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SYSTEM FOR PLANNING AND RESEARCH IN TOWNS AND CITIES FOR URBAN SUSTAINABILITY (SPARTACUS)

SUMMARY FINAL REPORT

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I. OBJECTIVES

The general goal of this project was to develop and pilot the use of a comprehensive analytical framework, with a sound and theoretically consistent basis, for building and evaluating long term strategies for sustainable urban development, especially in Europe. The key objectives were:

1. To design and specify a system for analysing and providing forecasts of the interactions between land use, transport, economy, the environment and social factors and for forecasting these into the future.
2. To identify, on the basis of European initiatives and guidelines, a set of key policy actions which can be translated into development strategies and tested in the pilot city applications (Helsinki Metropolitan Area, Bilbao and Naples).
3. To develop strategies for urban sustainability by using combinations of land use, transport and environmental policy instruments (regulation, pricing and investment).
4. To simulate and assess the long-term effects of introducing these policy actions in each of the selected pilot cities, and to compare and explain any differences in the results attained.
5. To specify common sets of policy actions that are economically, environmentally and socially sound as well as viable, and that could be used successfully in other cities within the Union that have similar sustainability problems.
6. To give general recommendations and to effectively disseminate the results.
7. These objectives have been fulfilled. The dissemination and exploitation process will continue.

II. METHODOLOGY

Approach to urban sustainability

The three components of sustainability generally referred to in the literature (e.g. Munasinghe, 1993; Alberti, 1995; Hannequart & Schamp, 1995; Gardner & Carlsen, 1996; World Bank, 1996) have been taken as the points of departure for the SPARTACUS system (see Figure 1).

They are interpreted as follows.

Environmental limits are posed by the exhaustion of natural resources and exceeding natural carrying capacities.

Social sustainability includes the analysis of the distribution of policy impacts and access to resources and services, the justice of those distributions, and the state of the community with regard to health determinants and personal opportunities.

Economic efficiency of the use of resources examines whether most benefits are achieved with the least use of resources.

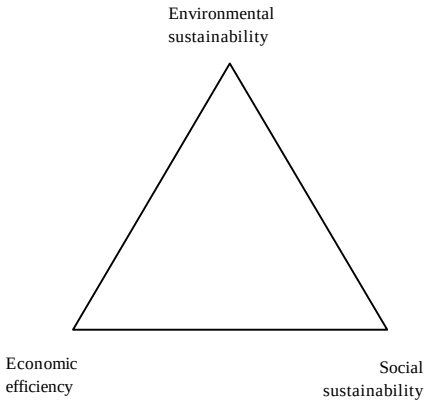

Figure 1. The components of sustainability

By definition, a city, as such, cannot be sustained unless all of its (relevant) components are sustainable. However, evaluating the sustainability of an urban system as a whole is a task beyond the present scope. The mere fact that SPARTACUS has not been examining the totality of the urban system but only parts thereof prevents the measurement of its degree of absolute sustainability, even in principle.

In the wider picture, it is also unclear whether urban sustainability—again in absolute terms—is a meaningful concept. This is because the sustainability of a system that is dependent on an external system cannot be evaluated without also examining the external system (which then loses its externality).

Despite these difficulties, it is the contention of the SPARTACUS project that urban sustainability can and should be measured, in relative terms. Policies, therefore, have been compared with each other with the help of the indicators.

The indicator system

The indicator system consists of three components in accordance with the three components of sustainability: environmental, social and economic. The indicators are grouped under themes (see Table 1). Indices are then built from the indicator values. For this purpose, the environmental and social indicators, which do not have a natural common unit, are scaled in the range [0…1] with user-defined value functions. Subsequently, the indicator values can be aggregated to the theme-level indices using indicator-specific weights and further to component-level indices by applying theme-specific weights. The component-level indices are not combined, because no substitution is assumed possible between them.

The economic index is expressed in one single value (ECU/capita/a) describing the benefits of any policy. It is composed of transport user and transport operator benefits as well as resource and external cost savings.

