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Sustainability screening tool for decision-making assistance in the field of urban mobility

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Abstract

Since the early 1990s, the concept of sustainable development has been broadly used in many areas. In the field of urban mobility, sustainability goes together, on the one hand, with sustainable products and services (i.e. with low negative impacts on the environment, on the economy and for people all along their life cycle) and, on the other hand, with the reduction of the utilization of the private car in favour of public transport facilities. Indeed, in the city, car is responsible for traffic jam, noise, air pollution and petroleum dependence.

Therefore, for the enterprise in charge of public transport, the challenge is to implement sustainable products or services that incite people to switch from their private car to public transport facilities. However, even if numerous ideas (i.e. products that are described with a low level of detail) exist to improve the attractiveness of public transport, it is difficult to identify the real potential about sustainability of these ideas since assessments are time and costs intensive.

In the hand of the enterprise in charge of public transport, a method – and by extension, a tool – that assesses quickly and simultaneously, on the one hand, the sustainability impacts of ideas and on the other hand, the resulted modal shift, is still missing.

The present study exposes the development of a sustainability-screening tool that estimates in a short time and with little expertness's need if ideas designed to improve the attractiveness of public transport are endorsing or countering sustainable development.

In the screening tool, the three spheres of sustainability (environmental, social and economic factors) are considered; however, the focus is on the environmental and social spheres. The methodology for the evaluation of environmental impacts is based on Life Cycle Assessment, though simplified. Environmental indicators have been chosen and their assessment is made quantitatively in connexion with an existing database. Social indicators that cover the main basic needs and wants of public transport users have been identified through experts' interviews and qualitatively evaluated.

A module runs on the background of the tool in order to evaluate thanks to the identification of target users and to the evaluation of the social indicators, if people will indeed switch from their private car to public transport.

Once the sustainability screening has been provided, the results are aggregated and represented for each idea in a descriptive way in resident-equivalents and comparatively regarding the situation before and after the implementation.

The screening tool has been modelled under a spreadsheet application with general data for Western Europe and specific data for the city of Munich (e.g., regarding demographic data). Simulations have been run for Munich for four case studies with ideas that come from user integration. The results of the case studies have shown that the screening is suitable to evaluate products or services that are related to infrastructure, to virtual services, to innovation or to none 'technology-innovative' projects. The flexibility of the screening, in particular within the analysis of the robustness of the results, helps for finding better solutions or adaptations of the initial idea.

Thus, the sustainability screening affords a first estimation to know in a short time if an idea will have positive or negative contribution to sustainability. In decision-making processes of enterprises, the screening is essential as 'pre-feasibility' study.

The screening tool can be transferred to other cities and other mobility systems by enhancing the database with adequate demographic data. Further research and development are required especially with regard to empirical social research in order to avoid arbitrariness during the evaluation of the social indicators.

Zusammenfassung

Seit den frühen 1990er Jahren werden Konzepte für eine nachhaltige Entwicklung in vielen verschiedenen Bereichen eingesetzt. Im Bereich der urbanen Mobilität gehen Fragen der Nachhaltigkeit einher zum einen mit nachhaltigen Produkten und Dienstleistungen (die zum Beispiel nur wenig negative Einflüsse auf die Umwelt, die Wirtschaft und auf das Leben der Menschen haben) und zum anderen damit, dass die Menschen immer weniger ihre privaten Fahrzeuge und immer mehr die öffentlichen Verkehrsmittel nutzen. Denn insbesondere die vielen Autos sind in den Städten für Staus, Lärm und Verschmutzung verantwortlich.

Gerade deshalb besteht für die Unternehmen, die für die Organisation des öffentlichen Verkehrs verantwortlich sind, die große Herausforderung neue Produkte und Dienstleistungen einzuführen, die die Menschen dazu bringen auf den öffentlichen Verkehr umzusteigen. Aber auch wenn es viele Ideen gibt, die die Attraktivität der öffentlichen Verkehrsmittel verbessern, ist es oft schwierig deren wirkliches Potential abzuschätzen, da komplette Beurteilungen oftmals Zeit und Kostenintensiv sind.

Für die entsprechenden Unternehmen gibt es immer noch keine Methode oder ein Tool, das eine schnelle Möglichkeit bietet, um zum einen die Nachhaltigkeit von Ideen und zum anderen deren Einflüsse auf den Verkehr darzustellen.

Diese Arbeit beschreibt die Entwicklung eines Nachhaltigkeits-Screening-Tools, mit dem in kurzer Zeit und ohne großes Expertenwissen beurteilt werden kann, ob Innovationen, die die Attraktivität des öffentlichen Verkehrs verbessern sollen, eine nachhaltige Entwicklung wirklich fördern oder nicht. In diesem Screening-Tool sind die drei Ebenen der Nachhaltigkeit (umwelt-, soziale- und wirtschaftliche Ebenen) zusammengefasst. Nichts desto trotz liegt das Hauptaugenmerk auf der umwelt- und der sozialen Ebene. Die Methode um die Einflüsse auf die Umwelt zu beurteilen basiert auf einer vereinfachten Ökobilanz. Es wurden Umweltfaktoren ausgewählt und deren Beurteilung wird quantitativ mit existierenden Datenbanken abgeglichen. Mit der Hilfe von Experteninterviews wurden soziale Indikatoren, die die grundlegenden Wünsche und Bedürfnisse der Menschen in Bezug auf die Nutzung der öffentlichen Verkehrsmittel beschreiben, identifiziert. Im Hintergrund des Tools läuft ein Modul ab, das auf Basis einer Identifikation von Zielpersonen und durch die Beurteilung von sozialen Indikatoren ermittelt, ob die Menschen wirklich von ihren privaten Autos auf die öffentlichen Verkehrsmittel umsteigen. Mit dem Nachhaltigkeitsscreening werden die Ergebnisse für jede Idee vergleichend für die Situation vor und nach der Implementierung dargestellt.

Das Screening-Tool wurde mit Hilfe eines Tabellenkalkulationsprogramms mit allgemeinen Daten von West-Europa und mit spezifischen Daten von München (unter anderen demographischen Daten) erstellt. Zusätzlich wurden vier Fallstudien für München simuliert. Die Ergebnisse dieser Fallstudien haben gezeigt, dass das Screening in der Lage ist, Produkte und Dienstleistungen, die mit der Infrastruktur, virtuellen Dienstleistungen und Innovationen zu tun haben, zu beurteilen. Die Flexibilität des Screening-Tools in Verbindung mit den belastbaren Ergebnissen hilft bessere Lösungen und Umsetzungen für neue Ideen zu finden. Dafür bietet das Nachhaltigkeits-Screening die Möglichkeit einer ersten Abschätzung, um in kurzer Zeit beurteilen zu können, ob eine Innovation positive oder negative Auswirkungen in Bezug auf die Nachhaltigkeit hat oder nicht. In dem Prozess der Entscheidungsfindung von Unternehmen ist diese Screening essentiell für eine Vorabstudie. Das Screening Tool kann leicht auf andere Städte oder Mobilitätssysteme übertragen werden, indem die Datenbank mit den entsprechenden demografischen Daten erweitert wird. In Zukunft sind weitere Forschungen und Entwicklungen mit der Betrachtung empirischer sozialer Daten erforderlich, um Willkür bei der Wahl der sozialen Indikatoren zu vermeiden.

Résumé

Depuis le début des années 1990, le concept de développement durable a été utilisé à de nombreuses reprises dans divers secteurs. Dans le domaine de la mobilité urbaine, le développement durable va de pair, d'une part, avec le développement de produits et de services durables (c'est-à-dire dont les impacts sur l'environnement, l'économie et les personnes sont faibles tout au long de leur cycle de vie), et, d'autre part, avec la réduction de l'utilisation de la voiture particulière en faveur des transports en commun. En effet, en ville, l'utilisation de la voiture est la cause d'embouteillages, de nuisances sonores, de pollution atmosphérique et de dépendance aux ressources pétrolières.

Ainsi, pour l'entreprise responsable des transports en commun, le challenge est de développer des produits et des services durables qui incitent les personnes à ne plus se déplacer en voiture mais en transport en commun. Cependant, même si de nombreuses idées (c'est-à-dire des produits décrits avec un faible niveau de détail) existent en vue d'améliorer l'attractivité des transports en commun, il est difficile d'identifier le potentiel réel au niveau du développement durable de ces idées puisque les évaluations impliquent des facteurs de temps et de coûts élevés.

Dans les mains de l'entreprise en charge des transports en commun, une méthode – et par extension, un outil – qui évalue rapidement et simultanément, d'une part, les impacts qu'ont des produits sur le développement durable et, d'autre part, le changement modal induit par ces idées est nécessaire et n'existe pas.

La présente étude décrit le développement d'un outil de screening pour le développement durable qui estime en un court temps et avec un faible degré d'expertise requis si les idées développées pour améliorer l'attractivité des transports en commun soutiennent ou freinent le développement durable.

Dans l'outil de screening, les trois sphères du développement durable (environnement, société et économie) sont considérées ; toutefois, l'attention est portée sur les sphères environnementales et sociales. La méthode d'évaluation des impacts environnementaux est basée sur une Analyse de Cycle de Vie simplifiée. Des indicateurs environnementaux ont été sélectionnés et évalués quantitativement en rapport avec une base de données déjà existante. Des indicateurs sociaux qui couvrent les principaux besoins de base et personnels des utilisateurs des transports en commun ont été identifiés à l'aide d'interviews d'experts et évalués de manière qualitative.

Un module fonctionne en arrière plan de l'outil de screening afin d'évaluer le changement de comportement des personnes quant à leur moyen de transport, et ce, à l'aide de l'identification d'utilisateurs cibles et à l'évaluation des indicateurs sociaux.

Une fois que l'outil de screening a délivré ses résultats, ceux-ci sont agrégés et présentés de manière descriptive sous forme de « résident-équivalent » et de manière comparative selon la situation antérieure et postérieure à la mise en place de l'idée.

L'outil de screening a été programmé à l'aide d'un tableur avec des données générales pour l'Europe occidentale et des données spécifiques pour la ville de Munich (par exemple en ce qui concerne les données démographiques). Des simulations ont été opérées pour la ville de Munich sur quatre cas d'étude avec des idées provenant des utilisateurs. Les résultats de ces cas d'étude ont démontrés que l'outil de screening est approprié pour évaluer des produits ou des services qui sont liés aux infrastructures, à des services virtuels, à des innovations ou à des projets sans innovation technologique. La flexibilité de l'outil de screening, en particulier en ce qui concerne l'analyse de sensibilité des résultats, aide à trouver de meilleures solutions ou adaptations à l'idée initiale.

Ainsi, l'outil de screening du développement durable permet une première et rapide estimation des effets positifs ou négatifs d'une idée sur le développement durable. Dans les processus décisionnels des entreprises, le screening est nécessaire comme « pré-étude » de faisabilité.

L'outil de screening peut être transféré à d'autres villes et d'autres systèmes de mobilité en complétant la base de donnée avec les donnés démographiques adéquates. Des recherches et développements supplémentaires sont envisageables en particulier en ce qui concerne les indicateurs sociaux afin d'éviter que leur évaluation soit arbitraire.

Table of contents

1 Introduction and objectives

1.1 Purpose of the work

The purpose of the work is the development of an **integrated screening tool for the sustainability assessment of ideas (products or services) designed to improve the attractiveness of public transport**. "Integrated" means that the stakeholders (i.e., businesses) take part in the evaluation and not only receive it. "Screening tool" means that the process is systematic and thus can run partly automatically after entry of data. It has to be flexible and transparent (especially concerning the assumptions made), and with easily available input data. Adapted to the field of research "urban mobility and public transport", the screening tool is at the interface during decision-making processes among public authorities, enterprises and individual consumer. "Sustainability" in the tool is related to the assessment of environmental, economic and social impacts. Sustainability indicators have to be chosen in relation with the goal of the study and the screening-tool practitioner.

1.2 Definition of sustainable development in the context of the work

1.2.1 Sustainable development: Origin and interpretation of the concept

Origin of sustainable development

Every one speaks about sustainable development: politics, NGO in summit meeting, industry, urban planning, agriculture, or even in marketing schemes. Sustainability and sustainable development are catchwords that dominate today's environmental science and policy discourse (Graedel & Klee 2002). However, what is sustainable development exactly? The expression "sustainable development", beyond the first official definition from the Brundtland report (WCED 1987), is seen as a multi-interpretable notion, even if everyone agrees on the fact that our world is not sustainable since it is not extensible in time and space (Bourg 2002).

Looking back before the World Commission on Environment and Development (WCED) of 1987, the **first thoughts** about the scarcity of resources (i.e. the limitations in time and space) can be found concerning forestry management in German literature. In 1713, the concept of "durable use" (in German "nachhaltende Nutzung") came for the first time from

Hans Carl von Carlowitz in order to find a reasonable and durable method to manage forests (Carlowitz 1713; Grober 2000; Weber-Blaschke 2009; Weber-Blaschke et al. 2004).

By the 20th century, the industrial revolution had led to an exponential increase in the human consumption of resources. Accordingly, economists, ecologists and philosophers are questioning about the growth of material and energy flows and about the limits that are induced (Weber-Blaschke 2009).

Sustainability: A multi-interpretable notion

It is, however, difficult to give an **objective definition** of the term sustainable development, since there is a value problem depending if we speak of developed or developing countries, market-oriented or centrally planned. Interpretations will vary, but can share, for instance, certain general features on the basic concept of sustainable development proposed by the World Commission on Environment and Development (WCED) "Our Common Future", also known as the **Brundtland report** (WCED 1987):

> **Definition of sustainable development within the Brundtland report (WCED 1987, p.24)**
>
> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The definition establishes a diplomatic **compromise** between the **protection of the nature**, introduced by the northern hemisphere countries, and the **economic growth**, needed for the southern hemisphere countries (Bourg 2002).

