subtracts from total social resources, and the project should not be undertaken, at least on economic grounds.

The theoretical basis of benefit-cost analysis can be better understood by using a diagram of a simplified economy. Two aggregate supply curves and one aggregate demand curve for transportation are thus pictured in Figure 1.

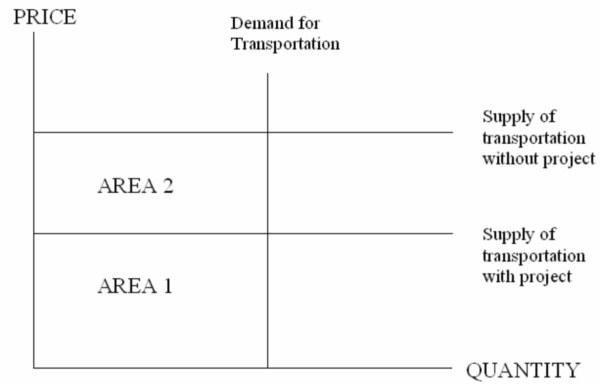

Figure 1: simplified aggregate supply and demand curves for transportation

For simplicity, the transportation supply curves are horizontal, the transportation demand curve, vertical. There are two supply curves: the supply of transport available in the presence of the project and the supply of transportation when the project is unavailable. The amount spent on transport is equal to the appropriate price times quantity. With the project available, the amount spent on transportation equals area 1. Without the project, the amount spent on transportation equals area 1 plus area 2. The social saving, that is, the resources which the project frees up for social uses other than transportation, is equal to the resources which would have been spent on transport without the project minus the resources which are spent on transport with the project. It should be clear that this difference is area 2.

It should be clear that this is what economists refer to as a partial equilibrium analysis. Only the market for transport, and the effects of changes in that market on the overall economy, is being considered. The various ripple effects that transport projects have, for better or for worse, on markets outside of transport, are not considered in this approach. So, for example, a transport project might involve technological innovations or improvements that have applications beyond its particular application in a particular transport setting, and those applications will not be captured in this partial equilibrium analysis.

Economists have obviously thought a lot about this particular problem and the academic literature (though not so many actual project analyses) contains quite a few examples of what is called general equilibrium analysis (Hey, 2003). General equilibrium analysis looks at how a particular investment will affect not just the immediate market in which it takes place but also all other related markets. A fuller analysis will then look at second-round and third-round effects. Such analyses are complex and subject to many assumptions but are conceptually closer to what actually happens in a real-life economy.

2. STRATEGIC AND HUMAN FACTORS

The argument presented here, however, will go a step further conceptually. Instead of treating highway investments as situations where agents react to exogenous prices ("dead variables"), which is what partial and general equilibrium analysis does, their decisions can additionally be treated as strategic reactions to other agents' actions ("live variables"). People are making decisions in the end and people acting in groups often act quite differently than people acting singly.

The equilibrium of benefit-cost analysis is partial not just in the sense of isolated markets but also in the sense of abstracting away from real-world factors such as human politics, human institutions, and physical space. Of course any theory or model requires simplification and abstraction, so this observation is not offered as a criticism of benefit-cost analysis per se. However these aforementioned factors often (if certainly not always) can play a significant enough role in consideration of potential highway investments that they require some consideration.

Let's consider a hypothetical, but 'realistic' situation: an agency situated in a political state that is responsible for making a decision about a particular proposed highway corridor project. There is a neighbouring country that could be significantly affected by the project. The agency must now consider design of the project and it adjusts its design according to whether the project passes the benefit-cost test.

We can see a number of potential pitfalls that the agency could fall into when it conducts its analysis. First, will the agency consider all the relevant economic impacts of the project? And, a closely related question, will the agency consider all the relevant parties to those impacts? These may, some might argue, collapse into a single question, i.e. the first one. But it will be argued here that the second question takes into account those 'live' variables mentioned at the start of this section and these 'live' variables need explicit and separate attention.