One of the central principles in the selection of the indicators has been to follow the causal chains of impacts as far as possible. It is not unusual to describe the sustainability implications of policies e.g. in terms of how they affect various transport variables. Regarding, for example, air pollutants, several of the SPARTACUS indicators deal with emissions. For impacts depending on local concentrations, the concentrations within the study areas are modelled and the data is combined with information on where people live thus resulting in a simplified indication of potential exposure in residential areas.
In addition to the actual indicators, a good deal of explanatory information is available from the SPARTACUS system including information that helps in the interpretation of changes in the values of the indicators. These data are called background variables.

Table 1. The components, themes and indicators of urban sustainability in the SPARTACUS system.

Environmental indicators		
Air pollution	Emissions of greenhouse gases from transport	EAGT
	Emissions of acidifying cases from transport	EAAT
	Emissions of organic compounds from transport	EAOC
Cons. of natural resources	Consumption of mineral oil products	ERMO
	Land coverage	ERLC
	Consumption of construction materials	ERCM
Social indicators		
Health	Exposure to particulate matter in the living environment	SHEP
	Exposure to nitrogen dioxide in the living environment	SHED
	Exposure to carbon monoxide in the living environment	SHEC
	Exposure to noise in the living environment	SHEN
	Traffic deaths	SHTD
	Traffic injuries	SHTI
Equity	Justice of exposure to particulates	SEJP
	Justice of exposure to nitrogen dioxide	SEJD
	Justice of exposure to CO	SEJC
	Justice of exposure to noise	SEJN
	Segregation	SES
Oppor-tunities	Total time spent in traffic	SOTT
	Level of service of public transport and slow modes	SOPT
	Vitality of city centre	SOVC
	Accessibility to the centre	SOAC
	Accessibility to services	SOAS
Economic indicator (index)		
	Total net benefits (ECU/capita/a)	

The analytical framework

The SPARTACUS system is based on the MEPLAN land use transport model whose results are utilised by the Raster and MEPLUS modules that calculate the values for most of the indicators used. These values are transferred to the USE-IT module for postprocessing, i.e. weighting and valuation.

Land-use transport modelling

The heart of the SPARTACUS system is an integrated land use transport model developed using the MEPLAN simulation modelling framework. The MEPLAN model brings together relevant information on transport, land use and economic activity. Development strategies can be simulated through the model by changing the inputs in order to represent a proposed change in the real world. The model outputs then provide an indication of the wider socio-economic and environmental effects of introducing the change and these effects can be evaluated against an alternative strategy or a do-nothing scenario. The process of building a sustainable development strategy can then begin.

The MEPLAN system has been enhanced for the SPARTACUS project. It has been modified to allow for a large number of environmental functions to be defined. In addition, a new module, MEPLUS, has been developed. MEPLUS is a GIS-based policy analysis tool designed to process and manipulate the various model outputs produced within the SPARTACUS system. MEPLUS also computes most of the economic,

environmental and social indicators output by SPARTACUS and offers a range of facilities for analysis, display and reporting.

Raster methodology

Some indicators for assessing urban sustainability require a disaggregate representation of space. The modelling of locally important environmental processes and their social implications requires the exact spatial location of input information and output data. Raster cells or pixels can be used as a spatial reference framework for environmental and social impact models. However, most of the data available and most urban models are spatially aggregate and work within a zonal framework. The method chosen in the SPARTACUS project to overcome the mismatch between the required spatial framework and the existing data and models is to maintain the zonal organisation of the model and to add a disaggregate raster-based representation of space for specific modules, for instance for the calculation of local environmental impacts of policies. For this purpose the so-called Raster Module has been developed.

The USE-IT module

The valuation and weighting process is facilitated by the use of a decision-support tool designed in the project: USE-IT (Urban Sustainability Evaluation and Interpretation Tool). The User is provided with a library of value function shapes. The Analytical Hierarchy Process (Saaty, 1980) is offered as a means to set the weights, or direct rating can also be used. Consistency checks can be made, and alternative theories of justice can be chosen and used as a basis for analysing the justice of the distributions of various impacts. A selection of graphical output formats is available.