The Brundtland report led to the first Earth Summit - the United Nations Conference on Environment and Development - at Rio de Janeiro in 1992, and to the formulation of Agenda 21, a program of actions for the 21th century (UN 1993). Agenda 21 is a comprehensive plan of action to be taken **globally, nationally and locally** by organizations of the United Nations System, governments, and major groups in every area in which human activity impacts on the environment. The European Union sets its Sustainable Development Strategy (SDS) key objectives relating to environmental protection, social equity and cohesion, economic prosperity and international responsibilities to encourage the establishment of democratic institutions across the world, based on peace, security and freedom (EU 2009a). In response to the Agenda 21 program, at the national level, in Germany, the Federal Government, assisted by Federal Ministry for the Environment, published its "Strategy for Sustainable

Development" as guidelines for politic decisions, which can be resumed in the development of an **sustainability indicator system** adapted to the country (BMU 1999, 2003; Bundesregierung 2002).

Environmental policy and sustainable development programmes have to consider the issue of the appropriate scale at which processes and actions should be targeted and deployed. There are economic and political reasons why structural change has to deal with things on a large scale (global, national). However, attitudes and values are not homogenous and programmes have to be developed **at the local level**, with the involvement of all the stakeholders (local authorities, businesses and individual consumers). As crystallized in Rene Dubos's aphorism, **"Think Globally, Act Locally"** since global initiatives are inadequate without local actions attuned to the different needs of each locality (Dubos 1981).

1.2.2 Actors of sustainable development at the local level

Sustainable development – like any development – is inducing diverse stakeholders, which have their own drivers and their own influences. Tukker (2008) speaks of a **triangle of actors** with power balances (Figure 1.1), which should be analyzed and mutually re-enforced on a sustainable way.

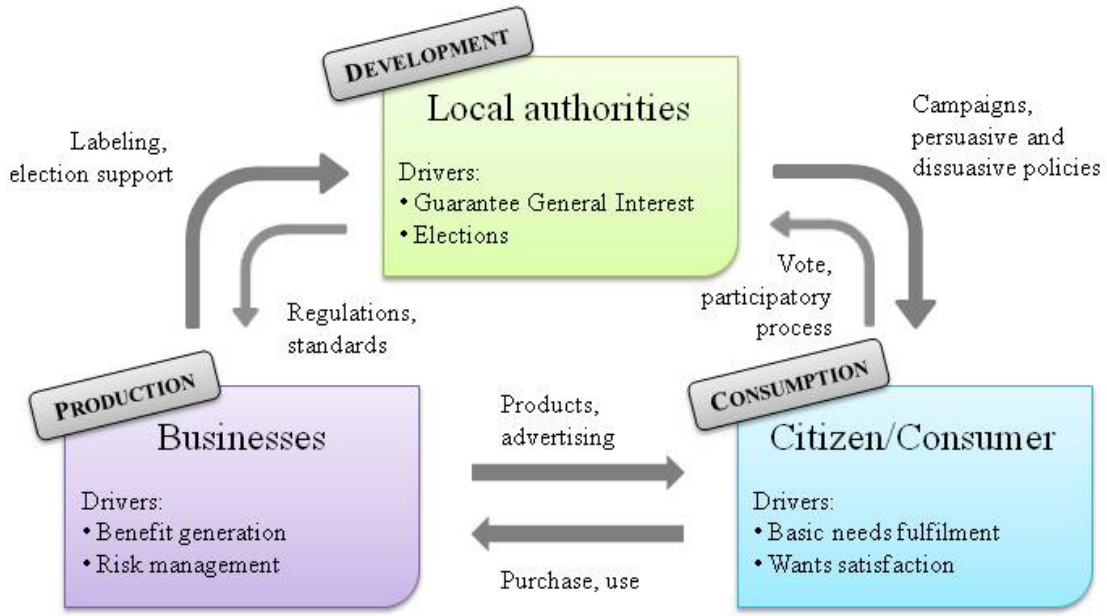


Figure 1.1: Triangle of stakeholders for sustainable development with drivers and power balances (own representation on the basis of Tukker et al. 2008)

Local authorities

Local authorities are responsible for the **guarantee of general interest**, i.e., interest of every member of the community or city. With elections' interest in the background, local authorities are supporting economic growth and in the same time, they promote respect of environmental and social standards. Governmental role of supporting sustainable market frameworks is very relevant. Influence on consumer behaviour and businesses via **push and pull measures**, i.e., dissuasive and persuasive policy. For instance, push measures consist in fostering the greening of innovation systems and support sustainable entrepreneurs, promote consumer power and choice, promote transparency on social and environmental issues related to products. Pull measures are for instance regulations with setting of minimum standards or setting of basic advertising norms (Tukker et al. 2008).

Practically, numerous cities and communes adopted their own Agenda 21. For instance, the senate of Berlin has developed its action program e.g. for protecting health of citizen, encouraging economic development of the city and reduce the criminality (Berlin-Senat 2009). Similarly, "Agenda 21 for Munich" initiates diverse projects like residential building cooperative, climate change campaigns, involvement of young people in city planning decision process, survey about life-style, etc. (Landeshaupstadt_München 2006).

Private enterprises (businesses)

The vital role of business in contributing to sustainable development is now well established as a principle both in governments and in leading business circles (Charter et al. 2008). Traditional strategies and decision-making are influenced by the need to generate profit, manage risk, reduce costs and meet internal ambitions. Related to sustainability, enterprises might have reasons to switch to more sustainable production, for instance, to avoid crises related to environmental pressures or rising prices for energy and materials, or to fulfil consumers' expectations.

Within the enterprise, researchers focused on solutions to attain sustainability goals, which have to stay closed to the intern goals of the enterprise, i.e. reduction of costs and generation of benefits. With the promise of a **factor four**, Weizsäcker (1997) has put the accent on the **resource efficiency** thanks to new technologies and adaptation of market situations (Weizsäcker et al. 1997). Similarly, the **resource flow management** encourages conservation of natural resources, waste avoidance and reduction of environmental stress by copying functions and strategies of natural systems, which are stable and durable, in

comparison with our technical and economic systems (Weber-Blaschke 2009). Lastly, the concept of **industrial ecology** draws a closed cycle between industries, namely the waste from one enterprise can potentially be the resource of one other (Bourg & Erkman 2003).

Looking beyond the boundaries of the enterprise and taking into account the triangle of actors and power balances (Figure 1.1), the most common approaches to contribute to sustainable development, and especially to sustainable consumption, are through the creation of **sustainable products**.

Citizens – Individual consumers

At the **individual** level, the involvement of the consumer reminds us that the sustainable development is a **participatory process**. Individual consumers can act on sustainable development depending on their **consumption** and on their **lifestyles**. Therefore, consumer behaviours and consumption patterns must be studied in relation to sustainability. However, it is necessary to take into account that consumers are not only individuals and actors in the market; they belong to communities with specific values and local cultures influenced by political and economic context. From this perspective, norms, habits and routines are decisive factors explaining **everyday life consumption practices** (Stø et al. 2008). We must not forget that consumption in modern societies is, to a very large degree, the consumption of ordinary products, with few opportunities for excitement. Therefore, to reach a change in the individual behaviour, people need good reasons to change their habits. These reasons can be new products that improve the consumer quality of life.

Indeed, in the everyday life, the decisions that we take are governed by our **quality of life**, defined as the interaction of the basic human needs and personal wants on the one hand, and the subjective perception of their fulfilment on the other hand (so-called "subjective well-being") (Max-Neef 1992). Nevertheless, even if the basic needs are at the centre of the sustainable development definition in the Brundtland report, they rarely appear in decision-making processes, since they are dealing with sociological, psychological, and even philosophical concepts which are not always tangible for policy makers (Rauschmayer et al. 2010). It is indeed difficult to give an objective definition of what are needs and wants. Researchers are often looking for other points of departure because of the reductionist character and the moralistic bias of the needs approach (Stø et al. 2008). More than sixty years ago, Maslow (1943) makes a distinction among material needs (at the bottom of his hierarchy), social needs and self-realisation needs (at the top of his pyramid). His – controversial – argument is that materials needs have to be, at least partially, satisfied before

needs that are higher in the hierarchy may become important sources of motivation (Maslow 1943). Based on the work of Max-Neef (1992), Costanza et al. (2007) proposed a list of basic human needs, which is comprehensible and universally applicable. Subsistence, reproduction, security, identity, and freedom are – among other needs – the foundation of our quality of life and embrace individual, environmental, economic and societal aspects, in the same way than sustainable development approaches. These **basic needs** are reflecting the general interest, since they are similar for everyone around the globe. Nevertheless, even if the fulfilment of these basic needs is a sine qua non condition of happiness, it does not define the entire satisfaction of everyone. Indeed, each human being has individual expectations, so-called "**personal wants**" (Stø et al. 2008), which he/she tries to fulfil. Depending on place of living, personality and preferences, these expectations are different for everyone and they are therefore mostly subjective, whereas the basic needs are predominantly defined in an objective way. Both needs and wants are anchored to the concept of sustainable development through the – intergenerational – **equity principles** about human rights and individual freedoms (Padilla 2002; Sneddon et al. 2006).

1.2.3 Sustainability: the thesis's normative stance

Now that the actors at the local level involved in sustainable development are known, it is possible to define the stance of the present study relating to sustainability.

'Traditional' and 'modern' sustainability

As with many concepts, there is agreement as long as a concept is expressed as a general notion, but there is interpretative conflict when the notion is specified (Tukker et al. 2008). The same is the case with the concept of sustainable development. Nevertheless, independently of the level of application, sustainable development is commonly correlated with **three pillars.** The first one, the **environmental** pillar, introduces the idea of limits, and implies not to exceed the regenerative capacity of the nature. The two other pillars, the **social** and **economic** pillars, are there for the satisfaction of the needs. The famous "sustainability triangle", portraying sustainability as interrelated development throughout economic, social and environmental axes, reflects the "traditional" sustainability approach (Figure 1.2).

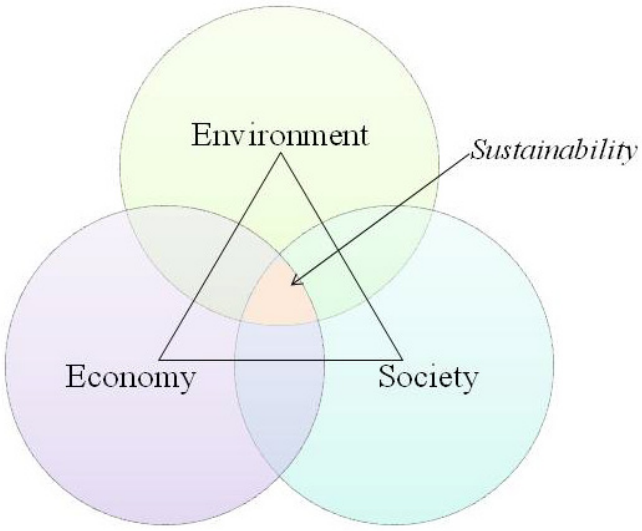


Figure 1.2: “Traditional” definition of sustainability (Weber-Blaschke 2009; Weber-Blaschke et al. 2004; Williams et al. 2003)

Beyond this definition, a “modern” concept of sustainable development emerges from many discussions in which the environment builds the boundaries of our development; and the society and the economy evolve within it (SRU 2002; Weber-Blaschke 2009; Weber-Blaschke et al. 2004; Williams et al. 2003) (Figure 1.3).

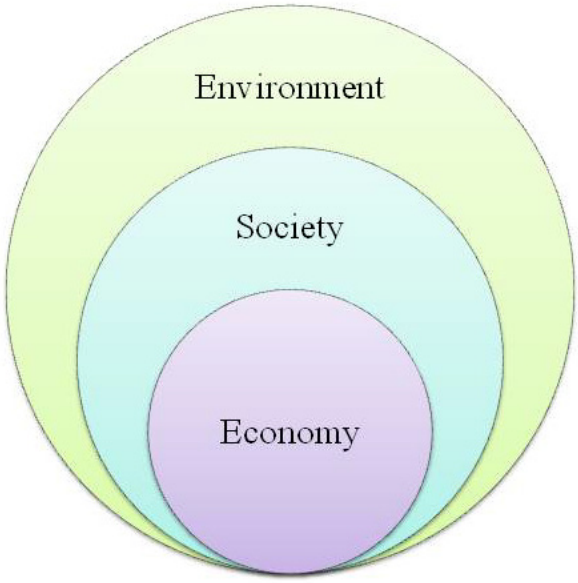


Figure 1.3: “Modern” definition of sustainability (Weber-Blaschke 2009; Weber-Blaschke et al. 2004; Williams et al. 2003)

Nevertheless, this concept is suitable for the development of an entire country, and it is difficult to apply it to a restrictive area where the individual consumer/citizen is specifically considered.

For companies, a recognized concept is the **triple bottom line**. Coined in 1996 by Elkington, the triple bottom line captures the idea that a sustainable business considers the needs of all stakeholders instead of solely maximizing profit for shareholders (Elkington & Trisoglio 1996). The triple bottom line is made up of the following:

- **People**: A business that wants to succeed sustainably must have a heightened commitment to providing products or services that comply with social norms and rules while contributing to an enhanced quality of life for all stakeholders.
- **Planet**: For businesses, it means lightening their impact on the planet and it includes decreasing waste flows and reducing their use of energy and other non-renewable resources.
- **Profit**: A company must generate profit and cash flow in order to remain solvent and continue its operations.

The triple bottom line is in the same vein as Dubos's aphorism "Think Globally, Act Locally" (Dubos 1981), since the local actions of businesses attuned to the different interests of each stakeholders (e.g. profit for the company) have global impacts, mainly on the environment. Beyond the geographical scale, the triple bottom line underlines that economy and ecology are two concepts interrelated on a time scale since ecology can be seen as **long-term economy** (Lubbers 2005).

Sustainability within this work

Inspired from the representation of the modern sustainability (Figure 1.3) and from the triple bottom line definition, sustainable development is illustrated in this work with **people in the foreground** and the **planet as boundary** (Figure 1.4).

