

**Evaluation of Multifunctional Land
Use:
Design and application of policy criteria**

Research Memorandum 2002-28

Faculteit der Economische Wetenschappen
en Bedrijfskunde (FEW&B)

Universiteit

Limburg





**Evaluation of Multifunctional Land
Use:
Design and application of policy criteria**

Research Memorandum 2002-28

**Caroline Rodenburg
Peter Nijkamp**



EVALUATION OF MULTIFUNCTIONAL LAND USE: DESIGN AND APPLICATION OF
POLICYCRITERIA

Caroline Rodenburg
Peter Nijkamp

Free University Amsterdam
Department of Spatial Economics
De **Boelelaan** 1105
1081 HV Amsterdam
The Netherlands
email: **crodenburg@feweb.vu.nl**

Abstract

Multifunctional land use has **recently received increasing** attention, **both** as a planning concept and **as a tool** for **integrated modelling**. **When** e multifunctional **spatial** planning design is **used**, socio-economie **synergy** benefits **may** be obtained, if **several (complementary or mutually strengthening)** functions **are** exercised at the same **place** and **time**. The present paper aims to offer a new **contribution** to the economics of multifunctional land use by analysing this concept in greater detail from an operational end **integrative** perspective. A **functional** typology of specific land use functions is **presented, along** with the development of assessment **criteria** to measure the degree of **multifunctionality** of specific land use **projects**. A Dutch **case** study of a multifunctional land use **project**, the **so-called** Amsterdam South-Axis, is presented and analysed **as an illustrative** case.

PN059CR

1. Introduction

The **economic** science has traditionally put great interest in land use. This interest stems from three characteristics of land: i) land is scarce, ii) land has alternative use options, and iii) land has a **social** value in the **economy**. Economists have typically **focused** on questions of efficiency and (more recently) sustainability of land use. These studies are generally concerned with 'monofunctional' land use patterns. Since recently, **however, also** the concept of multifunctional land use has gained interest. Multifunctional land use attempts to combine several socio-economic functions in the same area, so as to **conserve** scarce space and to exploit **economies** of synergy. The aforementioned characteristics of land use **can also** be used to study the concept of multifunctional land use from a socio-economic perspective. The present paper aims to analyse the concept of multifunctional land use in greater detail by focussing on **specific** land use functions and by analysing the opportunities for benefiting from multifunctionality in designated land use **projects**. Therefore, in **Section 2** a set of different land use functions is defined, along with the relationships between them. Since this paper **focuses** mainly on urban **areas**, not **all** land use functions **will** be taken into account. This paper **concentrates** mainly on multifunctional land use **projects** that include, at the **very** least, an **infrastructure** function. Definitions of the most important **concepts** dealt with in this paper (land use, **infrastructure** and multifunctionality) are presented in **Section 3**. **Before** the relationship between these **concepts** is analysed, the **factors** that determine **urban** land use are examined (**Section 4**). These are investigated from a multifunctional point of view as **well**. **Section 5** then **provides** a theoretical overview of the relationship between land use, **infrastructure** and the multifunctional organisation of space, as it relates **to** possibilities for the emergence of synergy **effects**. These **analytical** contributions form the basis for the indicators framework presented in **Section 6**, through which multifunctional land use **projects may** be quantitatively analysed in terms of the degree of multifunctionality. **Section 7** is an initial **attempt to** explore a multifunctional land use project (the so-called South-Axis ('Zuid-as') in Amsterdam). **Section 6** offers some concluding remarks.

2. Identification of land use functions

An empirical analysis of multifunctional land use of **course** requires unambiguous definitions of its elements; i.e., of the different land use functions to be distinguished. Our study will distinguish nine **such** (rather aggregate) functions (Rodenburg, **2001**), namely:

Residential housing is defined as the space that is used for (permanent) living.

Work and business refers to the space that is **used for commerce** and **industry**. This includes, for example, office locations and **industry** locations.

Amenities include **non-profit** organisations (hospitals, schools, museums, churches, etc.) as well as **shopping** facilities.

Infrastructure refers to the space (including safety buffers) that is used to facilitate movement of goods and **persons**. This includes the transport **infrastructure** (roads, **railways**, waterways, terminals, **ports**, and **airports**), the communication **infrastructure** (data-communication **networks**), energy facilities (electricity network) and the water **infrastructure** (**dikes**, bridges, locks, sea **walls**, etc.).

Recreation and culture has a broad definition. Benches along public roads are not included. **Areas** included are day trip destinations, campgrounds and amusement parks. **Space** consumed by **cultural** functions is **also** included.

Water refers to the space taken up by **rivers**, watercourses, **lakes** and territorial waters that have a 'water management' function. This **also** includes **areas** that have a drinking water function, e.g. storage of drinking water, and filtration **areas**.

Agriculture refers to the space that is used for cropland, **pasture**, orchards, vineyards, and **horticulture**, but **also** to the **space** needed for intensive, non land-wstricted cattle breeding.

Nature end landscape means, in its broad definition, the space needed to maintain **or** guarantee the current quality of **nature** (biodiversity). In its narrower definition, it **may** refer to the **Main Ecological Structure**: a policy concept used in the Netherlands to **indicate** a spatially wnnected **network** of **larger** units of **nature** (including water). The broad definition **will** be used here.

Remaining includes the **use** of land that cannot be classified under one of the land use functions as described above.

These individual spatial functions are defined to be **mutually exclusive**. This **means** that the sum of the total land area cannot be exceeded by the sum of the land area consumed by the different functions. The initial starting point is therefore a monofunctional land use situation in which **each** type of land use has its own characteristics of **demand** and supply.

Figure 1 shows the relations between the various functions (**except** for the function 'remaining land') and the **external** forces that affect the system of land use and vice versa. Examples of **external** forces are the **actual** spatial organisation, as **well** as demographic and geographic influences. The highlighted part shows the focus of this paper: the transport function and the land use functions most directly related to it in a multifunctional context. Remaining land is not included in this figure since there are no direct relations to be indicated between remaining land and other functions. This will be dependent on the activities exercised on the remaining land.