The policy testing process

The process of testing urban policies began by defining thirty-seven policy elements, i.e. individual policy levers. Subsequently, the most promising ones were combined, first into policies and then, after further testing, into policy combinations. The number of the policies and policy combinations totalled thirty-three. At each stage, attempts were made to mitigate any possible negative side effects by redefining the measures tested.

III. MAIN RESULTS

Conclusions

The SPARTACUS project has shown that it is possible to use an urban land-use transport model as a platform to produce environmental, social and economic urban sustainability indicators that can be used in assessing policy options and when searching for new and effective ways to attaining urban sustainability. The research has demonstrated what types of policies are likely to produce positive results and has highlighted areas in which further work would be fruitful. General recommendations have been made based on the research and the new methodologies applied.

The SPARTACUS system produces large amounts of information, but it also makes possible a drastic stepwise aggregation of the data—down to three sustainability index values per policy based on the preferences of the user or client of the system. In this way, also the transparency of the system is maintained. The aggregation was of great help in analysing the huge number of policies, but in order to establish the meaningfulness of this approach in practice, more experience is needed in applying this prototype system. Questions like, is it feasible for a large number of people to participate in setting the weights and value functions, or, are people willing to accept the aggregated results as being based on their 'average' judgmental values, can only be answered after practical experience, which could not fit within the scope of this project. In any case, a lot of information is available and different approaches can experimentally be used.

The policy element tests show that the pressure for urban sprawl is very strong. A one-percent growth in urban population leads to more than a one-percent growth in car mileage (in Helsinki 2%). Many measures intended to decrease travel demand may, in the long term, lead to increases in private car mileage. This was the case in the car pooling policy, the level down peak hour policy, the teleworking scenario, some public transport policies etc. Investments in public transport or lowering public transport fares may impact in ways that eventually lead to increases in private car mileage. Part of the reason for this is that the above policies resulted in less congestion in the transport network and made it possible for households to move to more peripheral areas resulting in increases in the average trip lengths and, thus, also private car mileage.

Some policies also leave their socio-economic footprint outside the urban area. It is important to identify and be aware of these effects. Pricing policies in particular can influence rural areas by encouraging people to move to the metropolitan areas or other cities in order to reduce their travel costs. This creates social and service level

problems in declining rural areas and creates demand for new construction in cities, with resulting environmental pressures. Some policies may also create effects within the urban area that are not necessarily expected nor wanted. For example, raising parking costs too much can have the effect of moving both inhabitants and jobs from the city centre, thus affecting its vitality.

The results clearly show that the most effective policies from an urban sustainability point of view are the pricing policies. In addition, the regulation policies, especially lowering car speeds, have significant effects.

The pricing policy of increasing car operating costs by 50% reduced the total private car mileage by 16% in Helsinki and Naples, the regulation policy (car speeds lowered on main roads) by 4% and the combined policies by 21% with simultaneous positive effects on emissions, noise, accidents, total travel times and modal split. By adopting a more severe pricing policy (car operating costs up 100 %) but in peak hours only, a reduction of private car mileage of 25–27% could be achieved (Helsinki). The optimum level of car operating cost increases was estimated to be about ECU 1/car trip on average (Helsinki). In addition, time based pricing and congestion pricing policies were tested. The results suggest that the most effective policy combination could be formed by combining congestion pricing with a general increase in motoring costs.

Reducing car speeds has positive environmental and social effects but economically it was found not to be feasible. The external and resource costs for cars decreased but the reduction was not large enough to compensate the disbenefits experienced by the car users mainly through small time losses.

Possibilities to substantially improve environmental and social sustainability through investment programmes were found to be limited. They may have considerable effects locally but regionally the effects were marginal. Sometimes they also included elements that did not produce cumulative effects since individual investment projects worked in opposite directions.

The land use policy element tests show that individual measures designed to encourage either inhabitants or employment to move to other areas in order to balance the inhabitant / employment ratio in different zones do not produce any significant positive effects. However, if the policies are combined so that both inhabitants and employment are redistributed at the same time, then positive effects can be gained. The rather limited effects result from the fact that land use has already adapted to changes in the transport system (and vice versa) and changes of the first type only disturb the total balance of the system.