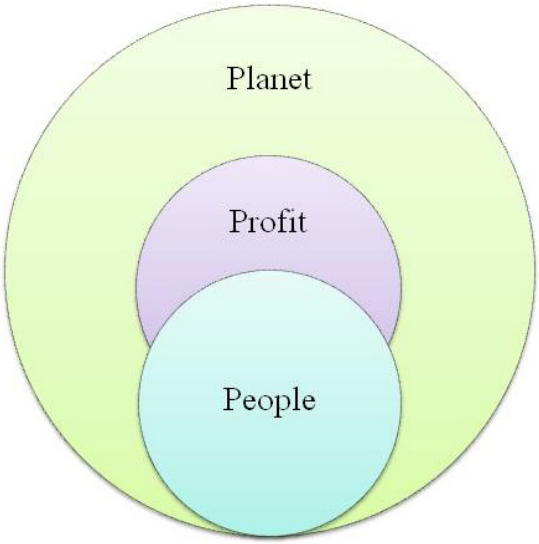


Figure 1.4: Definition of sustainable development within this work (own representation, adapted from Elkington & Trisoglio 1996; Williams et al. 2003)

In this definition, the profit is not encompassing the action of the people and their quality of life, but it is seen as an **endorsement** of the development within the boundaries of the planet. Considering Dubos's adage "Think Globally, Act Locally" (Dubos 1981), the study is **focused on individual consumers** (i.e., the smallest entity where actions can be done). It considers indirectly all the stakeholders of sustainable development at the local level and observes **the global impacts on the planet**. The stance in the study is to reach thereby – as far as possible – a **win-win situation** in development, production and consumption on a local level without crossing the boundaries of the planet, i.e. on a global level. The sustainability-screening tool is developed bearing in mind this stance: The people and their behaviour are at the foreground, and the planet is endorsing the resulting impacts of these behaviours and fixing the boundaries.

1.2.4 Sustainable development and public transport

The problematic of urban areas and transportation

The city is the centre for habitation, work, education, culture and the economy. In Germany, 85% of the population is living in urban areas (Destatis 2011), and the attractiveness is even growing. Even if there are more and more technologies for information and communication, there is still a high relevance for physical mobility (BMVBS 2009). Thus, transport system

in the city is often described as the **blood system of society** and especially that of the economy (Givoni & Banister 2010). The focus is here on person mobility, which is the **result of needs and wants** of the people to change place mainly in order to go to work, to go shopping and for leisure (MVV 2010b). Nevertheless, the achievement of these needs and wants are **restricted through time and budget** (Schafer & Victor 2000). On average in Munich, a person spends 85 minutes per day commuting (MVV 2010b) and devotes a predictable fraction of income to travel.

Everyone may choose for his/her travel in urban area a different transport mode, mainly among Motorized Individual Transport (MIT, i.e. cars, motorbikes), public transport, bicycle or by foot. Considering a specific population, the proportion of the different transport modes per trips is called **modal share** and can be assessed thanks to surveys, as it was done for example for the Munich area by the enterprise in charge of public transport, namely the Munich Transportation and Tariff Association (in German, Münchner Verkehrs- und Tarifverbund – MVV) (Figure 1.5) (MVV 2010b).

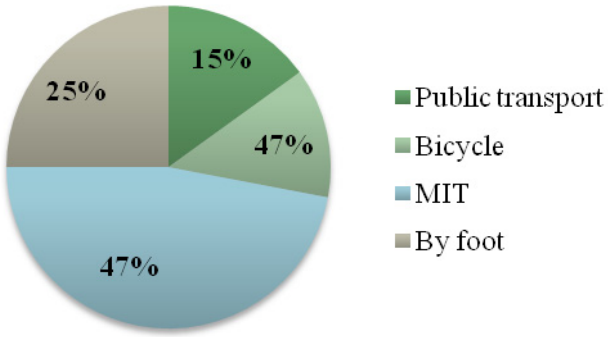


Figure 1.5: Modal share for Munich and its suburban area in 2008 (MVV 2010b)

Like in many cities in Europe, the attractiveness of the city has for consequence a **high share of MIT**, and as a result many problems occur, for instance, traffic jam, land use, traffic fatalities and injuries, noise, air pollution and petroleum dependence (IPCC 2007c; Knoflacher 2001; Schiller et al. 2010). The car – as leading mode of transport for personal journeys (Dupuy 2011) – has become a symbol of personal freedom and independence, and transport policy and urban planning are concentrated on motorized individual transport at that time (Bornemann et al. 2001; Cameron et al. 2003; Kenworthy et al. 1999; Steierwald et al. 2005). The automobile allowed cities to expand without limits. Nevertheless, whereas the automobile city has created great mobility opportunities for some segments of the

population, it has generated or maintained serious inequities in mobility and accessibility for the rest of the population (Schiller et al. 2010).

Therefore, sustainable development translated to transport planning means providing options to reach the locations where we wish to realise our activities without exceeding the system boundaries of **irreversible negative mobility impacts** (Wulfhorst et al. 2011). This definition has in its core the question of choices and therefore, the accessibility. Indeed, an old fundamental principle of urban transportation system is the delivery of effective "access for all" without discrimination as to income, physical ability, housing location, mode of travel or any other factor (Schaeffer & Sclar 1975). Whereas transport planning is considering the entire structure of the city, the focus of the work is, as previously mentioned, on individual consumers and on the way that they are travelling within the city. Therefore, it is possible to assess how local transportation systems meet consumers' needs without degrading the environment and depleting resources on a global level.

Influence of local authorities

Concerning sustainable transportation policy-making, some of the most interesting initiatives are occurring at the local and regional levels. Even if it is almost impossible to steer individual consumers and their choice of transportation modes, it is possible to influence them by encouraging sustainable transportation in the city, and thus to reduce the use of MIT in urban areas. Consumers need more options and diversity from which to make choices. Many cities have demonstrated that the affair with the automobile can be broken where sustainable modes are carefully and thoughtfully provided against the trend of automobile-based planning (Schiller et al. 2010). To incite the public to use a mix of transport services, governments and local authorities have two ways of action, namely **push or pull measures** (i.e., application of dissuasive or persuasive policies). Push measures involve placing obstacles in the way of using automobiles such as petrol taxes or car taxes, reduction of the speed, high parking charge in the city centre, etc. For instance, a push measure in favour of public transport is to build an urban settlement where the distance to the garage is at minimum as long as the distance to the first public transport station (Knoflacher 2009). Pull measures encourage the consumers to change their behaviour. The city of Munich speaks, for instance, about 'marketing for sustainable mobility' with the use of more and better information, consulting and education for specific target groups in order to organize the satisfaction of the individual needs and wants with the minimal use of MIT (Landeshaupstadt_München 2008; Schreiner 2009). Improve the attractiveness of public

transport is also a pull measure that requires special attention because of the complexity of the system.

The problematic of public transport

Public transport is not as any other products or services, since it is a complex system with many stakeholders and implications. Public transport is a service for the general public interest, responsible for the execution of the mobility. It is an instrument of regional planning, social and environmental policy (MVV 2007b). For instance, it promotes barrier free mobility, short ways and security for old people and handicapped persons; it offers mobility possibilities for social groups, which cannot afford a car and for rural areas with poor-activity and little demand. Enterprises in charge of public transport have an assignment to improve the attractiveness of public transport facilities (MVV 2007b). For instance, in local transport plans, review of the current situation and objectives for the optimization of public transport are formulated in term of pull measures, themselves differentiated between "soft" measures (e.g., related to the information) and "hard" measures (often related to the infrastructure).

Often, however, the public transport is organized inefficiently. This is to some extent due to a complicated financing system, partly from the public sector. This financing are not aim-oriented and not adjusted together. The enterprise is more oriented to use potentially the entire public financing at disposition, than to satisfy the needs of the public transport users (Werner 2009). Moreover, the public transport system is in structural deficit; it is not always transparent and runs often under monopole. Under these circumstances, there is little liberty and almost no occasion for the public transport to be innovative. Moreover, the involvement of public stakeholders goes often together with a low level of competition, which implies a limited consideration of the consumer expectations in development processes.

Therefore, we assist to a **conflict of interests** within the management of public transport, since the enterprises in charge, on the one hand, are profit-oriented and, on the other hand, general interest has to be maintained by public authorities.

In this state of affair, **we need environmentally friendly products that improve the attractiveness of public transport** and satisfy all the stakeholders involved: the enterprise in charge of public transport (or an extern enterprise that wishes to join a public transport project), the public authorities and its investment possibility, and the user and his/her needs.

1.2.5 The role of innovations: Sustainable ideas to improve the attractiveness of public transport

Following the footstep of the Lisbon strategy, the German Advisory Council on the Environment (SRU 2008) encourages the development of innovations as **driving power for a sustainable growth**. Indeed, there is no sense in designing superfluous products for saturated markets. Instead, design of innovations must fill the gap between production and consumption in a way that leads to real problem-solving and changes with the maximum benefits for consumers, producers and the natural environment (Tischner 2008). Tischner (2008) speaks of diverse types of innovations:

- Incremental innovations: relatively small changes of processes and products, result of learning by doing and learning by using;
- Radical innovations: results of research and development sections of companies, institutes or universities;
- System innovation: affects several industries and
- Behavioural innovations: behavioural changes and changes in use patterns.

In order to reach sustainable growth at the local level under study, there is a need of sustainable innovations to increase the attractiveness of public transport.

Depending on the degree of development and consequently the level of detail, it is usual in innovation management to speak about idea (i.e., single solution, plan or option that might solve a problem or fulfil a need), concept, and innovation until the status of invention when the initial idea is ready to be commercialized (Rogers 2003; Van de Ven 1986; Von Hippel 2005) (Figure 1.6).

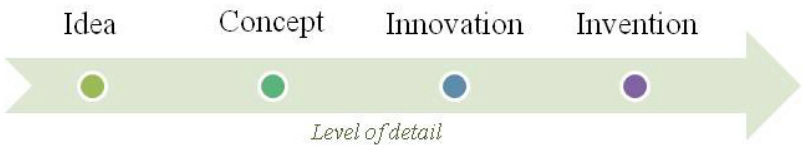


Figure 1.6: From idea to invention (own representation)

In the present study, ‘ideas’ represent products or services that are new – not especially in the sense of innovative – but mainly in the sense that **they are not implemented** in the system that is considered yet. Moreover, ideas may describe products or services that are **described in a low-level of details**.

Nevertheless, ideas – products or services, innovative or not – to improve the attractiveness of public transport are not missing: from basic ideas like new bus lines, until more modern ideas like car sharing, cell-phone ticket and real-time information. Face to this quantity of ideas, **a problem is, however, to distinguish the ideas that can really afford a sustainable mobility** as previously defined, from those that imply eventually costs, emissions and little attractiveness. Therefore, **sustainability evaluations** are necessary to identify if the ideas designed to improve the attractiveness of public transport are in fact sustainable.

1.3 Categorization of sustainability evaluation methods

1.3.1 Overview of the existing sustainability evaluation methods

For the transition to sustainability, goals must be assessed. This has posed important challenges to the scientific community in providing efficient but reliable methodologies and tools. As a response to these challenges, sustainability assessment has become a rapidly developing area (Ness et al. 2007). The numbers of evaluation methods that claim that they can be used for assessing sustainability have grown. Sustainability assessment has increasingly become associated with the family of impact assessment tools consisting of e.g. Environmental Impact Assessment and Strategic Environmental Assessment of the European Union.

For the following inventory-review process, the definition of sustainable development of Chapter 1.2.3 is considered and thus the consideration of the planet, which fixes the boundaries, the people at the centre and the profit in the background. Moreover, since the study is considering local actions (cf. Dubos' adage "Think Globally, Act Locally" (Dubos 1981)), the geographical boundaries are narrowed to the **urban area** and ideas developed in there. With these considerations, evaluation methods at a country level will be excluded of the inventory process.

The inventory is not exhaustive; indeed, the ambition has been to cover the methodologies and tools that most frequently appear in the literature and, as far as possible, to cover the variety of the broad fields that can be viewed as sustainability assessments.

The following rules have been considered for the inventory-review:

- **Three levels of practitioners** are under review: City – enterprise – individual consumer, in other words, every stakeholder who is involved in urban mobility;
- Methodologies and tools with **complex and simple utilization** are under review;
- As temporal coverage, **prospective and retrospective** evaluation methods are considered;
- The focus (i.e., the coverage area) is for the evaluation methods with **wide focus**, it means that the methods can evaluate **final products** as well as **ideas** described with a **low level of detail**. When the focus is limited (i.e., for specific products or services), the methods with **a linkage to urban mobility** are considered;
- Concerning the expecting results of evaluation methods reviewed, the three dimensions previously cited **planet, profit, people (needs and wants)** are considered, thereby, most of the evaluation methods have the environmental aspect in the focus. Methods that only consider the profit or the people are in this case **not considered as sustainability evaluation methods** (see definition of sustainability of Chapter 1.2.3) and will therefore not be described in detail. Moreover, the consideration of the review is only for the direct results proposed by the method and not the consequences from impacts (for example, relation between the consumption of resources and the profit of the enterprise).

In Table 1.1, the evaluation methods have been classified depending on the practitioner of the method. Moreover, it has been considered if the method is based on standards or directives, or if it is an initiative of an enterprise or an institute.