Putting this in economist's terms, we have to consider all the relevant utility functions in forming the problem at the outset and then have to consider all the relevant utility functions when considering what the final impact of the proposed solutions to that problem are (in this case a particular highway project). Although an aside here, this issue will get fuller explanation in later sections of this paper. It must also be noted that this is why some economists would argue that the two problems noted in the previous paragraph collapse into one, for everything comes down to the relevant utility functions; but that distinction between utility *before formulation of the problem* and *after a specific solution is carried out* is actually quite critical and perhaps hints at the nature of the two problems.

So this single agency in a single country can potentially make two mistakes. One mistake could be referred to as *horizontal exclusion*. This refers to a situation where the agency ignores relevant decision-makers and affected parties in the adjacent territory outside its political jurisdiction. The other mistake can be referred to as *vertical exclusion*, and this refers to the single agency ignoring relevant decision-makers and affected parties 'below' (and conceivably 'above') its relevant jurisdiction (or perceived brief) as an agency. These concepts parallel those of horizontal equity (all people in the same stratum treated equally) and vertical equity (all people across all strata treated appropriately with respect to relative burden), except we can say that we are referring horizontal and vertical *efficiency* in this case.

These questions are critically important and can be especially prone to occur when there are close but politically separate neighbours and when formal political institutions are prone to change over time. Thus political leaders can and do change and in some cases even political, and certainly jurisdictional, borders may shift. The question is of greater importance if there is an interaction caused by technological, economic or political reasons. In all of these cases it is evident that we can have competitors able to influence on decisions made by this agency and the biases of those competitors may lead traditional BCA to fail. Putting it in economic terms once more, the potential for 'strategic' behaviour will be quite high and traditional BCA tends to ignore the influence of such behaviour.

In general we can say that the more that the conditions of the territory where new infrastructure will be placed differ politically and economically with respect to their adjacent territories, the more that traditional BCA is likely to fail. Examples of such situations are new investments made in East Germany in 1990 and in Eastern European countries before, during and after the EU enlargement; the use of upstream water resources (e.g. Turkey with respect to Syria and Iraq); infrastructure financed by other governments in a politically foreign jurisdiction (e.g. new transport infrastructure in Iraq or Afghanistan that was financed and designed by the USA, UK or Italy); and so on. Moreover the increased level of interactions caused by ICT and globalization in general leads one to expect that these situations may increase meaningfully in the future. In all of these cases it is very probable that traditional BCA excludes or underestimates relevant points of view and therefore it could be useful to enhance such analysis with new approaches.

3. NASH EQUILIBRIUM

To get a better handle on this particular issue, one can turn to game theory. Game theory is a branch of economics that examines the strategic behaviour of economic agents with respect to other economic agents and considers equilibria that are possible in various situations, hopefully identifying those equilibria that are the both the most stable (in a 'positive' sense) and the most desirable (in a 'normative' sense). In a way game theory carries standard general equilibria a step further (depending upon how the analysis is designed) by considering not just the net change in social outcomes with mechanistic behaviour on the part of individuals, but also taking into account the calculations of agents as they consider what other agents are likely to do. It will be argued here that such considerations are essential, especially when looking at large-scale transport investment projects.

The Nash equilibrium, Nash solution and Nash question (Kuhn and Nasar, 2002) are topics that are met when there are at least two competitors. So a first question could be: are Nash topics coherent with Cost-Benefit Analysis in the case of transportation infrastructure investments? The answer could be 'no,' if the proposed infrastructure system has economic consequence on only one subject (conceptually speaking), i.e. there are no horizontal or vertical exclusions; otherwise we will argue that the answer is likely 'yes' in all the other cases.

Contrary to popular belief, Nash equilibrium represents a situation in which the rational choice is made by the subject evaluating the possible consequences of the behaviour of the other actors, but without dialogue with any of them (a non-cooperative game). Nash equilibrium is therefore founded on the idea that individual rationality is prior to and, in a certain sense, less complete, than the collective rationality. In the n-dimensioned decision space, where there are utilities of n actors to be considered, a Nash equilibrium point can be an optimum Paretian point also (so that it can be excluded to reduce the utility of someone without enhancing the utility of another) but it very well may not be. A classic example of this strategy is the famous case of the Prisoners Dilemma where rational actors, taking into account the rational self-interest of the other actors, all end up making decisions that make everybody worse off. If each actor, however, had coordinated with the others, they would have reached a different and utility maximizing outcome. However, the Prisoners Dilemma is set up so that such coordination is not possible and that leads to an important insight that if agents act *as if* everyone is cooperating, then one will achieve the same utility maximizing outcome that would have occurred if such cooperation did take place. Nash generalized this to say that every finite game with a mixed strategy has a Nash equilibrium of this nature (theorem 1 of Nash).