Innovative policy combinations could be sought and found. One example is combining the pricing policy with the teleworking scenario as teleworking efficiently works against the negative side effects of pricing policies described above. Another example is the pricing policy combined with an investment programme that was mainly composed of public transport investments, especially new rail links (Naples).

Theories of justice were operationalised and used in assessing social sustainability and the distributions of the effects between different socio-economic groups. The choice of a theory of justice was found to affect the ranking of policy alternatives in some cases. It is, therefore, important for the decision maker to define what principles of justice he/she prefers. The justice of the impact distribution also relates to the acceptability of a policy.

It may be concluded that it is possible to substantially increase urban sustainability (as measured by the SPARTACUS indicators and as compared with the Reference scenario) by adopting reasonable policy options and their combinations in the test cities. This indicates that the same policies could potentially be adopted in other cities with similar positive effects. However, neither the policies nor the policy combinations were always effective enough to maintain even the existing level of sustainability. Increasing mobility is, therefore, likely to decrease the level of sustainability in all test cities unless strict policies are adopted.

The results demonstrate the types of policies that are likely to give positive results and, therefore, merit further study. However, theoretical, methodological and data limitations mean that some care is required in their interpretation. In addition, any policy should always be examined in relation to the local conditions before planning its implementation. The interpretation of the results must also bear in mind the following various points. The model system can only give a partial view of reality as not all the factors affecting the urban land use and transport system are modelled. The indicator system only covers part of all the environmental, societal and economic aspects of an urban system. The USE-IT module applies user-defined weights and value functions that do not necessarily reflect society's values and weights and that are likely to change with time. Finally, the policy testing process covers a wide range of different types of policies but does not go into the details of any.

Recommendations

Based on the research and policy tests with the SPARTACUS system the following general recommendations can be made.

Environmental, social and economic sustainability can be substantially increased by adopting policies and policy combinations that are new and innovative compared to the continuation of existing policies. It may, however, turn out to be difficult with even the new policy options to maintain the existing level of sustainability. This is strongly dependent on the characteristics of an area including the rate of growth of population, car ownership, urban sprawl etc.

It is insufficient to merely evaluate policies on a one by one basis. Instead a complete urban policy programme should be evaluated both policy by policy and as a whole in order to completely understand its effects and the mutual interactions of the policy elements. It is particularly important to note that some combined policies reinforce each other but others may be incompatible to the extent that they may work against each other.

It is important to be aware of the negative side effects of policy options and especially of the socio-economic impact that the policy may have on the surrounding region. All of the policies had some negative side effects and what was good for e.g. the metropolitan area was not necessarily always good for the region as a whole.

Issues related to the justice of the distribution of the effects of policy options should be carefully investigated. Different approaches to justice issues may result in different orders of priority for policy options. The SPARTACUS research introduced the issue of justice to a comprehensive evaluation framework. This exercise revealed the fact that a very fundamental question has to be answered in order to have a consistent evaluation system. What is the right distribution of the individual effects of a policy between say different socio-economic groups? Is the present distribution of welfare fair? Should the net benefits be maximised? Should the distribution be as equal as possible? Should the worst-off be favoured etc?

The long term and land use effects of policy options should be carefully studied since the final effects may be opposite to the short term ones. The policy testing process and the SPARTACUS system revealed that some policy options intended to increase urban sustainability eventually had the opposite effect. When these long term effects were studied it was found that it does not always follow for example that car mileage could be reduced by introducing teleworking or car-pooling, lowering PT fares, increasing parking costs etc.

Adoption of pricing policies is recommended as a key means for increasing urban sustainability. Some of the pricing policy options that were tested turned out to be the most efficient ones environmentally, socially and economically in all test cities.

Detailed studies are needed to find the appropriate level for the pricing policies and ways to adopt them in the most efficient way. An optimum level could be found but it is likely to be city specific and a general recommendation cannot be made. The most effective way of introducing a pricing policy appears to be based on combining a congestion pricing element with a general motoring cost element. This concept is also supported by the economic theory of marginal cost coverage. The results also showed that public transport fares and parking charges have an optimum level and interact with the increased motoring costs policy, which indicates that pricing structures should be studied as a whole.