Table 1.1: Overview of the existing sustainability evaluation methods and main characteristics (own representation)

Legend: ✓ applicable, (✓) partially applicable, ⊘ uncertainty (lack of experience or lack of transparency)

	Origin		Utilization		Temporal coverage		Coverage area		Results			
Practitioner – practice area	Based on standard	Other / Self-initiative	Simple	Complex	Prospective	Retrospective	Limited	Wide	Planet	Profit	People needs	People wants
City – Urban planning policies												
Environment Impact Assessment (EIA)	✓			✓	✓			✓	✓		✓	
Standardized assessment for public transport	✓			✓	✓		✓		✓	✓	✓	
Costs Benefit Analysis (CBA), Multi-Criteria Analysis (MCA)		✓		✓	✓			✓	✓	✓	✓	
Sustainability Solution Space for Decision-making (SSP)		✓	⊘	⊘	✓			✓	✓	✓	✓	
Integrated Sustainable Cities Assessment Method (ISCAM)		✓	⊘	⊘	✓		✓		✓			
Enterprise – own performance												
Environmental Management System (EMS),	✓		⊘	⊘		✓		✓	✓			
Bilan Carbone, ecoWheel®		✓		✓		✓		✓	✓			
Mobitool		✓	✓			✓	✓		✓	✓		✓
EcoTransit		✓	✓			✓	✓		✓	✓		
Enterprise – products and services												
Life Cycle Assessment (LCA)	✓			✓		✓		✓	✓			
Carbon footprint	✓		⊘	⊘		✓	⊘	⊘	✓			
Eco-Labelling	✓		⊘	⊘		✓	✓		✓		✓	
GaBi, SimaPro		✓		✓		✓		✓	✓			
PROSA		✓		✓		✓		✓	✓	✓	✓	✓
SEEBalance		✓	⊘	⊘		✓	✓	(✓)	✓	✓	✓	
TREMOD		✓	⊘	⊘		✓	✓		✓			
EuPeco-profiler		✓	⊘	⊘		✓	✓		✓			
Individual consumer – own performance												
CO_2-Calculator, EcoPassenger		✓	✓			✓	✓		✓			(✓)

1.3.2 City – urban planning policies

Drivers

In policy decision-making process, and in the present case, for urban planning, assessment methods are required in order to choose among possibilities for infrastructure projects, for instance, construction of a new road, of a new tramway line, etc. Indeed, in the urban planning decision-process – as in any decision-process, the budget is limited and the pros and cons of each possibility need to be assessed. Several assessment methods exist in order to minimize the risk of making a wrong decision, to reduce the complexity of decision-making process and to illustrate potential damages, risks and benefits of the project (Rau 2010). Depending on the objectives, different methods can be applied.

In the context of sustainability assessment, integrated assessment tools have an ex-ante focus (prospective methods) and they are often carried out in the form of **scenarios**. Many of these integrated assessment tools are based on systems analysis approaches and they integrate nature and society aspects (Ness et al. 2007).

Evaluation methods based on standard and directives

At the Gothenburg Summit in June 2001, EU leaders launched the first EU Sustainable Development Strategy (SDS) based on a proposal from the European Commission. The European Council of June 2006 adopted a renewed SDS. It has been built on the Gothenburg strategy of 2001 and it proposed an integrated approach to policy making mainly thanks to better regulation with impact assessments. Within the diverse impact assessments, an **Environmental Assessment** is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. Environmental assessment can be undertaken for individual projects, such as a dam, motorway, airport or factory, on the basis of Directive 85/337/EEC (known as “Environmental Impact Assessment” – EIA Directive) or for public plans or programs on the basis of Directive 2001/42/EC (known as “Strategic Environmental Assessment” – SEA Directive) (European-Council 1985; European-Parliament&Council 2001). The common principle of both directives is to ensure that plans, programs and projects likely to have significant effects on the environment are made subject to an environmental assessment, prior to their approval or authorization. Consultation with the public is a key feature of environmental assessment procedures (European-Council 1985).

Concerning the urban mobility, the budgetary laws in the Federal Republic of Germany require that large items of public expenditure be subject to prior cost-benefit analysis. A cost-benefit method suitable for the analysis of urban public transport projects is the "**standardized assessment of transport infrastructure investment of public transport**", which has been since its creation in 1976 widely used by public transport companies (Meier 1985). The planning goals are merging environmental, social and economic indicators that are specific for urban planning decisions, inter alia: costs of operation, costs of maintenance, accounting balance of exhaust gas emissions, accounting balance of injuries, accounting balance of energy consumption, accessibility indexes, land use, frequency of transitions, available seats, distance by feet, impacts on separation effect, etc.

Other evaluation methods

Other methods do not necessarily pertain directly to sustainability issues, but they can be extended to a variety of other problem areas across disciplinary thresholds, like the cost-benefit analysis and the multi-criteria analysis.

In a **cost-benefit analysis** (CBA), all the positive and negative effects of a proposed project or policy are valued in monetary terms, providing a list of benefits and costs (Edwards-Jones et al. 2000). Cost-benefit analysis is an applied welfare economics method with roots reaching back to the early 20th century in civil engineering projects. Through a more systematic use in the 1960s, cost-benefit analysis has been – and still is – widely used for public projects for transport, health and safety (Edwards-Jones et al. 2000; Nas 1996). The main disadvantage of the method is that some indicators are hardly monetarisable, for example the costs for spoiling the cityscape or the value of saving life.

Multi-criteria analysis (MCA) is a formal approach helping decision makers to handle with complex decision situations in which the level of conflict between the diverse criteria is such that intuitive solutions cannot be satisfactory (Rau 2010). Benefit and costs components are considered in utility points thanks to the definition of scales for indicators with relevance tree and preference matrix.

Other methods (e.g. cost-efficiency analysis, input-output analysis, top-down and bottom-up analyses) will not be detailed here since there are similar to the two previous methods. For instance, the cost-efficiency analysis combines characteristics of CBA and MCA and is finally the most common form of analysis by government.

Tools like the Integrated Sustainable Cities Assessment Method (ISCAM) (Ravetz 2000) and the Sustainability Solution Space for Decision-making (SSP) (Wiek & Binder 2005) have been designed to appraisal sustainability of cities for decision-making, but their methodologies are unclear since the tools are still under construction.

1.3.3 Enterprises

Drivers

Beyond the drivers "Benefit generation" and "Risk management" formulated in Chapter 1.2.2, enterprises themselves have shown a need to assess their own performances as well as the products they develop **under sustainability aspects**. Increasing concern about climate change might drive enterprises into pursuing sustainable management measures. However, there is a large number of less altruistic and more tangible reasons for enterprises to assess their own performances and/or their products and services under sustainability aspects (Münzing 2010):

- Firstly, enterprises benefit from decision-making tools and methods, which might help with **product design and development**, purchasing decisions or as a support for regulatory measures and policy instrument. It can support decision makers in learning processes, like the characterization of production systems or the identification of improvement possibilities.
- It has also been shown that sustainability management measures are useful to **create awareness** with business management, employees and suppliers about the organization's products and services. Hence, it can be both, a tool for managers as well as a motivational instrument for employees, leading to a higher degree of positive identification with an organization.
- Furthermore, sustainability management contributes to **operational strategy development** by identifying those actions that contribute both to cost and to environmental performance improvements.

Looking at the external side, sustainability management can serve for communication purposes in form of Environmental Product Declarations (EPD). This means that it can be a method to differentiate an enterprise, a product or a service from its competitors by providing additional transparency to customers and end consumers (Belz & Pattie 2009; Dada et al. 2009; Münzing 2010).

Sustainability evaluation methods for enterprise's own performance

For businesses, own performance is in most of the cases synonym of financial performance, which can be calculated with diverse ratios (e.g. return on equity, profit margin, market share, etc. (Arditti 1967; Freshtman et al. 1990; Min & Wolinbarger 2005)). Nevertheless, as previously mentioned, evaluation methods that focus on the economic sphere are not considered as sustainability evaluation methods, since it does not suit the thesis's normative stance about sustainability (Chapter 1.2.3). Therefore, these methods are not under study and it is preferred to consider evaluation methods that contain the environmental sphere in their results.

Evaluation methods based on standards and directives

Many organizations have undertaken environmental reviews or audits to assess their environmental performance. Standards – especially the ISO 14001, which covers environmental management – are intended to provide organizations with the elements of an **Environmental Management System** (EMS) that can help organizations to achieve environmental and economic goals (ISO14001 2009). Especially relevant for us is the monitoring and measuring aspects within the EMS that encourage the organization to establish, implement and maintain a procedure to monitor and measure, on regular basis, the key characteristics of its operations that can have a significant environmental impact, e.g. releases to air, water and land, resource consumption and use of energy.

Specific for greenhouse gas emissions accounting, the ISO standard 14064 provides guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals (ISO14064-1 2006).

Proposed by the European Commission in 1995, **EMAS** (Eco-Management and Audit Scheme) is a voluntary EMS, under which companies and other public organizations evaluate, manage and continuously improve their environmental performance. EMAS was strengthened by the integration of ISO 14001 as the environmental management system required by EMAS. Third-party verification from independent auditors significantly adds credibility to registered organizations by guaranteeing the value of both the actions taken and the disclosed environmental information. Transparency is generated by the environmental statement, which an organization is required to provide as part of EMAS registration. The communication tool makes available to the public information on the environmental impact and performance of the organization. Finally, EMAS can be seen as an extension of ISO14011 with additional issues, mostly employee involvement and open communication

with the public. An EMAS toolkit is available for small organizations with checklists, templates, worksheet and guidelines (European-Parliament&Council 2009).

For both methods, flexibility enables the enterprise to feel free to innovate and adapt themselves to circumstances. An extern audit provides moreover a higher reliability and transparency, but the approach appears to be fuzzy under specific aspects and it does not provide a life cycle approach.

Self-initiatives evaluation methods

The French Agency for the Environment and Energy Management (ADEME) developed a method, so-called **Bilan Carbone**, which enables businesses to calculate greenhouse gas emissions using easily-available data in order to assess the direct or indirect emissions produced by their activity (ADEME 2007). Bilan Carbone is carried out by an extern consultant authorized by ADEME. The consultant makes an inventory of the energy consumption, emissions from intern processes and processes of subcontractor, material consumption, solid waste, waste water, packaging, buildings and – interesting in the present case – for transport of goods (intern and to customers) and of the employees (business trip and commuting between home and work place). Then, the calculation of greenhouse gas emissions is assessed thanks to impact factors linked to each activity. A version has been furthermore developed for administration and local authority. The main advantage of the method is that the calculation deals with easy-available data; nevertheless, extern expertise is needed and it takes time to assess the impacts of the entire enterprise.

Similarly, the **ecoWheel®** tool is a self-initiative approach for identifying a organisation's current environmental position, establishing a 'sustainability roadmap', and moving it from a defensive to a proactive approach to sustainability (Seidel et al. 2011). Focused on the transportation of goods and person within an enterprise, **Mobitool**, has been developed in Switzerland for the estimation of energy, CO_2-emissions, cost and time needed for the mobility within an enterprise (Tuchschmid & Halder 2010). The free-of-cost tool enables the enterprise to identify its weak points and to improve its performance concerning the mobility of its employees, but also the transport of its goods. The evaluation is simple for the user, fast and even flexible, since data can be easily adapted. Nevertheless, even if the objects of evaluation are numerous – the tool considers several modes of transport such as cars, scooters, electric cars, bicycle, but also telecommunication – there are restricted to simple and well-defined products, and the evaluation does not enable the consideration of complex systems and services. Comparable to it, in Germany, the Ecological Transport Information

Tool (**EcoTransIT**) has been developed to compare transportation modes for goods in term of energy consumption and CO_2 emissions. Thereby, it is possible to determine the energy consumption, CO_2 and exhaust emissions transported by rail, road, ship and aircraft in any combination (IFEU 2010b).

Products and services

Comparable to the assessment of their own performances, businesses dispose of diverse methodologies to assess the economic viability of their products under economic criteria. The most popular is the Life Cycle Cost Analysis, which comprises all costs attributable to a product from conception to those customers incur throughout the life of the product, including the costs of installation, operation, support, maintenance and disposal (Asiedu & Gu 1998; Dunk 2004). For the same reason as before, it would be out of scope to make a detailed review of these methods since methods that only evaluate direct profit are not considered as sustainability evaluation methods (cf. the thesis's normative stance about sustainability of Chapter 1.2.3).

Evaluation methods based on standards (methodologies)

Widely recognized by the scientific community, the **Life Cycle Assessment** (LCA) methodology has already proven its worth. Specified in ISO standards, this powerful method has the ambitious goal to compile and evaluate the inputs, outputs and potential environmental impacts of a product system throughout its life cycle (ISO14040/14044 2006). Thus, LCA is a tool for the analysis of the environmental burden of products at all stages in their life cycle: From the extraction of resources, through the production of materials, product parts and the product itself, and the use of the product to the management after it is discarded, either by reuse, recycling or final disposal (in fact, therefore, 'from cradle-to-grave') (Guinée 2002). However, the methodology is complex, it needs experts, and thus it costs time and money. Moreover, LCA is focused on the environmental dimension of sustainability. In the field of urban mobility, LCA – and often simplified LCA – have been provided for the comparison of vehicles, of fuels, and, for instance, of batteries within electric vehicles (Spielmann et al. 2007; Zackrisson et al. 2010). LCA is mostly applicable for well-defined products and not for services, since the complexity can be too high.

The concept of footprint – which stems from the language of ecological foot printing – has been gaining in popularity in the recent years. The fact that commercial organizations are

looking for a simplification of Life Cycle Assessments constitutes the backdrop of this trend (Pant et al. 2008). The **product carbon footprint** is a measure of the impact of activities in terms of climate change and it can be seen, in its current form, as a form of specialized LCA. At the moment, reference points for product foot printing are the international LCA methodology (ISO14040/14044 2006) and the Publicly Available Specification (PAS) 2050, which have been developed in the UK and provides so-called rules of interpretation for the parts of the ISO-standard that are controversial (BSI 2008). But, so far, harmonization of standardization is still lacking (Münzing 2010) and credibility, comprehensibility, comparability and transparency still need to be ensured (PCF 2009). There is a variety of ambiguous aspects in the calculation methodologies such as the inclusion of the boundaries issues and the type of gases considered (only CO_2 emissions or carbon-based greenhouse gases emissions). The ISO Standard 14067 for the quantification of carbon footprint of products should provide a clear methodology, but it is still under development (BMU 2009).