Turning to transportation we can see that such Prisoners Dilemmas (so to speak) can occur in transportation planning, and with the same potential for utility-minimizing results if agents act both non-cooperatively in fact and in inclination. We can have an example of this situation (fig. 2) if we consider the case of a territory (with a low density of activities) of a country C1 that penetrates into another country C2. If in the country C2 there are two towns T1 and T2 in the opposite parts of the country divided by C1, we can imagine a road that links T1 and T2 with two solutions: a, that passes through C1, and b, that goes round C1 along the border. In this case, applying Nash equilibrium (without dialogue), the chosen solution will be B, probably neglecting the general interest. A similar situation there is in effect near the border between Canada and USA.

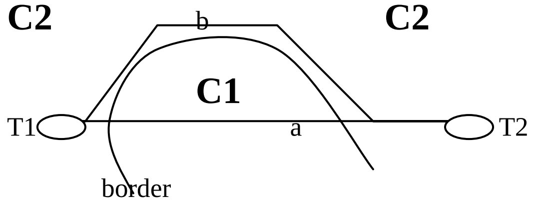

Figure 2: planning dilemma for transportation between two countries

4. NASH SOLUTION

If the agents that are in conflict decide to cooperate, or act as if the other parties will act with all other parties' interests in mind, then the situation changes. It changes, that is, if the following axioms are accepted (Li Calzi, 2002):

A1. The individual rationality axiom (every agent must have a utility not lower than previous one, when the cooperation was absent).

A2. The optimum Paretian axiom (an optimum exists where one agent's utility cannot be reduced without enhancing the utility of another).

In a cooperative game the Nash solution provides three other axioms:

A3. The solution must be symmetric.

A4. If the best solution b has been found between n possibilities, and if we exclude some of the n solutions (except b), the best solution remains b.

A5. The best solution is not dependent on the scale of the problem.

It is important to underline that A3, A4 and A5 generally assure that in the negotiation the weaker competitor is not overcome by the stronger one.

If all the axioms are respected, Nash solution is the one that maximizes the product of the utilities of the parts (theorem 2 of Nash).

The Nash solution seems a good solution to be applied for innovative BCA regarding new transportation infrastructure if there are risks of horizontal or vertical exclusion or conflict.

So the previous examples have possibilities to have a better BCA if the analysis takes account of the possibility of a Nash solution.

5. NASH QUESTION

Nash solutions are appliable if all the competitors have the same evaluation criteria, i.e., the same utility functions, and the same rules of the game. But in our globalized world it is always quite possible that very different people can come in contact directly (migration) or indirectly (when a government of a country can influence the people of another country). In this case it is possible that different people have a different scale of values and therefore it is not very easy to apply Nash solutions. This is the Nash question that is solved by theorem 3 of Nash (that is complex enough to be explicit simply).

If in a cooperative game the utility functions are not defined, it is preferable to say what the format of game is. The Nash question is to identify the format of game that implements the Nash solution.

For new transportation investments the Nash question could be very well applicable, for example, if the culture (and therefore the values) of the different people involved are very different (horizontal conflict) or if the consequences on people within the same value set are very different (vertical conflict); thus, for example, the people of a country where a transportation facility is being built can give more importance to the goal of accessibility than people in another country (horizontal conflict) but the people directly involved in the construction of the facility can give more importance to the environmental questions than others in the same country might (vertical conflict).

6. THE POSSIBILITY OF FORMAL IMPLEMENTATION OF NASH SOLUTION AND NASH QUESTION IN A BENEFIT-COST ANALYSIS

To summarize the argument thus far: traditional highway project analysis uses benefit-cost analysis; such analysis is partial equilibrium implicitly and explicitly even abstracts away from consideration of equilibrium entirely; general equilibrium analysis broadens the analytical horizon by considering the interrelationship of all markets and the effect that a project will have on those markets; and game theory carries the analysis even further by incorporating strategic behaviour into the model.