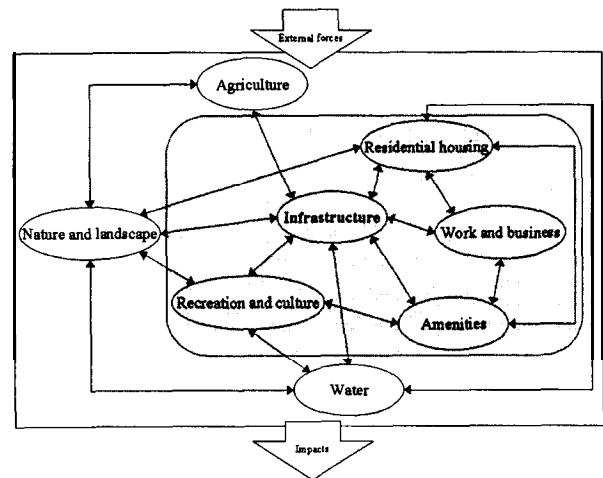


Figure 1 Land use functions

A few remarks should be made. First, **time** is an important aspect of this figure for two reasons. 1) The arrows **all** point in two directions, but this does not necessarily **mean** that both influences take **place** at the same **time**. For example, the influence of residential housing on amenities is direct, since people want shops, schools, etc., close to their **homes**, but the development of a big **shopping centre** does not **necessarily mean** that houses **will** soon be **established** near it. 2) **Also**, more generally, different arrows **may** refer to different **time** spans. For example, **infrastructure** has an influence on **all** other **functions**, but not necessarily at the same moment. Second, it is **very** well possible that certain relationships are more likely to occur than others are.

Urban spatial **structure** consists of the **layout** of the physical **components** of an urban area and their interrelationships. These are continually evolving, so that **spatial structure** is a **dynamic** phenomenon, changing over **time** and in **space** (Dowall, 1978). In determining urban **structures** and location behaviour, the land use system and the transportation system (regarded here as the system of transport **infrastructure**) are highly interdependent. **Briefly stated, location decisions** made as a **result** of land use activities are, to a large extent, the **result** of the relative **cost** of travel to various opportunities. Given the **structure** (**layout**, capacity, geographical position, etc.) of the transportation system, **the** pattern of trips generated by these activities **affects** the **costs** of travel in the region. **It can** be said, therefore, that the spatial organisation of land use determines and, at the same **time**, is determined by, the design and characteristics of the transportation system. It is interesting to analyse this dual relation in greater detail, especially in **light** of multifunctional land use.

3. Definition of land use concepts

Before disussing the dual relation between land use and transport infrastructure, it is important to determine the **main** concepts that **will** be dealt with in this paper: land use, multiunctional land use, and infrastructure. as well as factors determining land use decisions. The **latter** category **will** be **discussed** in Section 4.

Land use generally refers to **"how** land is put to use' (Chapin and Kaiser, 1979). As has been explained in Section 2, nine different land use functions are distinguished here, one of which is infrastructure.

When multiple functions emerge at the same location, there is a shift from monofunctional land use to **multifunctional** land use. To **define** multifunctional land use adequately, it is important to identify its **time** dimensions and its geographical scale **levels**. The **longer** the **time-span** the greater the extent of multifunctional land use. The larger the scope of the geographical scale, the greater the extent of multifunctional land use.

There are several current definitions of multifunctional land use. That of Legendijk and Wissershof (1999) is the most commonly **used**. It **states** that one **can** speak of multifunctional land use **if** at least one of the following four conditions are satisfied: (1) intensification of land use (an increase in the efficiency of the land use for a function); (2) intetweaving of land use (use of the same area for several functions); (3) using the third dimension of the land (the underground along with the surface area), and (4) using the fourth dimension of the land (use of the same area for several functions **within** a certain **time-frame**).

However, there are some remarks to be made that mainly concern the **first** element of the definition. In comparison with the other elements, intensification is **a process**, whereas the other three **elements** represent a **state**. This **means** that intensification itself **cannot** be **observed** in a **static** sense, but only in relation to developments over **time** or between different land use alternatives. Interweaving as **well** as the use of the third and fourth dimension **can** be obsewed as being present or not, at a certain moment. Furthermore, intensification **may strictly** spoken be **also** a matter of monofunctional land use. Only above a certain scale **level intensification can** lead to multiunctional land use. since more land becomes available for other functions. The interweaving of land use is defined by 'use of the same area for several functions'. but it is preferable to **call** this 'diversity'. Intenveaving, then, **can** be seen as the degree in which different functions **touch upon** other functions. For example, within **a** project area of 400 **m²**, four different functions of 100 **m²** each may be **less** interwoven than the same number of functions **having** in total **100m²** per function as **well**, but **scattered** over the project area.

The combination of different land use functions at one location **means** that the land use intensity increases. Since in **many** countries the intensity of land use has increased in the last decades and **will** probably increase further, it is difficult to develop a clear definition of multifunctional land use. The concept of multifunctional land use is **very** broad. It **can** range from **a** combination of two **economic** functions to the combination of **all** nine **economic** functions shown in Figure 1, depending on the **chosen** scale **level**. In this paper, the project **level** has been **chosen** as the scale **level**. The boundaries of the project **define** the area that will be analysed. **When** seen from **a** project perspective, it is **very** hard to **indicate** whether **projects** are multiinctional or not. They **can** only be considered more multifunctional or **less** multifunctional. Therefore, **a** more suitable definition of multifunctional land use in a **dynamic** context would be:

*A land use pattern is **said to** bewme more multifunctional **when** the **average number** of functions **and/or** units of land **increases** in the area **considered**. An **increased** degree of **multifunctionality may therefore result from** the addition of functions to **the area (multifunctionality by diversity) or from a decrease in the average size of monofunctional areas (multifunctionality by interweaving)**.*

Increased multifunctionality **may** be the **result** of market **forces**, government **policies**, or both. From an ewnomic perspective, market **forces can** be subdivided into **demand** factors (**such as an** increased **preference** for diversity of products and services and marketing externalities) and supply factors (**such as** agglomeration externalities).