Concerning communication mechanisms (between businesses or with consumers), the standard ISO 14040, which serves as a basis for LCA – and in extension for the carbon foot-printing – of products, is not specified sufficiently in detail to enable a comparison among many and differing products and especially in terms of competition laws operable comparison with competitive products (e.g. through displaying CO_2 values or CO_2 labels) (BMU 2009). For communication purposes, environmental product declarations and labels (especially eco-label or environmental label) provide comparability within a category of products.

For business-to-business communication, and in extension, business-to-customer communication, **Environmental Product Declaration** (EPD) presents quantified environmental information on the life cycle of a product to enable comparisons among products fulfilling the same function. Procedure and principles of such declarations are standardized (ISO14025 2010). Such declarations are based on independently verified life cycle assessment data in accordance with the ISO 14040 series of standards and, where relevant, on additional environmental information. The driver for the enterprise is to communicate the environmental performance of a product, and as overall goal, to encourage the demand for, and the supply of, those products that cause less stress on the environment. An environmental declaration may take the form of a statement, symbol or graphic on a product or packaging (cf. environmental labels), in product literature, in technical bulletins, in advertising or in publicity, amongst other things (ISO14025 2010). Labelling aims at designate products and services according to specific criteria and informs the public of the

fulfilment of these criteria. **Environmental labels** can be considered as the communication form of sustainability evaluations since their criteria are corresponding to the dimensions of sustainable development. The application of labels concerns mostly a limited group of products, for instance the Blue Angel (in German: Der Blaue Engel) for low-noise and low-pollutants municipal vehicles and buses (UBA 2010). The Blue Angel defines itself as 'eco-label', since it supports the development of climate-relevant and energy-efficient products. Since July 2010, it has proposed a label for Car Sharing with the goal to reduce the private ownership of MIT and thus reduce the consumption of resources, the costs and the emissions. The basic criteria for award of the label merge not only technical aspects concerning the vehicle and the service, but also informative aspects (the car-sharing agency shall give tips for fuel-efficient and low-noise driving) and economic aspects with reduced rates for holders of public transport season tickets (Blue_Angel 2010). Gaining in importance in the last decades, some environmental labels are merging the diverse stakeholders' responsibilities within sustainable development, for instance the label Solar®-Food that indicates to the user on a transparent way that the manufacturing process of the product he/she buys is performed with renewable energy, which supports the current policies of the government (Solar®-Food 2011).

The object of evaluation is, however, for each label restrictive and concerns only well-defined products.

Self-initiatives (tools)

There are numerous LCA tools available, but among small and medium sized enterprises (SME), software tools are rarely used by the SMEs directly, rather as a consulting tool of external experts. The leading LCA software tools on the market currently are **GaBi** from PE International and **SimaPro** from PRé (LiMaS 2010b). Nevertheless, the use of these tools is hampered by data availability barriers, since many databases are only available on a commercial, partly very costly basis and public data is very limited.

Inspired by LCA, many institutes, enterprises and organizations (e.g. NGO) have developed their own evaluation method in order to answer the problematic of complexity and high costs. Among others, a matrix-based software tool for life cycle assessment has been developed by the Leiden University (**CMLCA** – Chain Management by Life Cycle Assessment) (Heijungs & Suh 2002). Moreover, an open source initiative has developed **OpenLCA** modular software for life cycle analysis and sustainability assessments (Ciroth 2007). Founded by the Executive Agency for Competitiveness and Innovation of the

European Commission, in cooperation with the Technische Universität Berlin and enterprises, a free-cost Life Cycle Assessment software tool, namely **EuP$_{\text{eco-profiler}}$**, has been developed for SMEs that manufacture energy-using products (EuP). This is a tool for identifying, quantifying and communicating the environmental profile of energy-using products, which claim to be user-friendly for technicians without the need to be an LCA expert (LiMaS 2010a). Nevertheless, the assessment requires a huge amount of data, which could take time to gather it, and thus money.

Furthermore, the Institute for Applied Ecology (in German, Öko-Institut) has proposed the Product Sustainability Assessment (**PROSA**) method for the strategic analysis and management of product portfolios, products and services, mainly for companies, but also for product policy and dialogue processes (Öko-Institut 2007). The aim of the method is to complete the LCA methodology with the consideration of social indicators, like user utility (e.g. capacity, reliability, information) and user wants (so-called 'symbolic utility', e.g. design, prestige, fun). The assessment of the social aspects is qualitative in a form of a checklist. It is critical to consider the method as a tool, since it gives finally a list of indicators that should be considered, without explicitly indicating how the calculation should be done. Considering the high amount of information and time needed to realize the method, it is still considered as complex, even if a simplified version has been elaborated for small and medium-sized enterprises (Grießhammer et al. 2007).

Developed by BASF, the SocioEcoEfficiency Analysis **SEEBalance** considers the three dimensions of sustainability and is applicable for products and processes in order to measure sustainable development in companies. In addition to the environmental and economic aspects, the societal issue considers for example the working conditions for employees, international community (e.g. child labour), future generation relating to the research and development, consumer (e.g. toxicity potential), etc. (BASF 2008). Nevertheless, the process is not free, the methodology is not transparent and the calculation not obvious.

Specific to the field of mobility, the Transport Emission Model (**TREMOD**) has been developed by the Institute for Energy and Environmental Research (ifeu - Institut für Energie- und Umweltforschung Heidelberg GmbH) for the analysis of motorized transport in Germany, i.e. its mileage, energy use and emissions. Part of the project was the development and updating of corresponding calculation software. For every year between 1960 and 2008 and in scenarios until 2030, TREMOD analyzes all means of passenger transportation (cars, two-wheelers, busses, trains, aircraft) and all means of freight transportation (lorries, light-

duty commercial vehicles and trailers, trains, inland navigation vessels, aircraft) (IFEU 2010c).

1.3.4 Individual consumer

At the consumer level, sustainability assessments are often free-of-charge prompt evaluations, which claim to inform and educate the people about their contribution to sustainable development with every-day life factors consideration (mainly choice of transportation mode, housing criteria, alimentation, and consumption). Some methods of evaluation are available in Internet and usable by the people, for instance the **CO_2-calculator** of the Bavarian State Office for Environment (LfU 2008) or the Car-Energy Check from the German Agency of Energy (Dena 2010). With these methods, it is possible to draw a personal 'environmental balance' with few data in a short time. Restrained to the field of mobility, **EcoPassenger** is an online-tool to compare atmospheric emissions and energy consumption of different transport modes for passenger traffic through Europe. The transport modes to be assessed are road transport, rail transport, air transport (IFEU 2010a). The main advantages of these tools are that the consumer just needs few clicks to assess his/her performance, and thus not a long time. Moreover, it is possible to adapt the data for a more suitable assessment. Nevertheless, it concerns mostly only one dimension of sustainability.

1.3.5 Summary of the review process and lack of research

Table 1.2 contains the results obtained when crossing the requirements for a new sustainability screening with the previous review analysis of evaluation methods.

Table 1.2: Requirements for the necessary screening and interesting aspects covered by the existing evaluation methods (own representation)

Requirements for a sustainability screening	**Related evaluation methods**	**Aspects covered by the evaluation methods**
Main characteristics		
Easy to use	e.g. Mobitool, EcoTransit, CO_2 calculator	These methods are tools that are user friendly, have an easy navigation and are easy to follow by non-experts. However, the results are often limited to one or two aspects of sustainability.
Prospective analysis	e.g. EIA, CBA, MCA	These methods provide actual decision-making assistance by preventing potential impacts before implementation thanks to scenarios elaboration. Nevertheless, these methods are often complex and time and money intensive.
Wide coverage area (final products and services as well as ideas with low level of detail)	e.g. CBA, MCA, EMS, LCA	These methods are applicable for a wide range of products and services without restriction. However, it means often that the methodology is losing in clarity and transparency, since it stays very general and many assumptions have to be taken if the evaluation deals with ideas.
Considerations of the 3Ps (Planet, Profit, People needs)	e.g. CBA, MCA, SEEBalance, PROSA	These methods are not only dealing with the environmental issue, but also the socio-economic issue, and cover therefore the three spheres of sustainability. However, it is not always clear if the evaluation process implies an actual assessment (qualitative or quantitative) instead of a list of indicators to be considered.
Consideration of the user wants	e.g. PROSA	Beyond socio-economic indicators, the user wants and the effect on the user acceptance are integrated. In the only method found (PROSA), it appears to be rather a checklist of indicators, which should be taken into account, and no methodology is proposed for the assessment of these factors.

Requirements for a sustainability screening	**Related evaluation methods**	**Aspects covered by the evaluation methods**
Further features		
Flexibility	e.g. MCA, EMS, EPD,	These methods can be adapted to the enterprise and to the circumstances.
Easy availability of data	e.g. Bilan Carbone, Mobitool, CO_2 Calculator	The data needed for the evaluation are easily available within the enterprise.
Transparency	e.g. Mobitool, TREMOD	The background of the calculation is for these methods open to the public. For example, Mobitool publishes spreadsheets and reports to explain how the calculations run. Particularly important is transparency in terms of inherent assumptions.
Comparability	e.g. CBA, MCA, LCA	These methods provide comparisons among diverse products or projects. However, the comparison is limited to the scope of the study and the results cannot be comparable with another study.

There is, at the moment, neither tool nor method that is fulfilling **simultaneously all the requirements** of Table 1.2. Indeed, a prospective sustainability evaluation method, which is – among other requirements – easy to use, covers a wide area of products and services in the field of urban mobility (and especially public transport) and considers the three spheres of sustainability, is still lacking.

Moreover, no sustainability evaluation method exists yet that is integrated into businesses and their decision-making processes, taking into account the interest of public authorities as well as the needs and wants of consumers.

Especially for urban mobility, no method integrates in its assessment the evaluation of sustainability impacts of a product and at the same time the estimation of the induced modal shift.

1.4 Objectives

The objectives of the thesis have been divided into two parts: The overall goal sums up the general aim of the study, whereas specific questions are addressed to the development process of the screening, and are therefore answered throughout the thesis.

1.4.1 Overall goal

The goal is the development of an integrated screening tool for the sustainability assessment of ideas that have be designed to improve the attractiveness of public transport.

The products to be evaluated can be final products as well as **ideas** (i.e., described with low level of detail) that have been designed to improve the attractiveness of public transport in urban areas. The screening tool is intended in a first place for an **internal use** by the **enterprise responsible for public transport** as a 'pre-feasibility' study in order to give a **first insight** about the **local and global impacts regarding sustainability**. In this state of affairs, since the financing possibilities are reduced, the tool should be **simple** enough to provide quickly an **overview** of the impacts of an idea.

The assessment within the screening tool must cover the **three spheres of sustainability** (People (needs and wants), Profit, Planet) considering the thesis's normative stance (Chapter 1.2.3). Indicators must be selected to reflect this stance as well as Dubos's motto "Think Globally, Act Locally".

Respecting the adage "learning by doing", the goal of the present study is, moreover, to run the screening tool for evaluating diverse **case studies for the city of Munich** in Germany in order to identify its pros and cons. Then, its transferability to other Western European cities has to be analyzed.

1.4.2 Specific questions

Specific questions are addressed for the comprehension of the screening's development.

Concerning the final products or ideas to be evaluated:

- What is specific to urban mobility in contrast to other fields?
- How "low" can the level of detail for the products be?

Concerning the methodology:

- What is essential for the screening (in comparison, for example, to LCA)?
- How complex does the screening need to be? What can be simplified?
- How "wrong" can the screening be? How precisely must the results be expressed?

Concerning the evaluation's goal:

- How many indicators are required?
- Which indicators can reflect impacts related to a local implementation on the one hand, and to the global thinking on the other hand?

Concerning the actors (i.e., the enterprise responsible for public transport in the city):

- What are their expectations?
- Which degree of integration do they have in the evaluation process?
- How "expert" do they need to be? Do they need assistance or external support?

Concerning the case studies:

- How many case studies should be run to identify the pros and cons of the screening?
- Can a screening be developed and be applied for all various subtopics of urban mobility?

2 Development of the screening tool

2.1 Requirements and constraints

Focus of the screening and related complexity

As we have seen in the previous chapter, the biggest constraint for the screening tool is the field of application: urban mobility, and in particular public transport, is complex and the evaluation is expected to be consequently even more **complex**. It must be possible to evaluate with the screening tool products or services in early phase of development (i.e., **ideas** that are not concretely described). The goal of these ideas is to improve the attractiveness of public transport. It has to deal with different notions (transport of person, choice of transportation modes, promotion of public transport, etc.) and with different stakeholders (public authorities, businesses and individual consumers). The screening tool considers the diverse interests of the stakeholders, which could be different, or even conflicting.

Purpose

The screening tool provides a sustainability impact assessment of products related to the field of public transport, which means that the possibilities for the objects of application are plentiful. Thus, rather than dealing only with well-defined physical goods or simple services, the developed screening can also be applied to complex business strategies or government policies relating to consumption and lifestyle choices in various sectors of society.

The screening tool is developed for the city of **Munich** and its related public transport system.

The screening is a tool that provides the assessment with few easy-available data. In that sense, it has to run **automatically**.

Relating to its use, a **non-expert**, which is nevertheless employee of the enterprise in charge of public transport, and had therefore a wide overview and good knowledge of the system, should be able to get the screening into application without difficulty and in a short time. In this state of affairs, the screening must be very **simple to use**. The challenge is to make a low detailed evaluation for a complex system (whereas Life Cycle Assessment could be seen as a high detailed evaluation of simple products).

Beyond the sustainability impact assessment, the screening brings a better knowledge about the interactions that exist in the complex field of urban mobility.

2.2 Development process

Thanks to a transparent and detailed methodology given by the standard ISO 14040 (2006) and Guinée (2002), the evaluation method '**Life Cycle Assessment**' has been selected to be the basis for the development of the screening tool. The phases of goal and scope definition, inventory analysis, impact assessment and interpretation (Figure 2.1) constitute indeed a solid foundation usable for the screening tool.