Large-scale highway projects probably require this more full-bodied approach. To better understand how such an approach might be carried out, and what its broader implications might be, one can consider Nash equilibrium in the specific context of public goods provision.

There is a large literature on economics regarding what is termed the private provision of public goods. This is the case where a set of private consumers collectively contribute to the provision of a public good. A typical formulation would appear as follows (Ley, 1996 – the discussion follows the argument as outlined in this article, though the discussion, with slightly differing notations and expositions, is widespread throughout the literature):

There are two agents, $i = 1; 2$, each of whom consumes one private good, x_i, and one shared public good, G. The agents have the standard utility functions assumed for consumer behaviour theory (i.e. a differentiable and strictly quasi-concave utility function, $U_i(x_i;G)$) and both goods are assumed to be strictly normal goods (i.e. their consumption increases with income). $(w_1; w_2)$ will signify the agents' initial endowments of private goods and agents choose their private contributions, g_i, to the public good. Assuming that the public good can be produced at a constant marginal cost, and choosing units so that the (constant) marginal rate of transformation between the private good and public good is equal to one, the total amount of public good provided is determined by the sum of the individual contributions, $G = g_1 + g_2$. The maximization problem for each agent i becomes:

max
xi;gi
Ui(xi; g1 + g2)
s.t. xi + gi = wi
xi; gi >= 0

This equation system simply shows that the actor number i is choosing private good x and quasi-public good g in amounts that will maximize agent i's utility subject to the income constraint. This problem focuses on private actors coming together to contribute to provide a public good. This is relevant to the transport problem in two ways: directly, if as often is the case, there is, in fact, private provision of roads and other transport (a quasi-public good); indirectly in the sense that where there are horizontal and vertical inefficiencies, public provision of the transport goods becomes similar to voluntary private provision since not all the relevant parties are included in decision-making to begin with and there is at least conceptually some voluntary level of participation in such contribution and some of the relevant parties are not, in fact, contributing. In searching for the optimal level of transport provision in this case we can model the world as if there is voluntary contribution and see what the optimal level is once all the relevant actors are considered together.

Bergstrom et. al. (1986), in a very influential paper on the topic of Nash equilibrium put the problem this way: "[The Nash case is] the case where people are concerned only about their private consumptions and the total supply of public goods." The authors note that "adjustments on the 'extensive margin' – the decision of whether or not to become a contributor – are at least as important as adjustments on the 'intensive margin' – the decision of how much to contribute. In general, only a small subset of consumers will actually contribute to the public good….Thus, usual practice of assuming interior solutions in doing comparative statics is, in this case, quite misleading. An appropriate analysis must involve careful consideration of the boundary cases as well."

To understand the full import of this statement, one can return to the optimization problem above and restate it slightly for the case of multiple consumers rather than 2 consumers. In that case each consumer is picking their level of private good consumption, their own contribution to the public good g, and the overall level of the public good offered. Following Bergstrom et. al. this last term would be G*- *i* to denote that the total level of G provided is equal to his own contribution plus the total contribution of others to G minus his own (ith) contribution. "Implicitly each consumer is choosing not only his own gift, but in fact the equilibrium level of G itself. For a consumer can decide to make a zero gift, in which case he chooses G = G*- i , or he can choose to make G larger than G*- i ."

Here we now see the crux of the problem in many transport analyses which compare the state of the world with one level of G to another state of the world in which G is at a different level ('comparative statics'). This classic benefit-cost problem, in which G is taken as exogenous, is problematic where, in situations with significant horizontal and vertical exclusion, there is a choice as to whether to contribute to G or not, thus making G endogenous. This is what is being referred to above when it is stated that an appropriate analysis must consider boundary cases as well. In other words, we have to consider what the best and worst cases are and work backwards from there to come up with the ideal social optimum. Traditional benefit-cost analysis, with its assumption of exogenous G and focus on comparative statics will likely miss the mark. This gap is what Nash equilibrium addresses, taking a system view when on the ground, so to speak, actors are taking an individual view.