It is important to identify **specific focal** points in order to design an operational definition of multllunctional land use in actual situations (case studies). Nijkamp et al. (2000a) have **carried out an electronic interactive** consultation about the **definition** of multifunctional land use. The consultation made clear that

when applying the definition of multifunctional land use to actual situations. the **time** dimension and geographical scale **level** must be **specified**, but **also** the following **aspects** need **explicit** consideration:

1. The **efficiency** of the multifunctional land use project, compared to the current use of the land, not only as far as the **costs** of space and space-saving are concerned, but especially, as far as quality of space and sustainability are concerned;
2. The **diversity** of the **project's** appearance: this **can** be an extension, **such** as a new development, **or** an intensification, which **means** a change in the organisation of space;
3. The **synergy** of the **economic** and spatial functions that are brought together. leading to increasing returns to scale.

The third **specific** concept that **will** be **focussed** on in the context of this paper is infrastructure.

Infrastructure is a **very** broad concept that will not be dealt with in full detail in this paper. A **general** description **will** be given **first**, **after** which we will focus on certain **areas**. To **define** the concept of infrastructure turns **out** to be more problematic than one might initially think. Definitions **often** consist of **partial** descriptions or enumerations of elements summarised by the author under the heading of infrastructure. One of the efforts to come to an **integral** definition of infrastructure **can** be found in Nijkamp et al. (2000b) **where** infrastructure is **defined** as **follows** (translated from Dutch): **'infrastructure contains those immovable services that increase the efficiency of the use of production factors and that fulfil the following conditions: infrastructure is directly productive, is characterised by a stock character (capital good) and has the character of a (semi) public good'**.

Nijkamp et al. **define** three **categories** of infrastructure: physical network infrastructure, immaterial knowledge infrastructure and **natural** and environmental infrastructure. The physical network infrastructure **fulfils** the following conditions: it has, to a **large** extent, a **network** character. is largely **non-substitutable**, and is, to a large extent, location-bounded and polyvalent. It is related to transport, public utilities, water management, and industry locations. Since the other two **categories** **fall** outside the scope of this paper, they will not be **discussed** here. This paper addresses transport infrastructure. In the spatial interaction between different **economic** activities, transport **plays** an important **role**. Transport infrastructure facilitates the movement of people and goods, as well as the provision and distribution of services. Transport infrastructure therefore **fulfils** one of the most important spatial functions; transport is one of the most pervasive activities in **any** society or **economy** (Hoyle and Knowles, 1992). The definition of transport infrastructure that **will** be used in this paper is as **follows**: **all** infrastructure present in the **case-**study area that serves the physical movement of people **and/or** goods.

Transport infrastructure **typically** is not supplied through the market **mechanism**. It then **may** become unclear whether **demand** for and supply of infrastructure are harmonised. **If** it is assumed that infrastructure development **follows demand**, norms **can** be set that infrastructure has to **fulfil**. In this case, infrastructure **follows economic** and demographic developments, complementing them. Conversely, infrastructure **can** steer **or** initiate economic development. Investment in infrastructure **can** lead to an increase in productivity and to the creation and relocation of employment and other activities.

4. **Factor0 determining land use decisions**

The most important **concepts** in this paper were defined in the previous **section**: now it is important to analyse why and **how** the concept of multifunctional land **use** originated. To understand land use decisions, we must consider the **factors** determining profitability and utility. Five **main factors** can be identified (based on Harvey, 2000): **accessibility, agglomeration economies, historical/ development, topographical** features, and **technological development**.

. **Accessibility** can be defined as 'the money, **time** and trouble **costs** of getting anywhere' (Harvey, 2000), **where** accessibility increases if these **costs** decrease. **Firms** require accessibility to **factors** of production (especially labour) and to **markets**. Households, on the other hand, require accessibility to work opportunities, shops, schools and recreational facilities. Accessibility is largely dependent **upon** transport facilities; transport **costs** are therefore an important determinant of the locations of **firms** and households. Other determinants are the money, **time** and trouble **costs** of travel as well as communication costs. These **costs** **result** from the **fact** that spatial interaction • in a **general** sense • involves the movement of people, goods, production **factors** or services, or the transfer of ideas and information.

. **Agglomeration** economies, in the broadest **sense**, may also influence location decisions. This **means**, for example, that by locating **closer** together, **firms can produce** at lower **cost**. In agglomeration economies, activities **compete** for **scarce** space. There are various types of agglomeration **economies**, **such** as localisation economies, urbanisation economies and **shopping** externalities (e.g. O'Sullivan, 2000). To **create** localisation **economies**, firms **locate** themselves close to other **firms** in the **industry**, **clustering** in order to decrease their production **costs**. Urbanisation economies occur if the production **cost** of an individual firm decreases as the total output of the urban area increases. **Shopping externalities** arise if shops selling comparable goods **profit** from their mutual proximity by offering consumers greater choica and improving the location's reputation as a **source** for a particular good.

. **Historical development**: current and future development is **often** dependent on past development and on the current function of an area. At some geographical locations, land use patterns **may** be heavily influenced by location decisions made by the Romans or by nineteenth-century **industrialists**; other land use patterns are clearly the product of twentieth-century planning. This path dependency **means** that present spatial organisation is a **logical** starting point for **an** analysis of the future land **use** of certain **areas**.

. **Topographical** features: geographical heterogeneity is an important factor in the location decisions for certain activities. An activity's **ultimate** location is **often** dependent on physical features **such** as rivers, mountains, plains, **slopes**, wind, climate and geology.

. **Technological developments**, together with increases in **real income**, are important **factors** that determine land **use** decisions. The widespread ownership of **cars** and freezers, together with new retailing techniques, largely **accounts** for the setting-up of **out-of-town** hypermarkets, retail warehouses and **shopping centres**. The development of road transport has **also** resulted in the construction of residences on the land between the major transport routes of urban **areas** and in the movement of households towards the peripheries. For **offices**, the **effects** of technological development are mixed. New **building** techniques have reduced the **cost** of upward building, leading to more intensive development of the CBD. Improved information technology. in contrast, enables the majority of office procedures to be **carried out** at sub-centres.

The aforementioned **factors** influencing **ultimate** land use decisions **can also be** used to explain the increasing attention now being paid to multifunctional land **use**.