The negative side effects of the pricing policies should be identified and mitigated. The pricing policies may have a pronounced effect on urban structure. This leads to increased need for construction with related environmental problems as more people move into the urban area demanding new floorspace, although part of the pressure is channelled into higher densities. Another problem is related to rural areas that tend to lose their inhabitants and jobs. Encouraging teleworking could be one way to mitigate the above problems.

In terms of the regulatory policies, the reduction of car speeds had strong environmental effects. However, the economic feasibility of the tested policies was unsatisfactory mainly because of travel time increases. This indicates that new concepts should be found in order to maintain economic feasibility e.g. by being very specific about which zones and road types are targeted.

The overall effect of land use policies on urban sustainability is limited. However, locally the policies are important and land use policies can be designed to support the chosen general policy line. The limited effect is due to the fact that the change in the whole urban system is marginal unless the city is growing very fast. Secondly, the land use system has adapted to the transport system (and vice versa) over time and radical intervention is required to change the balance between the systems.

Investment programmes should be designed to be consistent with the general goals set for the transport-land use system. The test results obtained with the SPARTACUS system showed that the programmes tested were not all as efficient as expected. This may be because the elements of the programmes encourage development towards different goals. This emphasises the need for co-ordination between different policies. If, for example, pricing policies are considered they should be supported by investment programmes that promote the use of public transport in order to manage the increased demand.

Reducing car traffic through the adoption of policy types tested improves some indicator values, especially emissions. There is, however, no guarantee that, for example, the exposure and opportunity indicator values would improve simultaneously. Additional measures may be needed to maintain and improve the conditions in these respects.

A good urban policy consists of co-ordinated elements that work together to produce cumulative effects that attain a balanced set of environmental, social and economic goals. These elements may include:

- combination of pricing policies, near the optimum level, directed at car users with differentiation between peak and other hours, with a appropriate level of pricing of public transport fares and parking;
- speed reductions taking into account the type, role and location of the road/street;
- investment programmes supporting the changes in demand caused by the above policies;
- a land use plan supporting the new need for people to live near central areas or in satellite cities and their increased need and opportunity to use public transport;
- measures necessary to mitigate the negative side effects of the above policies.

Regulation, investment and land use policies should be tailored for each individual case. The SPARTACUS research has shown what types of policies have potential to add to sustainability.

Further Work

The main concept for further development builds on the premises that urban transport and land use form one integrated environmental, social and economic system that interacts with the surrounding region without a clear border. Thus, the effects of alternative policies should be estimated by simultaneously studying both land use and transport systems as well as their interaction with environmental, social and economic systems and the surrounding region.

Theoretical research is needed to better understand the economic flows between land use activities and transport systems. There is a long tradition of calculating economic indicators from transport models but this tradition does not exist where integrated land use and transport systems are concerned.

Similarly, more research is needed to understand and model the interaction between environmental quality and land use in order to have a fully integrated land use / transport / environment / economic model. Steps in this direction were taken in the SPARTACUS project by modelling a number of land use based environmental indicators but without a feed-back system.

The indicator system associated with the transport and land use modelling framework should be further developed in order to include additional important social and environmental indicators (e.g. effects on employment, distribution of economic effects) that had to be dropped from the SPARTACUS indicator set because of the lack of a supporting theory.

More efficient use of GIS and, in particular, a more radical move towards micro-simulation models would bring several benefits, including:

- better presentation of transport and other activities in space and time;
- new, more detailed policy types could be evaluated;
- better inputs into environmental models;
- better inputs to the exposure models as estimates could be made about where and when people are and what the air quality is there at that time;
- possibility to calculate a set of new and important detailed indicators such as access to open space or impacts on biodiversity.

The land use / transport model could be developed further by modelling some important new features that would allow the calculation of additional improved, new or more comprehensive indicators. For example, the total energy consumption or CO_2 emissions from both the land use and transport systems could be modelled and better estimates of new construction and its location could be obtained. Some policies affect the floorspace

prices and consumption of space by households and employers. This has an effect on total building volumes and their location that in turn affects the magnitude and pattern of emissions.