It should be noted that the exposition above is an 'extreme' case of full endogeneity of G. The endogeneity arises because actors have full choice as to whether to contribute or not. In the real world such choice is not typically 'full.' Some actors will be bound by institutional or other factors, to participate or not, and only some subset of actors will have a full choice regarding contribution. Even with excluded or included parties, the choice may be imperfect, i.e. a party may only be able to partly opt in or opt out. This continuum complicates the analysis but the main point remains in that not all situations can be usefully analyzed using benefit-cost analysis with the standard assumptions of exogeneity of transport provision. At the same time, the Nash equilibrium case, and the private provision of public goods case in particular, shows that benefit-cost analysis can be suitably modified to take into account cases where such exogeneity does not exist.

There are other possible Nash extensions to benefit-cost analysis which could be developed as well but this case will work as a start.

7. THE CASE OF EU CORRIDOR 8

In selecting potential candidates to apply a Nash-modified benefit-cost analysis, The EU corridor 8 would seem to fit well since there is significant horizontal and vertical exclusion.

The EU corridor 8 (fig. 3) is a project directed at the realization of many infrastructures (not only roads and railways, but also pipelines, telecommunications, ports and airports) that would connect the Black Sea (Bulgaria) with the Adriatic Sea (Albania and Italy).

Many factors work together to make this corridor very special social corridor:

- The possibility of connecting two quite culturally distinct worlds, West Europe and South-West Asia;
- The possibility of making more efficient the transport network between East Europe and Mediterranean Countries (Greece, Turkey);
- The very difficult topographic conditions of the lands;
- The low level of economic development of Albania, Macedonia (FYROM) and Bulgaria with respect to all the other near countries;
- The political history of the last fifty years that had isolated and troubled especially Albania, but also Macedonia;
- The condition of Albania and Fyrom that will not enter the EU;
- The illegal use of the corridor with its present low level of infrastructure provision that allows the transport of arms and drugs the entry to the EU of terrorists (an example of how relative inaccessibility can also breed the greater ability to hide movements of goods and people).

Figure 3: EU corridor VIII

Recently, after a lively debate, the EU has decided not to finance this project.

In 2003 Polytechnic University of Bari (Caporusso, 2003) produced a study of feasibility for Corridor 8, conducted by the software HDM 4 of PIARC (International Road Association). Three scenarios were considered:

- Scenario 0, without new transportation investments;
- Scenario 1, with few improvement works;
- Scenario 2, with the fullest set of transportation investments.

The results of the analysis show that scenario 1 seems to be inadequate, while scenarios 0 and 2 are comparable. However it is important to underline the following observations:

- Some input data were not available, so that reasonable approximations have been made;
- The social benefits and all the positive externalities have been certainly underestimated because the software has not been designed to assess these situations. Note that this characteristic is common for almost all the traditional software for the Benefit-Cost Analysis.

The results of the analysis in such a dramatic fashion produced, in one of the authors of this paper, the conviction that traditional Benefit-Cost Analysis can fail greatly in some real situations and therefore that it is necessary to find new methods (for example Nash theories) that are able to assess and to compare in a more adequate and equilibrated manner costs and benefits.

What possible distortions of traditional benefit-cost analysis are likely in this particular case? There are certainly many issues of both vertical and horizontal exclusion that have been illustrated in previous paragraphs of this paper which are present in the case of corridor 8, because it is evident that the proposed infrastructure system can have economic consequences that vary dramatically across the many subjects of this region who operate under very different social and economic characteristics.

For example vertical conflict can exist between the EU and Bulgaria (a nation that has recently entered into the EU) or between the EU and Italy or again between the EU and Greece. For every one of these cases (either between countries and regions or between subjects within regions) there is a different level of intensity of conflict. Thus some observers more easily will find possible examples of horizontal conflicts between peoples of the different countries involved that have different marginal utility for the different solutions and overall have different level of political freedom, expectation of life, unemployment, woman rights, education, legality, etc. In these cases different peoples can assign different value to the benefits. This kind of dynamic can also be played out vertically, i.e. the same differences in marginal utility might be found within a given country or region.