If different land use functions are combined, **accessibility** becomes even more important. In **every** urban area there are locations **where** the transport routes and systems converge. These locations are the positions with the greatest accessibility for the population of the urban area (Lean, 1969) and are therefore **very suitable** for multifunctional land use. At these locations, transport **costs** are lower (shorter distances, but **also** multipurpose trips), enabling firms and households to save **time** and money on transport. Concerning the **agglomeration economies**. their number could increase with an increase in **multifunctional** land use. Urbanisation economies and **shopping** externalities are particularly likely to **result** kom multifunctional land use. Obviously, *historical/* **development** and *topographical* **features** do not change as a **result** of the combination of functions in space.

The **final** factor, **technological development** is an important reason for the development of the concept of multifunctional land use. Not only improvements in construction techniques, but **also** developments in ICT possibilities have created new insights into opportunities for combining **economic** activities.

Another important element must be taken into account concerning location dectsiions and multifunctional land use: **scarcity of land**. The scarcetty of land is an important reason for the developpment of multifunctional land **use**. People do not want only to live in densely populated **areas**, but **also** want to be able to work, shop, move around, etc. in order to **maximise** their utility. If **all** these different activities have to be carried **out** in a limited space, land use functions will have to be **combined** (e.g., by using the third **and/or** fourth dimension). This type of development corresponds with one of the **main** charactertstics of the urban **economy**; the interdependenca of land **uses**, which is largely created by **external** economies and diseconomies of production and consumption. These **interdependencies** bring about entirely different **uses** and **values** in **areas** with the same **level** of **general** accessibility. The theories on the concentric ring pattern of the spatial distribution of land use and the smooth pattern of the rent gradient **may**, therefore, have to be modified. The spatial distribution of land use patterns **can** be expected to bewme far more

patchy as complementary land use patterns are gathered together in specific parts of the city where they can more easily enjoy the benefits of their proximity. The rent gradient will consequently show "bumps"; temporary rises in land values reflecting areas of land use where neighbourhood economies are very favourable (Newell, 1977).

5. **Relation between land use, infrastructure and the multifunctional organisation of space**

Different relationships between land use and transport infrastructure can be identified. The pattern of influence is mutual: land use influences transport infrastructure, since general spatial and land use patterns have an impact on transport volumes; and transport infrastructure influences land use, since transport infrastructure has certain spatial/land use requirements. This relation is dynamic and ongoing, as is illustrated in Figure 2. The figure shows that basic forces, such as demography, historical developments, geographical location, soil conditions and economic development, form the basis for decisions about land use. Once the land use pattern has been determined, transport infrastructure must be developed to enable the transport of persons and goods to the area (t). Transport infrastructure can also provide access to new areas, thereby enabling land use patterns to change (t+1). Once established, however, land use patterns largely determine demand for transport.

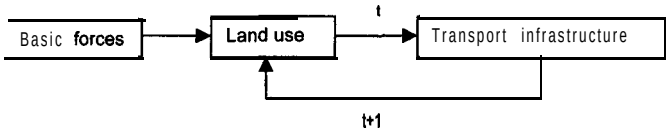


Figure 2 Dynamic relations in the land use - transport system

As early as in the classical economic theories on land use, a relation between transport and land use was identified. The role of transport infrastructure is, directly or indirectly, present in traditional economic growth theories. An example is the location theory, which shows that changes in infrastructure networks lead to changes in the spatial organisation of activities (Bruinsma, 1994). Transport infrastructure influences spatial organisation in various ways, but its major influence on regional economies is that it enables specialisation. A simplified example can serve as an illustration (Taaffe and Gauthier, 1973). If there is little or no transportation as a result of a lack of infrastructure, cities are isolated from each other (Figure 3a). Each individual city (X and Y) produces a range of products dependent upon its own consumption needs. X might, for example, have the best conditions to grow product 1, but the amount of land used for the production of product 1 will depend upon the amount of product 1 consumed by the inhabitants of city X. The same might hold true for city Y for product 2. If transport opportunities arise when a road is constructed between X and Y (Figure 3b), the first signs of specialisation will appear; X will expand its production of product 1, whereas Y will expand its production of product 2. Each city will transport its surpluses to the other. For city Y, the costs of transporting product 1 into its area are lower than the costs of producing product 1.

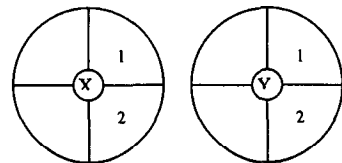


Figure 3a Isolated cities without infrastructure

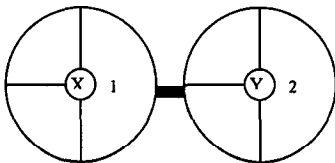


Figure 3b Specialised cities with infrastructure

This example shows the importance of transport infrastructure to regions. The same logic can also be applied to the determination of land use functions. Different land use functions cannot exist in an isolated state in the way that cities can. Different functions always need transport infrastructure between them, since, for example, a residential housing function cannot be economically self-sufficient without a place to grow crops and the opportunity for its inhabitants to buy food. If different land use functions are

combined in **space**, infrastructure is **still** important, since not **all** land use functions **can** be combined in an economically **efficient** way. A certain combination of functions **will** most likely **generate** high revenues, but it is clear that there will always remain **scattered** functions without synergy. The **latter** must be made **accessible** via the transport infrastructure. In other words, only those combinations of functions that are expected to have synergy (or at least no dis-synergy) **effects will** occur.

Transport costs form an important element of the relation between land use and infrastructure. A substantial part of the interaction among urban activities takes place via the urban transportation system. This system **can also** create **changes** through the imposition of its costs on **its** users and on the community at large. A distinction must be made between public and private **costs**. Public **costs** consist of the expenditure of funds by public bodies for the construction, operation and maintenance of transportation facilities, whereas private costs are mainly **out-of-pocket** money and **time** costs to individuals. Public costs **result** from and affect community decisions about **how** the transport system should perform as a **whole**. Private **costs**, on the other hand, **result** from and affect the trip-making and locating behaviour of **persons**. Together, these **costs** have a **huge** impact on the spatial organisation of an urban region, since public investment in infrastructure **tends to reduce** the private **time** or money **costs** of movement. If these **costs** are reduced, the wsts of **economic** linkages of the movement of goods and **persons** will **also** be reduced (Wingo, 1963).