However, the screening tool differs from LCA regarding the following aspects:

- The screening tool considers the **three spheres of sustainability** (people, profit, planet), whereas LCA focuses on environmental impacts assessment;
- The screening tool is, as its name says, a **tool**, which means that it runs automatically;
- The screening tool is usable by non-expert persons, i.e., it runs **faster and more easily** than a LCA.

Therefore, the methodology of LCA has been modified and adapted to the present case (Figure 2.1).

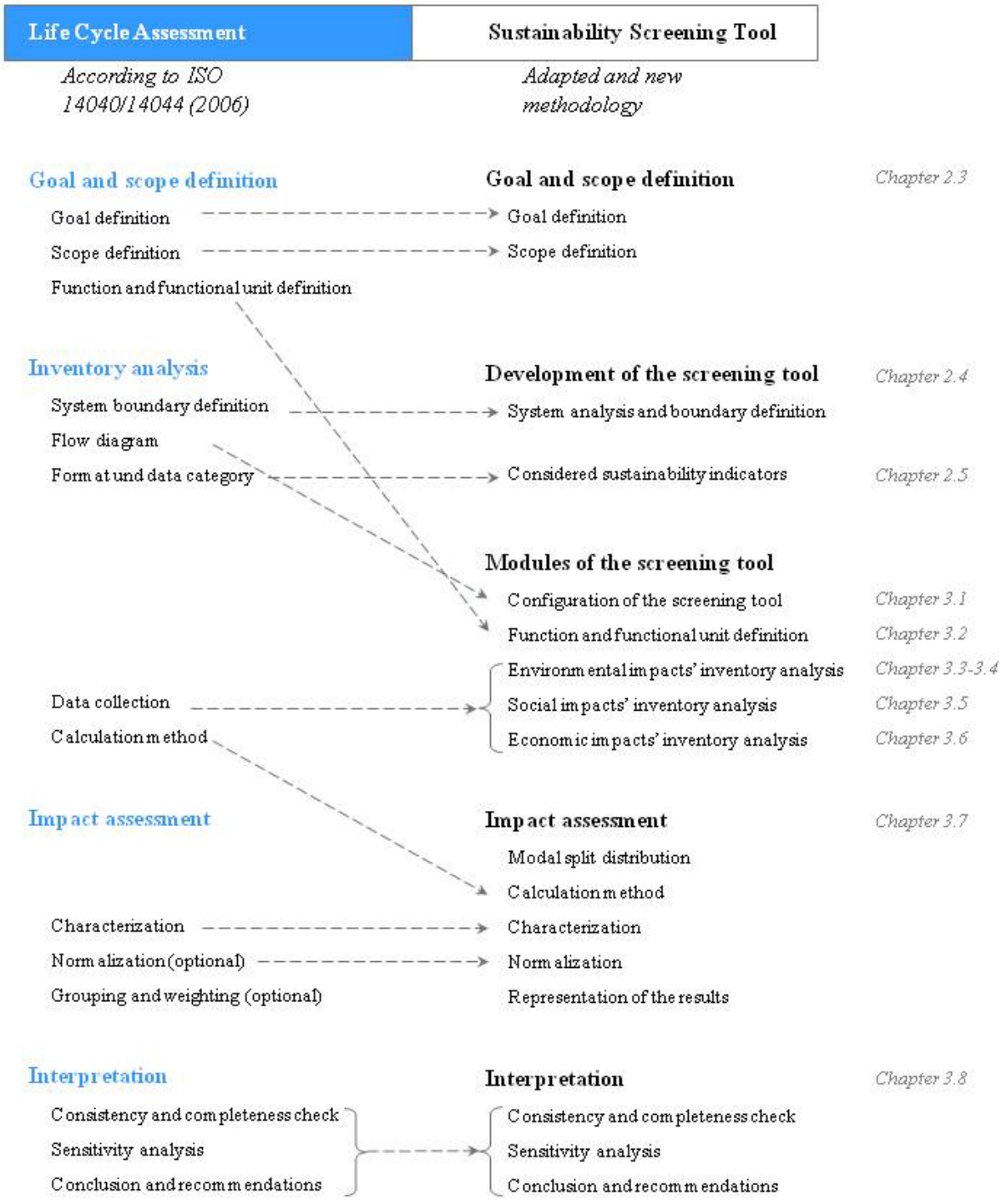


Figure 2.1: Development process and comparison with the LCA methodology (own representation)

2.3 Goal and scope definition

This step merges the initial choices that determine the **working plan** of the entire screening. The goal of the screening has been formulated in terms of the exact question, target audience and intended application. The scope of the screening has been defined in terms of temporal, geographical and technological coverage, and level of sophistication in relation to the goal.

This step is based on the methodology recommended by Guinée (2002) and can be seen as rules that have been kept in mind during the organization, assignment and progress of the evaluation (Table 2.1).

Table 2.1: Methodology and rules for the new screening tool (based on Guinée (2002))

Recipe according to Guinée *Determine, justify and report…*	**For the new screening tool**
Goal (aim or objective) of the study	The aim of the screening tool is the global exploration of a product or the comparison of products in order to get a first impression of the **sustainability impacts** (environmental, social and economic impacts) of diverse options. It could concern a **company-internal idea, a prototype or an innovation**.
Intended use of the results	The applications of the screening are comparable to those of LCA: – Comparing improvement variants of a given product; – Designing new products; – Choosing among comparable products. The screening provides **assistance for decision-making.**
Initiator of the study, practitioner, stakeholders, intended users	In LCA, the initiator and the practitioner are used to be different actors. In the screening, an **employee of the enterprise in charge of public transport** gets the screening into application and he/she is therefore the initiator, the practitioner, the interested party and the target audience at the same time. However, the role can change within the enterprise from one employee to another.
Temporal coverage of the study	The screening is for a **short-term until middle-term application**. Data have been selected mainly from the Ecoinvent database (Ecoinvent 2007), in which the selection of products and services to be analysed mainly relies on the market and consumption situation in Europe in the year 2000. The reference year of electricity mixes and power plant performances is 2004/2005.
Level of sophistication	The screening enables a **simplified analysis**, but could be attuned and improved with extensions.
Geographical coverage of the study	The screening has been built for **Munich** and its suburban area. Nevertheless, with an adaptation of database, it can be transferred to **every Western-European city**.
Technology coverage of the study	**Modal-modern technology** (i.e., average level of technology currently installed in the area under study) is considered. It could be the best available technology, but it is not necessary.
Operating investment	The operating investment is strongly dependent on the data availability. In the present case studies (for Munich in 2011), once the data has been merged, it requires around **one day of work**.

According to Guinée (2002), as well as to the standard ISO 14 040 (2006), the step "Goal and scope definition" implies the definition of the function of the product that will be analyzed. This step is not applicable for the entire screening, but depends on the idea and will be considered inside a specific module of the screening tool.

2.4 System analysis and boundary definition

This part refers to the first part of Life Cycle Inventory of LCA. However, the screening tool behaves on a complex system (urban mobility). It is thus impossible to describe shortly the boundaries and the interactions within the system, as in the case of LCA. Therefore, it was necessary to elaborate a **strategy for the development of the screening**. Since urban mobility is highly complex, the present work refers to Vester (2002) and his approach with complex systems. For the development of his Sensitivity Model, he proposed indeed a method in order to **deal with complexity**. From his experience, a strategy has been built by taking into account from the beginning the difficulties to be encountered. The first step was to understand in which system the screening is integrated and which variables it deals with.

We know from the beginning that we need to put a limit to the amount of information to look for, if we want to understand the overall **cause-and-effect relations** of the system. The approach of the work is holistic, as in the case of LCA, and the aim is to bring the different impacts of the idea into one consistent model.

> **The Sensitivity Model (Vester 2002, p.21)**
>
> "As soon as we go into detail, no matter how small our specialist area we shall sooner or later be overwhelmed by data. Where does the limit lie?"

A model, i.e. the basement of any tool, is a simplified representation of a part of reality. It has to be kept in mind that no model of "true reality" exists, and it must inevitably introduce a multiplicity of crude **simplifications** (Guinée 2002). The first step is to understand what a system is, and then to describe the system in which the sustainability screening behaves.

Definition of a system

According to Bossel (1994), a system is a **set of interrelated objects** (elements, parts). It fulfils a certain function and it has a characteristic constellation of elements. On closer look, a system is dynamic if it has **state variables** and **behaviour variables** (output, i.e., action of the system on its environment). State variables are defined as those variables that determine

completely the state of the system at any instant. They are independent of each other. The system has also its own system environment; for this reason, it is necessary to define a system boundary that clearly separates the system from its environment. There are two fundamental causes of state changes: Firstly, influences from the system environment may lead to state changes, and secondly, processes in the system itself may cause state changes (Figure 2.2).

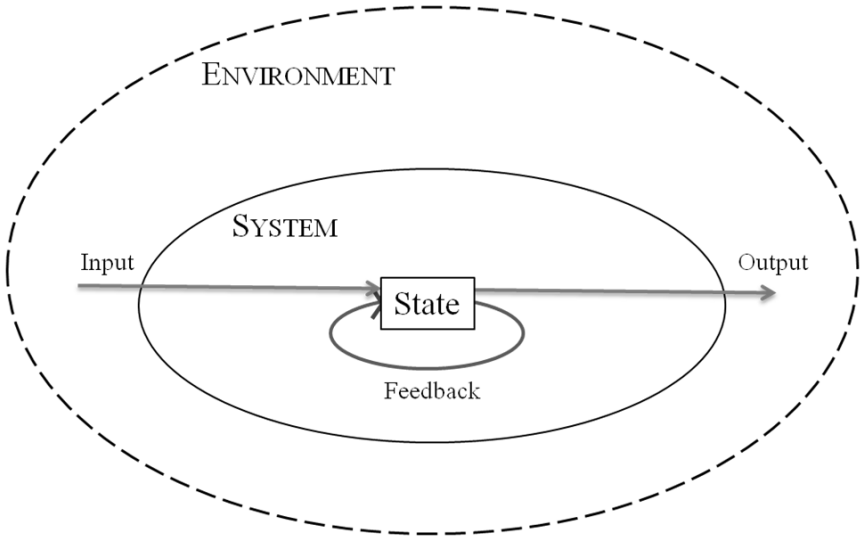


Figure 2.2: System dynamics (Bossel 1994)

In order to have a screening tool, which is based on a model and runs partly automatically, with coherent interactions and feedback loops, a description of the system was necessary, concretely: It was needed to analyze the variables and their interactions within the system.

Respecting the requirements previously defined, the aim was to "**scan**" the system as a whole in order to filter out vital key data and actuating variables that play a role in the way the system behaves. This process was possible thanks to brainstorming sessions, literature analyses, and expert interviews. It was important to find a uniform plane of aggregation, and avoid any doubling-up. The aim was therefore to examine the effects of all actuating variables in order to gain a picture of influences and dependencies.

To understand the inherent effects of the system, a suitable tool is a "**cross-impact matrix**" (Vester 2002), which leads to a cartography of the networks within the system. From this cross-impact analysis, it is possible to build the modules of the screening, as well as their interconnections.

Identification of the variables of the system

The starting-point for the **identification of the variables** was the implementation of a new mobility-idea for the improvement of the attractiveness of public transport. "New" is not in the sense of innovative, but means that it is the first time that it is implemented.

Therefore, the **key variables** of the system have been first identified and their relative behaviour has been analyzed. The system's people and the condition they are in have been taken into account with the same thoroughness as the field of economic or other activities, including use of space and the way the system relates to its environment. Therefore, the "three entities" of matter, energy and information have been represented in the same way as variables that open the system up towards the outside world.

Based on the methodology of Vester (2002), attention was paid for **actors**, **activities**, **space**, **mood of people**, and **internal processes**, which are playing a role in the system "urban mobility" and which are varying throughout the implementation process. Consideration was made for the actors of the microenvironment (customers, competitors, suppliers, intermediaries, communities, government, investors, financial institutions, media organizations, interest groups, and the public) and the influences of the macro environment (social, cultural and economic spheres, infrastructure, communications, administrative and institutional influences).

The system "urban mobility" has often been under study. Among others, researches have been led for better understanding of the field of mobility correlated with sustainability in general (Vester 1990), related to local public transportation (Albalate & Bel 2010; Litman 2008; MVV 2007a; Wall & McDonald 2007; Wulfhorst 2003) or related to private motorised urban mobility (Cameron et al. 2003; Kenworthy & Laube 1996; Knoflacher 2009). Analyses of sustainable transportation as a whole system have been under study with references to an "integrated system" (Givoni & Banister 2010; Schiller et al. 2010) and in the specific European context (Greene & Wegener 1997). Moreover, the problems related to sustainability and mobility (Chapter 1.2.4) as well as the requirements for the tool (Chapter 2.1) have been considered. On this basis, the variables of the system have been drawn up (Table 2.2).

Table 2.2: Variables for the considered system (own representation)

Category	**Variables**
Actors	Enterprise, user behaviour, public authority
Activities	Profit, investment
Space/Environment	Greenhouse gas emissions, pollutant emissions, resource consumption
Mood	User's wants satisfaction, user's basic needs fulfilment
Processes	Infrastructure

The main **ACTORS** in the screening have been highlighted:

- The **enterprise** that implements the idea is responsible for all decisions concerning the implementation of the idea. The enterprise can be the one in charge of the public transport or an enterprise that cooperates with the one in charge in order to implement a new idea.
- When an individual consumer is using public transport facilities – and thus potentially the new idea, which has been implemented, he/she becomes **public-transport user**. The public-transport user is perceived in the screening under two levels: First, he/she uses the public transport with different levels of implication (regular user, occasional user, etc.); and he/she is part of the population with different age structure, gender, etc. Depending on these factors, his/her behaviour for purchase decisions or choice of transportation modes is influencing the system; that is why the variable is called "**User behaviour**".
- The **public authority** is responsible for the financing of public transport facilities. In the case of Bavaria, the involved authorities are the Free State of Bavaria (in German "Freistaat Bayern"), the administrative districts (in German "Landkreise") and the municipalities (in German "Gemeinde") (Art. 8 und 9 of the law about public transport in Bavaria (BayÖPNVG 1996)).