Pricing policies were identified as having the most potential. More research is needed to define the optimum method and level of pricing, to carefully analyse the negative side effects of the pricing policies and, finally, to determine suitable countermeasures to mitigate these side effects. There are several alternative principles to implement the pricing schemes (road pricing, distance-based, time-based, tolls etc.), and the choice is also connected to the technology of how the charges could be collected. Behavioural and technical research is needed in addition to research on the acceptability issues.

More experience is needed in the use of decision support tools, such as USE-IT. Are there systematic differences between weights, value functions and justice theories given by different groups? If so, how significant are they and what are their effects on the final policy evaluation? Answers to these questions would help to improve the functionality of the tool. It could also be developed to form a platform for public participation.

IV. SCIENTIFIC INTEREST AND NOVELTY

When SPARTACUS was conceived the idea of using models as an aid to the assessment of sustainable development was in its infancy, and the idea of using an integrated modelling framework remains novel. Within the project, this idea has been extended to include an indicator system for measuring the sustainability of urban development in a comprehensive way. The indicator system measures the environmental, social and economic impacts of the different types of land use and transport policies. The system of indicators and their weights and value functions is governed by computer software developed in the project.

A GIS-based Raster method has been developed in order to enhance the spatial resolution of the system and to take a step forward from the traditional modelling of air pollutant concentrations towards the assessment of the exposure of the urban population to pollutants.

Theories of justice have been experimentally used in an urban land use and transport planning context to derive some social indicators in order to measure the fairness of the distribution of the impacts of the policies.
The systematic policy element, policy and policy combination testing process revealed the negative and positive effects of different options and showed in this way the general direction for forming sustainable urban policies.

V. POLICY RELEVANCE

The SPARTACUS approach is of high political relevance for urban policy-makers. The methodologies developed for the SPARTACUS system have been designed to test and evaluate relevant practical policies at the strategic level. The three test cities have been used as an experimental platform.

The policy elements and policies tested are mainly based on ideas developed from the literature and on general urban policy guidance. Some are also based on discussions with the Client-Partners and reflect policies that are under discussion in the test cities. A consensus was found among the test cities on relevant indicators although not all of these could be modelled.

Research on pricing policies has been emphasised both because of their effectiveness and because fair and efficient pricing is one of the main policy lines under development within the European Union. Test results also produced information that is relevant when formulating and evaluating other policies and measures. Such information includes estimates of CO_2 emissions and consumption of oil products.

The project also aimed at providing general recommendations about policies that are efficient and will find general application.

The SPARTACUS team has maintained active contact with the local authorities of the test cities throughout the project and has aimed at allowing for local needs and interests in the development of the system as well as in the design of the policy tests.

The European aspect of the project is very important, particularly given the diversity of European cities. The project has shown that not only is it feasible to design and implement a system for analysing urban policies to be applied across the EU, but that it is also possible to devise consistent policy packages that do make a difference when it comes to making very diverse cities more sustainable. These findings are particularly relevant at a time when innovative transnational planning projects are seeking to advance the principles and objectives of the European Spatial Development Perspective (ESDP). It is hoped, therefore, that the

SPARTACUS approach can be carried forward to assist in these and other exciting new European planning activities.

VI. LIST OF PUBLICATIONS

In preparation:

The partners are intending to publish a book on the SPARTACUS system and the results of the project.
LT has submitted a paper for approval to the January 1999 conference of the Transportation Research Board in Washington, D.C.
IRPUD will publish its contribution to SPARTACUS, i.e. the Raster method and its application, in its research paper series and intends to submit papers on this to international journals.
IRPUD intends to present the SPARTACUS project with a focus on the Raster methodology at the Conference 'Social change and sustainable transport (SCAST)' of the US National Science Foundation and the European Science Foundation in Berkeley, CA in March 1999 and at the 'International Conference in Computers in Urban Planning and Urban Management (CUPUM)' in Venice in September 1999.

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