The effect of infrastructure on spatial patterns of **economic** activities is especially important in **areas** with high land use intensity, **where** there is multifunctional land use. The spatial **needs** of transport infrastructure might conflict with, for example, habitats, archaeological sites, cultural and historical **sites**, agricultural **areas**, recreational **areas** or settlements. Transport infrastructure consumes land directly (e.g. roads, rail stations) as well as indirectly (mainly by causing spatial development). The extent of the **space** needed depends on the mode of transport and on the speed of travel (ELTIS, 2002). Integrating the planning of transport, infrastructure, and urban and regional **policies can** help to **reduce** the need for travel and **can** decrease emissions, land use, and resource consumption. For sustainable development, **strategic** integrative planning, which involves impact assessment (i.e. the application of **strategic** environmental assessment), helps to create land use patterns that place activities close to **each** other, thereby reducing the need for travel between them. Planning should emphasise accessibility **rather** than mobility, i.e. the aim of planning should be to enable everyday activities to be **carried out** with less travel. A pattern of smaller urban **areas** is probably not suitable for attaining this goal, since they **generate** more **traffic** than compact centralised cities. On **average**, throughout the EU, travel **demand falls** if population densities are greater than 50 **inhabitants/hectare** (European Environment Agency, 1995). Multifunctional land use **could** be used as an instrument to decrease **demand** for **travel**, **when** it increases population density. One **could** say that the **current** congestion of major roads is a negative development that **encourages** multifunctional land use and multifunctional **time** use, whereas technological **factors** (including ICT) are a positive development that enwrages multifunctional land use and multifunctional **time** use (Priemus et al., 2000). Changes in the **time** and **space** budgets of individuals and households play an important role in this **process**.

6. Framework for analysis

The observations so far form the basis of a framework for the analysis of multifunctional land use projects. The analysis attempts to identify criteria that measure the degree of multifunctionality of a certain land use project. There are various **publications** about **all** kinds of **criteria** and indicators to measure, for example, specialisation, **diversity**, and **intensification** (see, e.g., Harts et al. (1999), Piepers (2001), McCann (2001), and Fouchier (1996)). **However**, the criteria used in this paper do not have to be assigned only to the different land use functions, but have to be **also** adjusted for the scope of a **specific** multifunctional project. The adjustment of criteria will mainly be dependent on the **specific** land use functions involved in the multifunctional project wncemed.

Operational indicators to measure the degree of multifunctionality of a certain land use project have to be **related** to the elements of the definition of multiunctional land use as presented in **Section** 3. As a **starting** point, it is important to **define** what we want to measure, or, in other words, from which viewpoint we want to reason. A **logical** starting point is the creation of a distinction between input and output (performance)

of land use. Since this paper deals mainly with the supply **side** of land use, our **starting point will** be the input **side**.

A **first** multifunctional indicator that **complies** with the definition of multifunctional land use is **diversity**, representing 'the different land use functions that **can** simultaneously be found in the project area at hand'. These **can** simply be **counted** as **frequencies** according to the definitions of land use functions as presented in Section 2:

$$Diversity = \frac{Actual\ number\ of\ functions}{Maximum\ number\ of\ feasible\ functions}$$

The actual number of functions in our case cannot exceed 9; the theoretically maximum number of feasible functions. This **means** that the maximum value of diversity is always 1. This indicator is **very** tentative, but **could** be made more **precise** by identifying and assessing sub-functions.

An indicator that is closely related to diversity is dispersion. This indicator is based on the **Herfindahl-Hirschman index (HHI)** (see Hannan, 1997, and Lijesen et al. 2002) and dependent on the actual number of functions as used for the diversity indicator. Dispersion measures 'the degree to which **each** function is present in equal proportions within the project area (in **m² land use**)', as represented by the following formula:

$$Dispersion = \frac{1}{I \cdot \sum_{i=1}^I (M_i/S)^2}$$

in which:

M_i = the amount of **m²** land used by a single function i (input)

S = the total amount of **m²** land use of the project area

I = the actual number of functions (where **I** has a maximum of 9 (according to the definition of land use functions in Section 2)).

This indicator has a maximum value of **1**, indicating that there is maximum dispersion within the project area, or, in other words, the proportion of **each** individual function is equal to that of the other functions. The minimum value of this indicator varies with the number of functions that are present within the project area. According to our maximum of 9 land use functions as defined in this paper, the minimum dispersion value will be **1/9**. This indicator **will**, ideally, be measured in **m²** land use, since this shows the proportion of territories of land used within the project area by the different functions, and with that, the spatial dispersion of the functions in a flat surface.

The **second** element in the **definition** in the definition of multifunctional land use is **interweaving**, which is defined as 'the degree to which different functions **touch upon** other functions'. This case of interrelatedness **can** be represented by the following formula:

$$Interweaving = \sum_{i=1}^I \frac{B_i}{S}$$

in which:

B_i = the length of physical boundaries with other functions within the project area

S = the total amount of **m²** land use of the project area

I = the actual number of functions (**where I** has a maximum of 9 (according to the definition of land use functions in Section 2)).

This indicator does not reckon with the third **(vertical)** dimension yet and **can** therefore only be measured in **a** flat surface. To solve this shortcoming, the surface of boundaries between land use functions could be measured for **B_i**, and **S** could then be expressed in **m²**. **However**, these are just tentative ideas that have not been crystallised yet, but this will be done in future studies.

Another relevant feature is concerned with intensity of functions. Although *intensification* is as a **process** - in **itself** is **difficult** to observe in **a static** sense, it is **useful** and **illustrative to** show the land use intensity for different land use alternatives. Therefore, it will be used here as one of the indicators representing the degree of multifunctionality of **a specific** land use project. Only in the case of **a** comparison between different alternatives we **may draw** conclusions about the degree of multifunctional land use (possibly related to the third dimension). Intensification should, in **first** instance, be measured for **each** single land use function (i = **1,, I**), which **can** be represented by the following formula:

Intensification = $\frac{Q_i}{M_i}$

in which:
Q_i = the amount of non-land input of **a certain** land use function (houses, employment, etc)
M_i = the amount of **m²** land used by a single function i (input)
I = the **actual** number of functions **(where I** has **a** maximum of 9 (acwrding to the definition of land use functions in **Section 2**)).