Ignored actors of the system are the employees of the enterprise, since they are not directly in relation with the implementation of the new idea. Ignored are also the intermediate enterprises that achieve, for instance, the infrastructure.

As **ACTIVITY** at the enterprise level, the **profit** and the **investment** have been considered. Other activities, like taxes, jobs, purchasing and sales of the enterprise have been excluded of the system since they do not play a major role within the system and they are not connected directly to the idea.

Concerning the **SPACE** and the **ENVIRONMENT** of the system, the main variables linked with the mobility identified in literature are **greenhouse gas emissions**, **pollutant emissions** and

resource consumption (EEA 2009; IFEU 2001; IPCC 2007c). Since these variables have different origins and different impacts, they are not aggregated.

The **MOOD** of the people is also an important variable of the system. Indeed, the idea needs to be accepted, in order that its – potential positive – sustainable effects are visible (Beck et al. 2009). The subjective perception of the idea by the user is represented by the variable "**User's wants satisfaction**" (i.e., individual happiness). The basic needs of the users are crucial and have to be respected. Therefore, they are merged under the variable "**User's basic needs fulfilment**". The user needs themselves are not varying, but the way they are considered (i.e., respected or transgressed) can be different according to each idea.

As internal **PROCESS**, the variable "**infrastructure**" merges the actual matter linked with the implementation of the new idea (road, telecommunication, vehicles, etc.). Ignored processes are freight transport and long distance transport since they are not considering the transportation of persons in urban area.

The different modes of transport are not explicitly considered as variables in the system, since they are system themselves. They are split into the same variables and thus, indirectly considered within the system.

In order to distinguish the variables that belong to the system – independently to their categories – and the excluded variables, the system is represented as a **mind-map** in Figure 2.3.

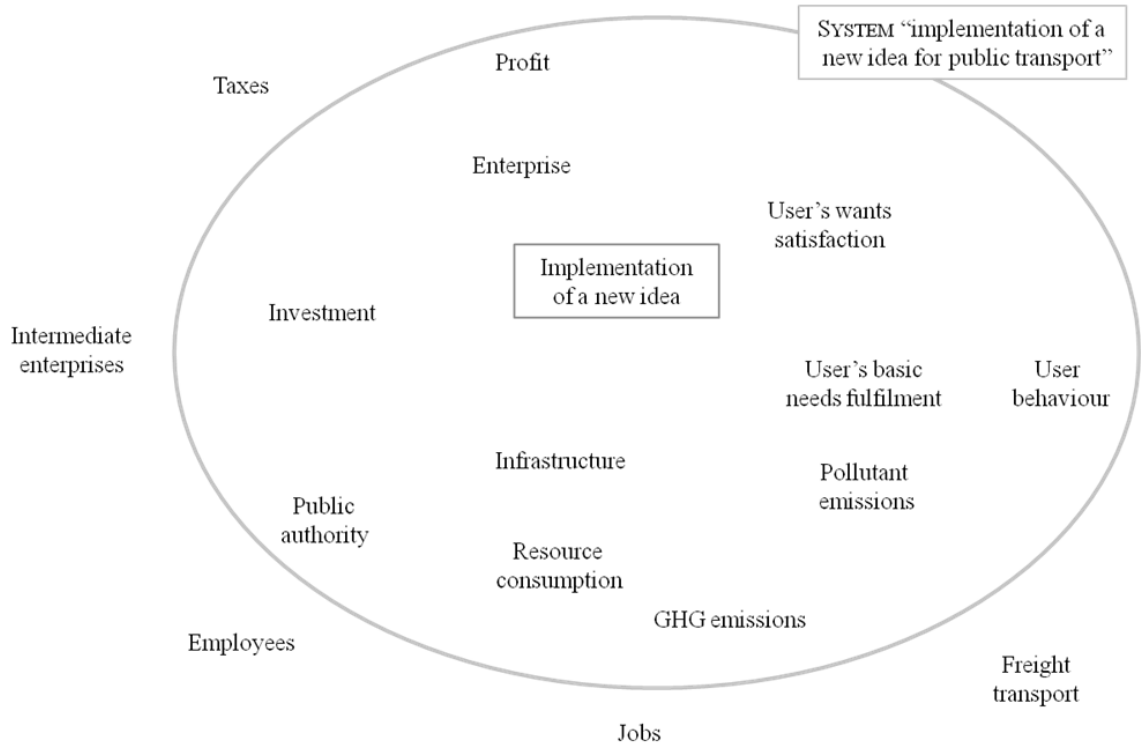


Figure 2.3: Considered variables, boundaries and extern variables of the system "implementation of a new idea for public transport" (own representation)

In that way, the variables are reflecting the actors, the activities, the environment and the processes resulting from the implementation of a new (public transport) idea. The next step has been the identification of the interactions that exist among these variables.

Allocation of properties thanks to the matrix of influences

In order to verify in a purposeful manner that the set of variables covers all the fundamental aspects of the system needed for the model to reproduce the reality, each individual variable has been checked to see **which function it fulfils**. The results have been entered in a matrix, so called "matrix of influences" (Vester 2002).

Matrix of influences (Vester 2002, p.219-220)

"Since the role of variable can never be identified from the variable itself (no matter how precisely it is studied) but only from the entirety of its interactions with all other components and their own interactions amongst themselves, the first step [...] consists in estimating the way in which that variable influences each of the others. [...] That examination occurs with the aid of a simple **matrix of influences**. In this process, a rough estimate will be reached both of the individual variable's dominance / susceptibility to influence and of the part it plays in events in the overall system. [...] In the matrix, the variables are listed from top to bottom and again in the same order from left to right. Since variables cannot directly influence themselves, all the boxes in which a variable encounters itself are marked with a cross. **Strengths of connections** are given values between 0 and 3. The question is always this: If I change element A, how strongly (in whichever direction) does element B change as a result of direct influence by A? [...] The number is entered [...] after a certain amount of thought and discussion, when all boxes have been filled in, depending on whether totals are active or passive, the first indications can already be gained. The "active" total of a variable and hence an indication of how strongly it affects the rest of the system is obtained by adding up the numbers in a horizontal row. Adding up the numbers in a column, on the other hand, gives the "passive" total, which indicates how susceptible the variable is to changes in the system and how it will react to them."

This process has been applied to the present system. In Vester's description, workshop(s) should take place in order to discuss which number should be entered in the table. In the case of the present work, the results of literature research, expert's interviews and outcomes from expert's workshops has been merged to fulfil the matrix (Table 2.3). In particular, the influences have been deducted:

- From a general logic which has been already highlighted in previous chapters,
- From literature (among others Albalate & Bel 2010; Cameron et al. 2003; Givoni & Banister 2010; Greene & Wegener 1997; Kenworthy & Laube 1996; Knoflacher 2009; MVV 2007b; Vester 1990; Wulfhorst 2003), and
- Thanks to expert interview and experts' workshops (Fink 2009; Kamphausen 2009; Kesselring 2010; MVV 2009; RMV 2009).

For the fulfilment of the matrix (Table 2.3), as underlined by Vester (2002), **only direct influences are considered**. In this state of affair, the following aspects can be underlined:

- The idea itself, and a change of it, influences on the one hand, the infrastructure, on the other hand, it can influence directly the user and his/her perception of the idea. Usually, the influence of the idea occurs through the infrastructure, but it is imaginable that the user does not have any contact with the infrastructure linked with the idea, for example, in a scenario with a virtual idea concerning the information. A little change of the idea can generate a big change for the infrastructure.
- Reciprocal connections are mainly among the enterprise, the investment and the infrastructure. However, there is no direct connection between the infrastructure and the enterprise; they are only connected through the investment.
- Concerning the environmental indicators, they are influenced mainly from the infrastructure and the user behaviour depending for example if they will use more or less their car (however, this second relation is not as strong as the first one). The resource consumption influences mainly the investment, the pollutant emissions influence the need of the user (concerning his/her health) and the climate change influences the public authority. These influences are however not strong.
- A change of the user's wants satisfaction and even more a change of the fulfilment of the user's basic needs are influencing the user behaviour (purchase behaviour and/or choice of transport modes).
- Public authority has an influence to the investment, since it is part of the German law (BayÖPNVG 1996; GVBI 2008). However, regulation is stringently established and big fluctuations are not possible.

Table 2.3: Matrix of direct influences (method from Vester (2002))

Legend: 0: no direct interaction, 1: big change of A changes a little B, 2: proportional change, 3: little change of A changes a lot B

Direct influence by / to	Implementation of new idea	Enterprise	Infrastructure	Investment	Profit	Public authority	GHG emissions	Pollutant emissions	Resource consumption	User behaviour	User's wants satisfaction	User's basic needs fulfilment	**Active sum**
Implementation of new idea	X	0	3	0	0	0	0	0	0	0	2	2	**7**
Enterprise	3	X	0	2	0	0	0	0	0	0	0	0	**5**
Infrastructure	0	0	X	2	0	0	2	2	2	0	2	1	**11**
Investment	0	2	3	X	2	0	0	0	0	0	0	0	**7**
Profit	0	2	0	2	X	0	0	0	0	0	0	0	**4**
Public authority	0	0	0	1	0	X	0	0	0	0	0	0	**1**
GHG emissions	0	0	0	0	0	1	X	0	0	0	0	0	**1**
Pollutant emissions	0	0	0	0	0	0	0	X	0	0	0	1	**1**
Resource consumption	0	0	0	1	0	0	0	0	X	0	0	0	**1**
User behaviour	0	0	0	0	3	0	2	2	2	X	0	0	**9**
User's wants satisfaction	0	0	0	0	0	0	0	0	0	2	X	0	**2**
User's basic needs fulfilment	0	0	0	0	0	0	0	0	0	3	3	X	**6**
Passive sum	**3**	**4**	**6**	**8**	**5**	**1**	**4**	**4**	**4**	**5**	**7**	**4**	

According to Vester (2002), a good way to represent the role of each variable in the system is a **two-dimensional diagram** in which the current position of a variable between four key roles (active, passive, critical, buffering) can be seen at a glance and properties can be assigned accordingly (Figure 2.4).

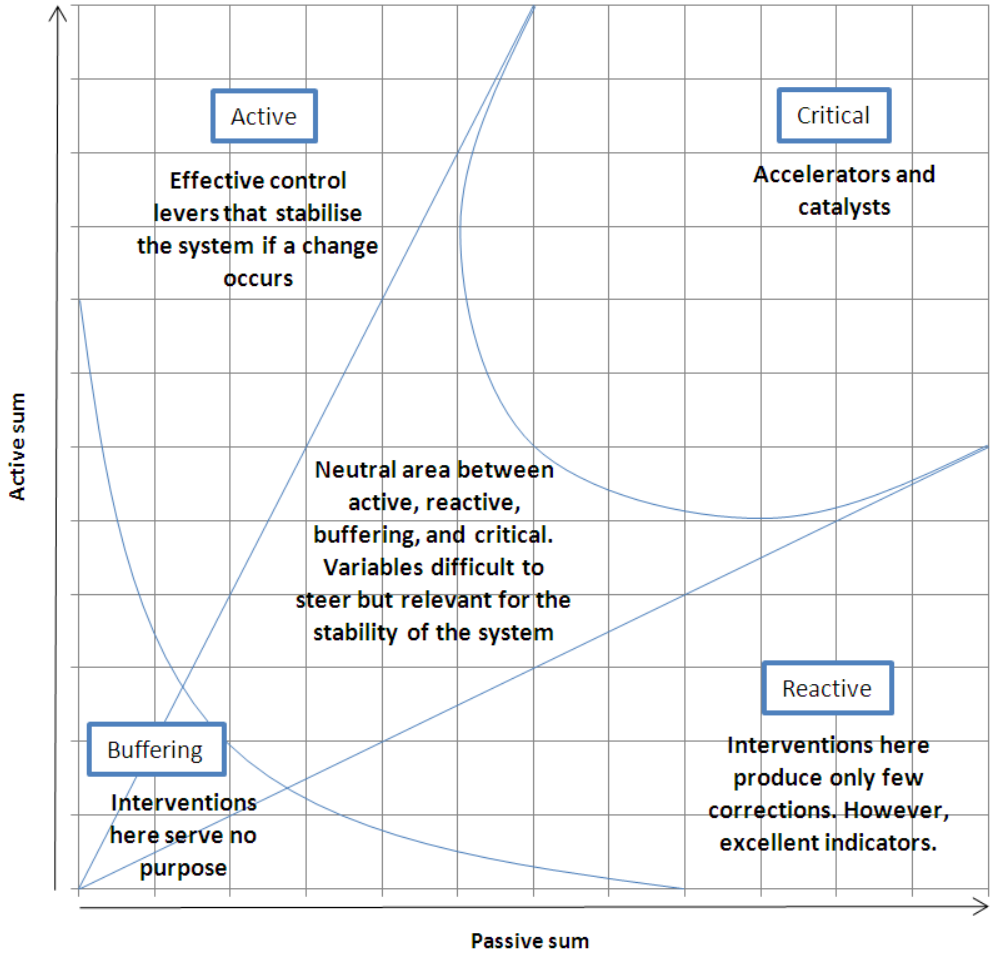


Figure 2.4: Two-dimensional diagram to interpret allocation of roles (Vester 2002)

For the considered system, the active and passive sums have been calculated (Table 2.3), which enables to allocate role (i.e., property) to each variable. Inspired by the Vester's method, the aim was here to identify the **most critical variables** of the system and to assign the properties of the other variables accordingly (Figure 2.5).