Thus the case of corridor 8 could be a good opportunity to check the possibility of applying Nash theory as a new method of application for Benefit-Cost Analysis. The hypothesis offered by the authors is that the actual decision of EU represents a point of Nash equilibrium but not an optimum Paretian point and therefore is a good solution for a non-cooperative game. Instead, if we consider the possibility that all the agents can cooperate, we could have a different solution (Nash solution) oriented to fund the investments for the corridor 8. This solution would be almost sure if we could apply the

Nash question, modifying the rules of the Benefit-Cost Analysis so that the situation can be assessed with greater emphasis the social effects and the externalities.

8. CONCLUSIONS (AND A NOTE ON EXTERNALITY)

The lessons from the history, the geographic location of the affected countries and the socio-economic condition of the involved populations of EU Corridor 8, make it evident that new infrastructures could generate forms of “benefits”, “opportunities” and “equities”, which at the moment we cannot forecast at all. The reasons for this limitation could lie in the fact that there are deeply different traditions and values held by the residents of the area, which may lead to different evaluation criteria at a local, national and continental level. In this case the traditional BCA methods may not be suitable and thus cannot be used without supplementary techniques or without modification.

Future research suggests two questions for the assessment of Benefits and Costs:

1. To find new evaluation criteria taking into account all factors (such as economy, equity, globalization, values, etc.) in a BCA of a transportation network
2. To ask for the criteria to be able to assess the dynamic equilibriums of effectiveness of a transportation network.

In this sense the possibility to apply Nash theories (in particular Nash solution and Nash question) could be valid. A first incomplete example of application done for the EU corridor 8 seems to confirm that this is a fruitful area for further work.

A word does need to be said about the issue of externality. Thus far most of the discussion has been on equilibrium and actor preferences and knowledge. The classic exposition of economic externality is found in Buchanan and Stubblebine (1962). Seeking a perfectly general construct, the authors define externality “to be present when…the utility of an individual, A, is dependent upon the ‘activities’…that are exclusively under his own control or authority, but also upon another single activity…which is…under the control of a second individual, B, *who is presumed to be a member of the same social group.*

There is much about the concept of externality, and Buchanan and Stubbeline’s treatement of it, that can be fruitfully discussed but two points can be made now. First, using this definition, externality can be said to be rife. True, it may not always be significant, but its commonness buttresses the points made earlier that situations where externality are thought to be possibly important should be analyzed using methods that will likely pick up the externality and its impact.

Second, the italicized portion of the definition is significant. Many factors can give rise to externality (positive or negative, it should be added), including the asymmetries in knowledge and preference that have been discussed above.

In any case Nash theories seem more applicable when the diversity of agents is high. In such cases the presence of vertical conflict (between different institutions or groupings) and horizontal conflict (within institutions and groupings) are more likely as are the attendant externalities. These factors are likely to have a great influence on outcomes and as it is very difficult to assign a value to “immaterial” goods, the analytical solution is still far from being solved.

REFERENCES

Bergstrom, T., Blume, L., Varian, H. (1986) – "On the private provision of public goods" – Journal of Public Economics, volume 29, pp. 25-49.

Buchanan, J., Stubbeline W.C. (1962) – "Externality", Economica, New Series, Vol. 29, No. 116, pp. 371-384.

Caporusso, G. (2003) – La pianificazione degli investimenti di viabilità – metodologie ed applicazione progettuali – Thesis of degree, tutor P. Colonna, Polytechnic University of Bari

COLONNA P., PASCAZIO R., Sinatra M. (2005) – "Historical and Motivational Analysis of Transport Relationships between Adriatic Coasts (and in the South Europe)" – Proceedings of the Final Conference COST 340 Towards a European Intermodal Transport Network: Lessons from History, Paris.

Hey, J. (2003) – Intermediate Microeconomics: People are Different – McGraw-Hill, London and New York

Kuhn, H.W., Nasar, S. (2002) – The essential John Nash – Princeton University Press

Ley, E. (1996) – "On the private provision of public goods: a diagrammatic exposition", Investigaciones Economicas, volume 20, issue 1, pp 105-123.

Li Calzi, M. (2002) – "Un eponimo ricorrente: Nash e la teoria dei giochi" – Proceedings of Assemblea UMI

ACKNOWLEDGMENTS

The authors thank Glen Weisbrod for the example of the case Canada/USA cited in this paper that he has proposed in an informal meeting during a coffee-break of a TRB 2005 summer congress in Chicago.