Intensification **may also** be measured for the project area as **a whole**:

Intensification = $\sum_{i=1}^I \frac{Q_i}{S}$

in which:
Q_i = the amount of non-land input of the project area
S = the total amount of **m²** land use of the project area
I = the actual number of functions **(where I** has **a** maximum of 9 (according to the definition of land use functions in **Section 2**)).

In this case, in measuring the intensification for the project area as **a whole** we need to have a common unit of measurement to express the non-land **inputs** of the different land use functions. For example, in the **first** indicator for intensification, the input for working and business and amenities is measured via the number of jobs created, and the input for residential housing is measured via the number of houses to be realised. These units cannot be summed up and should therefore be expressed in **a** common unit of measurement. An example of **such a** unit is to express **all** non-land **inputs** in Euro **(€)**.

For future studies, it will be interesting and necessary to analyse the ceteris **paribus** influence of the aggregation **level** of the land use functions on the indicators.

In the next **section**, an example of a multifunctional land use project will be analysed in terms of 'degree of **multifunctionality**'. The aforementioned criteria **will** be applied to the different alternatives for developing the **so-called** South-Axis **(‘Zuid-As’)** in Amsterdam.

7. The Amsterdam South-Axis

The Amsterdam South-Axis ('Zuid-As') is in **general** regarded as **a** location with a high development potential for **offices**, houses and amenities. It is intended to become **a** location with an adequate mix of functions, which should not have **a** negatie effect on the functioning of the city **centre** of Amsterdam. The development of the South-Axis is intended to **create a** new urban environment with its own identity. There are **a** number of goals for the development of the South-Axis, in **particular**: to eliminate the barrier effect

of the ring road around Amsterdam, to prevent monofunctionality. and to create a solid and consistent public space. With the South-Axis project, this part of the city is intended to undergo enormous improvements in quality. Currently, there is already a certain mix of functions available at the South-Axis. There are housing areas of high quality on both sides of the ring road, as well as an international exhibition centre and conference facilities (RAI), the World Trade Centre, a university (Free University) and an academic hospital, the Court of Justice and various office buildings. The Masterplan South-Axis aims at strengthening this mix of functions in order to increase the status of the location as an office location.

In the planning process thus far three alternatives for the development of the South-Axis are distinguished: the Dock alternative, the Dike alternative, and the Combination alternative. These alternatives will be compared with a reference situation, assuming an autonomous development of the area (DRO, 1998).

The Dock alternative puts all infrastructure underground over a length of 1.2 kilometre, providing a huge extra amount of available building space.

In the Dike alternative, all through traffic will be guided on an elevated dike infrastructure. The latter will be situated at the current level on a broadened dike body of 170 m wide. This alternative has a compact terminal for public transport with short transfer distances, the external architecture of the dike is on a qualitatively sophisticated level, and there is an extra underpass for slow traffic.

The Combination alternative combines different aspects of the Dock and the Dike alternative. The essence of this alternative is that only parts of the infrastructure will be brought underground: road traffic will be positioned underground, whereas the rail infrastructure will stay at its current level. In this alternative, the dike will become narrower, allowing for construction of offices and houses on both sides of the dike on top of the road infrastructure (that has been constructed underground).

Table 1 shows the number of m² floor space occupied by certain functions as well as the number of planned jobs and houses within the project area.

Table 1 The three alternatives for the Amsterdam South-Axis ('Zuid-As') and autonomous development in m²

	Autonomous	Dock	Dike	Combi
Total built-up area	962300	2362300	1467000	2004800
Offices	461700 (48%)	984600 (42%)	790200 (54%)	1063900 (53%)
Residential housing	334700 (35%)	1056000 (45%)	466900 (33%)	717200 (36%)
Amenities	165700 (17%)	321700 (13%)	209900 (14%)	223700 (11%)
Infrastructure	1374091	1423031	1374091	1397454
Green	309153	370328	309153	335190
Water	80000	100000	120000	90000
Remaining	827626	562926	787626	723921
Planned jobs	24800	35000	40500	53100
Planned houses	2880	8450	3730	5730

With the data in this table we can try to calculate the indicators as developed in Section 8 (see Table 2). The first indicator is diversity. The value of this indicator is for all four alternatives the same: namely, 1; there are seven land use functions (offices, residential housing, amenities, infrastructure, water, natura and landscape, and remaining) out of seven possible. feasible functions (according to the definitions used in Section 2). Agriculture is not a feasible land use function at the Amsterdam South-Axis.

The second indicator, dispersion, is more difficult to calculate. The only alternative for which all necessary data are readily available is the Dock alternative. For the other alternatives, the data for the Dock alternative have been adapted to the characteristics of the alternative concerned. This means that with the help of a land use map for the Dock alternative, the proportions of land that will be lost by applying the Combi alternative, Dike alternative or Autonomous development (in which only a part of the layer on top of the infrastructure will be realised (Combi alternative) or no extra layer at all (Dike alternative and Autonomous development)) are attributed to the respective land use functions. Furthermore, as a result of a lack of data, the dispersion has been calculated by means of the amount of m² floor space instead of

land use, for the individual land use functions as well as the total project area. The result shows that the Dock alternative has the highest value for dispersion. A value of one would mean that all functions occupy the same share of the project area. Therefore, its value of 0.71 means that, of all alternatives, the land use by the different land use functions in the Dock alternative is most evenly spread.

Also, the calculation of interweaving creates some difficulties. There are no data available on the length of physical boundaries with other functions within the project area for any of the four alternatives. This means that this indicator can only be judged qualitatively. However, since there is no information on the distribution of the functions over the project area (to which extent will the functions be realised in a flat surface or will the third dimension be used), nothing can be said about the qualitative value of this indicator either.

The final indicator of intensification cannot be calculated for each single land use function, since there are no detailed data on land use per function. However, the second indicator for intensification as presented in Section 6 can be calculated, but only for work and business, residential housing, and amenities. It shows some differences between the alternatives as a result of differences in the number of planned jobs and houses in the project area. Since the distribution of m² floor space for houses, offices and amenities differs per alternative as well, the values for intensification for offices, houses, and amenities can best be considered in combination.

Another calculation that could be made with the available data and that is illustrative for intensification is the amount of m² floor space created for work and business, residential housing, and amenities divided by the amount of m² floor space of the total project area, and by the land used for these functions (variants on floor space index (FSI)). These values show which alternative creates the biggest amount of m² floor space within the project area, and which alternative uses the area for offices, housing and amenities most intensively. It is not surprising that the Dock alternative has the highest value on the first indicator, since it has more space available to build offices, houses and amenities, due to bringing the infrastructure underground. However, for the second indicator, the highest value can be found in the Combi alternative. This shows that in this alternative, the buildings will have to be higher in order to create the planned floor space within the planned area. This alternative uses the land for offices, houses and amenities most intensively, which is also reflected in the value for intensification on offices (Q/S).

Table 2 Indicator values for the four alternatives for the Amsterdam South-Axis ('Zuid-As')

		Autonomous	Dock	Dike	Combi
Diversity		1	1	1	1
Dispersion		0.60	0.71	0.67	0.69
Interweaving		n.a.	n.a.	n.a.	n.a.
Intensification:					
1) Q/S	Offices	0.009	0.013	0.015	0.019
	Residential housing	0.001	0.003	0.001	0.002
	Amenities	0.001	0.001	0.001	0.001
2) Floor space created /total project area		0.35	0.85	0.53	0.72
3) Floor space created / total commercial land use		4.97	7.20	7.57	0.42

We have distinguished in an illustrative case study four development alternatives, each characterised by distinct numerical indicators which may be seen as quantitative approximations of attributes of these plan alternatives. This is a clear case of a multi-criteria evaluation problem, which aims to identify the most promising choice possibilities. The four alternatives have been evaluated by means of the so-called Regime analysis, which is a discrete multi-criteria method (Hinloopen et al., 1953; Nijkamp et al., 1990). This method is based upon two kinds of input data: an impact matrix and a set of political weights. The impact matrix shows the effect of each alternative on the indicators considered. The set of weights provides information about the relative importance of the indicators considered. In this analysis no policy weights have been given to the indicators, so we used a uniform weight factor. On the basis of these

inputs, the Regime method provides us with a ranking of the alternatives in terms of multifunctionality (see Table 3).

Table 3 Performance scores of alternatives based on Regime analysis

Alternative	Score
Autonomous	0.00
Dock	0.82
Dike	0.35
Combi	0.83

This table shows that the Combi alternative has the highest score on multifunctionality, although the difference with the Dock alternative is negligibly low. The Dike alternative has a much lower score, whereas the Autonomous development shows the lowest score. A sensitivity analysis attributing different weights to different indicators gives no really different results. Depending on the indicator that will be attributed the highest score, the Combi alternative or the Dock alternative has the highest score. The Autonomous development always has a score of 0, whereas the Dike alternative always has an intermediate score.

Table 3 shows furthermore that given the current available database the Combi and the Dock alternative are obvious examples of alternatives with a high multifunctionality value. The two others are inferior and do not offer a clear contribution to multifunctionality. It should be added that multifunctionality in itself is not a policy goal. It serves merely to realise other objectives, such as a keen management of scarce space. In our particular case, both the Dock and the Combi option reduce the barrier function of the infrastructure and may therefore be attractive policy options, while the multiunctionality is just the instrument through which this objective is met.

These results show that bringing the infrastructure underground creates favourable opportunities for multifunctional land use. The choice for the Dock alternative as the most optimal filling in of the project area, however, is mainly based on the increase in connectivity between the different areas of Amsterdam, which, in this alternative, will no longer be separated by the infrastructure. The importance of infrastructure for the Amsterdam South Axis is recognised and travellers are best facilitated in the Combi and Dock alternative.

8. Concluding remarks

The concept of multifunctional land use has turned out to be a very interesting one in urban and infrastructure planning. Economic research has traditionally put great interest in mainly monofunctional land use based on issues of efficiency and (more recently) sustainability. Multifunctional land use, however, attempts to combine several socio-economic functions in the same area, so as to conserve scarce space and to exploit economies of synergy. Clearly, multifunctional land use shows several relations with monofunctional land use, but is, nevertheless, different in that, from a project perspective, projects can only be considered more multifunctional or less multifunctional. In order to operationalise the concept of multifunctional land use, a functional typology of specific land use functions is needed, along with the development of criteria and indicators to measure the degree of multifunctionality of specific land use projects. From a critical analysis of common definitions of multifunctional land use, the most important elements for measuring the degree of multifunctionality became clear. Applying these indicators to a case study (the Amsterdam South-Axis) showed that different project alternatives might have different degrees of multifunctionality. It is interesting to analyse this in further detail in the light of underlying assumptions regarding the ultimate choice for one of the alternatives. Another future challenge is to adjust the current indicators for a comparison between different projects, instead of an analysis of different alternatives for one project as presented in this paper. Therefore, a reflection on the nature of indicators concerning factors such as aggregation level of land use functions, dispersion, concentration, diversity, interweaving and intensity, taking into account the state of affairs in other disciplines, is likely to be a very interesting exercise.

Acknowledgement

This research is part of a **PhD** project financed by HABIFORUM, the Dutch expertise network on multifunctional land use.

References

- Bruinsma, F., 1994, *De Invloed van Transportinfrastructuur op Ruimtelijke Patronen van Economische Activiteiten*, Academisch proefschrift, Universiteit Utrecht, Nederlandse Geografische Studies, Elinkwijk b.v., Utrecht
- Chapin, F.S. and E.J. Kaiser, 1979, *Urban Land Use Planning*, University of Illinois Press, Urbana
- DRO (Dienst Ruimtelijk Ordening), 1998, *Masterplan Zuidas*, Gemeente Amsterdam
- Dowall, D.E., 1978, *Theories of Urban Form and Land Use: a Review*, Working Paper 295, Institute of Urban & Regional Development, University of California, Berkeley
- European Local Transport Information Service (ELTIS), 2002, <http://www.eltis.org/en/concepts/concept7.htm>
- European Environment Agency. 1995. *Europe's Environment - The Dobbris Assessmant Eurooean Environment Agency, Copenhagen*.
- Fouchier, P., 1996, *Measuring the density: but which density?*, Evry New Town Corporation. French Institute of Town Planning, Paper presented at the Norwegian Ministry of Environment Workshop on 'Density and Green Structure' in Oslo, 25-27 January. 1996
- Hannan, T.H., 1997, Market share inequality, the number of competitors and the HHI: an examination of bank pricing, *Review of industrial organisation*, Vol. 12, pp. 23-35
- Harts, J.J., C. Maat and D. Zeijlmans van Emmichoven, 1999, *Meervoudig Stedelijk Ruimtegebruik; methode en analyse*, Stedelijke en Regionale Verkenningen 20, Delft University Press, Delft
- Harvey, J., 2000, *Urban Land Economics*. MacMillan Press Ltd., London
- Hinloopen, E., P. Nijkamp and P. Rietveld, 1983, *Qualitative Discrete Multiple Criteria Choice Models, Regional Planning, Regional Science and Urban Economics*, pp. 77-102
- Hoyle, B.S., and R.D. Knowles. 1992, *Transport Geomphy; an Introduction*, in: Hoyle, B.S., and R.D. Knowles (eds.), *Modem Transport Geomphy*, Belhaven Press, London, pp. 1-11
- Legendijk, A., and J. Wissershof, 1999, *Geef Ruimte de Kennis, Geef Kennis de Ruimte, deel 1: Verkenning van de kennisinfrastrcutuur voor meervoudig ruimtegebruik*, Rapport aan de Raad, RMNO-nummer 138
- Lean, W., 1969, *Economics of Land Use Planning; Urban end Regional*, The Estates Gazette Limited, London
- Lijsen, M.G., P. Nijkamp and P. Rietveld, 2002, Measuring Competition in Civil Avlation, *Journal of Air Transport Management*, Vol. 8. pp. 189-197
- McCann, P., 2001, *Urban end Regional Economics*. Oxford University Press, Oxford
- Newell, M., 1977, *An Introduction to the Economics of Urban Land Use*, The Estates Gazette Limited, London
- Nijkamp, P., P. Rietveld and H. Voogd, 1990, *Multi-criteria Analysis for Physical Planning*, Elsevier, Amsterdam
- Nijkamp, P., R. Vreeker an H. van Delft, 2000(a), *Electronische Interactieve Consultatie EMR: Een gezelschapsdiscussie over het begrip Meervoudig Ruimtegebruik*, Vrije Universiteit, Amsterdam
- Nijkamp, P., B. Ubbels en M. Koetse, 2000(b), *Infrastructuur als portfolio. Een duurzaamheidsvisie op infrastructuur*, Delftse Universitaire Pers, Delft
- O'Sullivan, A., 2000, *Urban Economics*, Irwin McGraw-Hill, Boston
- Piepers, P., 2001, *Financiële Haalbaarheid van Meervoudig Ruimtegebruik bij Infrastructurele Knooppunten*, Afstudeeronderzoek Technische Universiteit Delft, Delft
- Priemus, H., P. Nijkamp en F. Dieleman, 2000, *Meervoudig Ruimtegebruik: stimulansen en belemmeringen*, Stedelijke en regionale verkenningen 24, Delftse Universitaire Pers, Delft, 116 p.
- Rodenburg, C.A., 2001, *Multifunctional land use in The Netherlands*, Paper presented at the ERSA Conference of the European Regional Science Association, August 29-Sept 1, Zagreb
- Taaffe, E.J., and H.L. Gauthier, jr., 1973, *Geomphy of Transportation*, Prentice-Hall, Inc., Englewood Cliffs. N.J.
- Wingo, L., 1963, *Urban Space in a Policy Perspective*, in: *Cities end Space; the Future Use of Urban Land*, Essays from the fourth RFF forum, Wingo, L., (ed.), The Johns Hopkins Press, Baltimore

1999-1	Antoon van den Elzen Hans Kremers	An Adjustment Process for Nonconvex Production Economies , pp. 24
1999-2	Peter Nijkamp Aura Reggiani Wai Fai Tsang	Comparative Modelling of Interregional Transport Flows Applications to Multimodal European Freight Transport, pp. 22
1999-3	Elly Lancker Peter Nijkamp	A Policy Scenario Analysis of Sustainable Agricultural Development Options , pp. 21
1999-4	Peter Nijkamp Gabriella Vindigni	Impact Assessment of Qualitative Policy Scenarios A Comparative Case Study on Land Use in Sicily, pp. 22
1999-5	Peter Nijkamp	Advances in Comparative Assessment Research in the space-economy , pp. 20
1999-6	Cees Gorter Peter Nijkamp	Experts on Speaking Terms with Public Policy-makers A case study on the IJssel-Vecht delta, pp. 21
1999-7	Frank Bruinsma Peter Nijkamp Ron Vreeker	Experts at Arm's length of Public Policy-makers A case study on Utrecht, pp. 23
1999-8	Peter Nijkamp	Critical Success Factors for Soil Remediation Policy: A meta-analytic comparison of Dutch experiences , pp. 17
1999-9	M.J.N. Keijer P. Rietveld	How do people get to the railway station; A spatial analysis of the fust and the last part of multimodal trips, pp. 21
1999-10	Peter Nijkamp	Meta-analysis : A methodology for research synthesis , pp. 10
1999-11	Marina van Geenhuizen Peter Nijkamp	The learning capability of regions : patterns and policies , pp. 23
1999-12	Bart Wiegmans Peter Nijkamp Enno Masurel	Intermodal Freight Terminals: Marketing Channels and Transport Networks, pp. 23
1999-13	Frank A.G. den Butter Egbert L.W. Jongen Udo Kock	Competition Between Unemployed and Non-Participants , and Unemployment Hysteresis, pp. 16
1999-14	Bas van der Klaauw Udo Kock	Deregulering van de Nederlandse Woningmarkt, pp. 19
1999-15	Louise Gogran Gerard J. van den Berg	The Duration of Unemployment in Russia , pp. 43