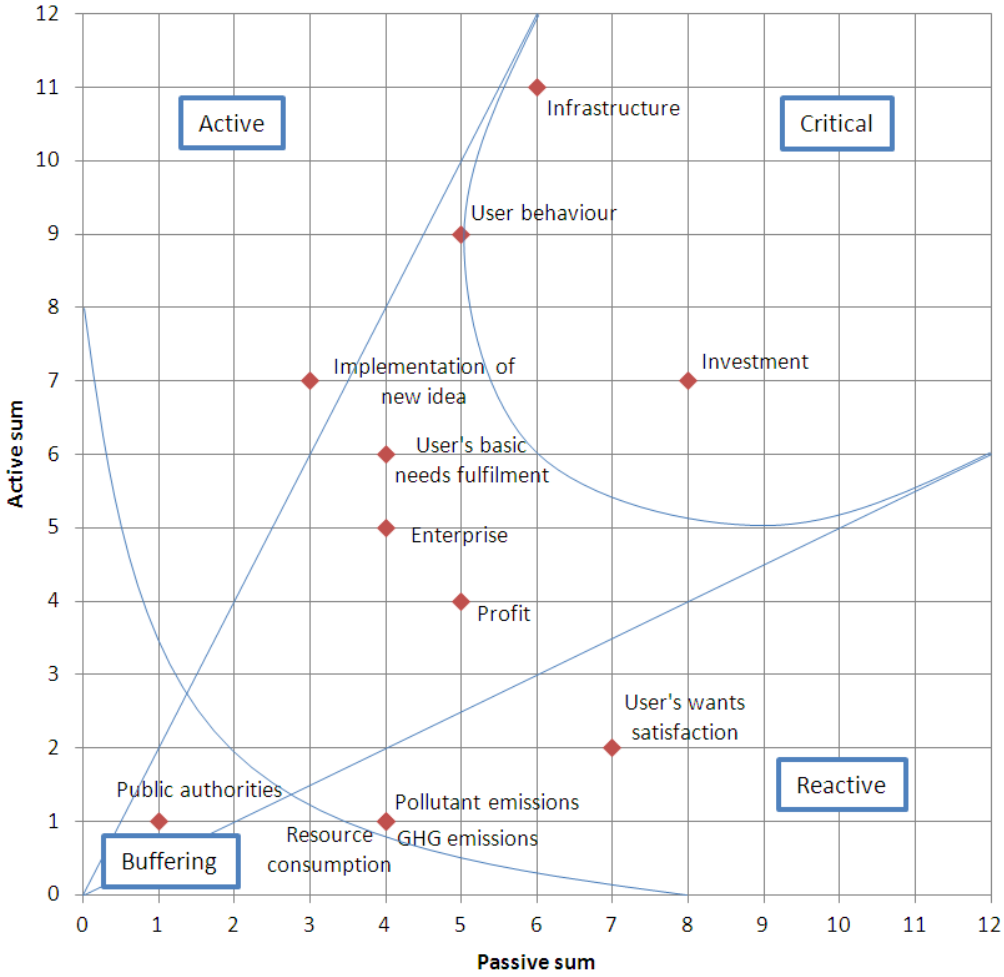


Figure 2.5: Allocation of properties in the system (own representation inspired by Vester's method (2002))

The critical variables – according to the graph – are the infrastructure, the user behaviour and the investment. For the screening tool, it means that these three variables have to be **at the focus**. The variable "implementation of new idea" plays an important role in the system and it is therefore used as **input** for the screening. Reactive variables are the environmental impacts and the user's wants satisfaction. According to Vester (2002), variables in this area are **excellent indicators**. It makes sense to use these variables as **output** for the screening (i.e., results of the screening). The buffering variable "Public authorities" has no direct role in the system and it will thus not be further considered. In the middle, the neutral area merges the fulfilment of the user's basic needs, the enterprise and the profit. They are important variables that play a big role in the system, however, according to Vester (2002), they are difficult to steer.

Analysis of the interactions of the variables

Thanks to the matrix of influence, actors, activities, environment, processes, and their interconnection have been represented in Figure 2.6.

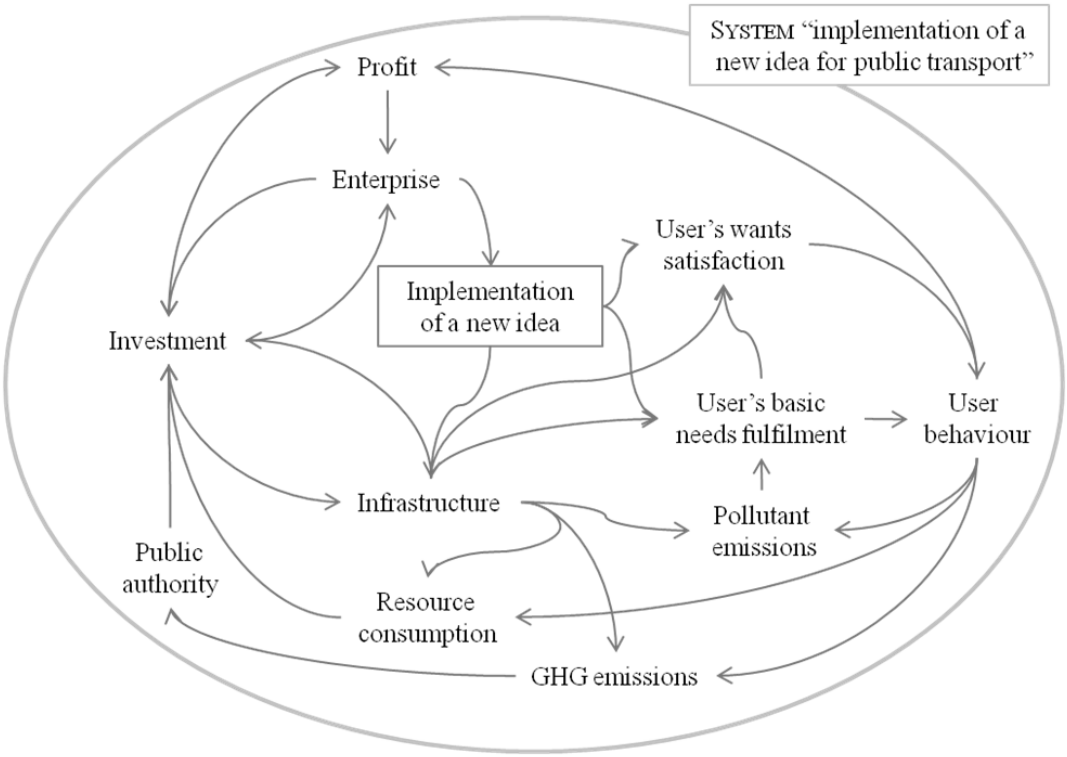


Figure 2.6: Network of the variables of the system (own representation)

Figure 2.6 shows that the system, as expected, can be considered as a complex system with multiple interconnections of variables and feedback loop. These feedback loops are important for the screening, since the modules within it must be also interconnected and have a feedback control possibility.

The process of identification of the variables and their respective properties was the basis for the choice of indicators (Chapter 2.5) and for the configuration of the screening tool (Chapter 3.1).

2.5 Choice of sustainability indicators

The choice of indicators is a critical determinant of the behaviour of a system (Meadows 1998). This also applies for the sustainability screening, making the selection of the sustainability indicators a critical point within the whole assessment.

The word indicator, based on the Latin "indicare", means "something that indicates, that shows". In the screening, indicators enable to indicate the impacts of the idea at the end of the evaluation process. The choice of indicators was initiated with the use of the previous method from Vester (2002) by identifying the variables. This analysis has highlighted that the **environmental impacts** and the **user's wants satisfaction** are excellent indicators for the system. It suits the definition of sustainability previously defined with the environment in the background fixing the boundaries and the user at the centre. The **investment** is also a highly reactive variable (high passive sum); therefore, it will also be considered as an indicator for the system.

2.5.1 Review of existing indicators systems

In the literature, **indicators systems** can be found, applicable from international to local level. These indicators systems consider the three spheres of sustainability or, at minimum, the environmental sphere of sustainability (Table 2.4). The list is not exhaustive, the aim was here to review possible compilations of indicators depending on the level of application.

Table 2.4: Overview of existing indicators systems (selection, own compilation)

Level of application	**Indicator system name**	**Institution**	**Indicators** (*: indicator with **direct** functional relationship to the system "urban mobility" under study)
International	OECD Key Environmental Indicators	Organisation for Economic Co-operation and Development (OECD 2003)	▪ CO_2 emissions intensities* ▪ Indices of apparent consumption of ozone depleting substances ▪ SO_x and NO_x emission intensities* ▪ Municipal waste treatment connection rates ▪ Intensity of use of water, forest and fish resources ▪ Intensity of energy use* ▪ Threatened species

Level of application	**Indicator system name**	**Institution**	**Indicators** (*: indicator with **direct** functional relationship to the system "urban mobility" under study)
International	CSD Indicators of Sustainable Development	United Nations (UN 2007)	Selection among the 50 core indicators: ▪ Population growth rate ▪ Percentage of population living in hazard prone areas ▪ Carbon dioxide emissions* ▪ Consumption of ozone depleting substances ▪ Ambient concentration of air pollutants in urban areas* ▪ Arable and permanent cropland area ▪ Proportion of total water resources used ▪ Proportion of terrestrial area protected ▪ Gross domestic product (GDP) per capita ▪ Material intensity of the economy ▪ Intensity of energy use* ▪ Generation of hazardous waste ▪ Waste treatment and disposal ▪ Modal split of passenger transportation*
International	TERM indicators 2008 (indicators tracking transport and environment)	European Environment Agency (EEA 2009)	▪ Freight and passenger transport and modal split* ▪ Greenhouse gas emissions from the transport sector* ▪ Local emissions and air quality* ▪ Transport fuel developments* ▪ Transport noise*
International	Sustainable Development Indicators (SDI)	European Union (EU 2009b)	▪ Growth of GDP per capita ▪ Greenhouse gas emissions* ▪ Consumption of renewable* ▪ Energy consumption of transport relative to GDP* ▪ Resource productivity* ▪ Abundance of common birds ▪ Healthy life years ▪ Risk of poverty ▪ Employment rate of older workers ▪ Official development assistance

Level of application	**Indicator system name**	**Institution**	**Indicators** (*: indicator with **direct** functional relationship to the system "urban mobility" under study)
National	Sustainable development indicators for Germany	Federal government (Destatis 2010)	Selection among the 21 indicators: ▪ Energy and raw material productivity* ▪ Greenhouse gas emissions* ▪ Share of renewable energy sources in total energy consumption* ▪ Increase in land use for housing and transport* ▪ Species diversity and landscape quality ▪ National deficit ▪ Private and public spending on research and development ▪ Gross domestic product per capita ▪ Intensity of goods and of passenger transport* ▪ Air pollution* ▪ Employment rate
Regional	Bavarian Environmental Indicator System	Bavarian Environment Agency (LfU 2004)	▪ Land for nature conservation goals ▪ Environmental farming ▪ Species endangerment ▪ Representative species ▪ Quality of treated wastewater ▪ Fertiliser use ▪ Acid and nitrogen, heavy metal input ▪ Water quality ▪ Carbon dioxide emissions * ▪ Air quality index* ▪ Road traffic noise* ▪ Total noise pollution in residential areas* ▪ Land take* ▪ Energy consumption* ▪ Waste and recycling ▪ Hazardous waste ▪ Contaminated sites ▪ Environmental management

Level of application	**Indicator system name**	**Institution**	**Indicators** (*: indicator with **direct** functional relationship to the system "urban mobility" under study)
Local	Core set of indicators for sustainable mobility in city and region	Umweltbundesamt (UBA) - German Federal Environmental Agency (UBA 2005)	▪ Modal split* ▪ Proportion of roads with good conditions for pedestrians and cyclists* ▪ Proportion of car-free areas and limited-speed areas in the city centre* ▪ Proportion of inhabitants living up to 300 metres to public transport facilities* ▪ Proportion of inhabitants with a noise exposure higher than 65 dB(A)* ▪ Proportion of inhabitants with a critical exposure of particle matter (PM10)* ▪ Proportion of dead or injured person through road traffic for 10.000 inhabitants*

From this overview, it is visible that the choice of indicators is strongly dependent on the goal of the study. For the screening tool, related to the goal of the study, it is necessary to restrict the amount of indicators to the **strictly essential** in order to keep the comprehensibility as clear as possible. Therefore, a criteria catalogue is used to restrict the amount of indicators (LfU 2004; Reul 2002; SRU 1998):

- **Relevance to sustainability** principles and goals;
- **Functional relationship** to the system "urban mobility";
- **Comprehensibility** (i.e., understandable for lay-persons);
- **Data availability** (i.e., data for the indicator easily and constantly available and up to date).

These criteria help to **filter** the high amount of available indicators to a restricted list of indicators that are suitable for the screening tool.

2.5.2 Environmental indicators

The following indicators have been previously identified for the system "urban mobility". Moreover, they are widely used in LCA practice across Europe and they cover the range of indicators used in the approach for "environmental evaluation in LCA" applied by the German Environment Agency since 1999 (Detzel & Krüger 2006; UBA 1999) and in studies

that relate to sustainable mobility (Greene & Wegener 1997). The screening deals with **aggregated pressure indicators** for comprehensibility reasons. With the help of the criteria catalogue, three indicators have been selected: Greenhouse gas emissions, energy resource consumption and pollutant emissions. The indicators "Noise" and "Land take", instead of their high functional relationship to urban mobility, have not been considered for the present framework because of their poor data availability. Moreover, noise is often evaluated on a qualitative way and may be considered as a social indicator (Chapter 2.5.3).

Greenhouse gas emissions

The anthropogenic greenhouse effect is a global problem with regional causes and impacts. On account of the rise in concentrations of the six greenhouse gases (CO_2, CH_4, N_2O, H-fluorohydrocarbons, fluorohydrocarbons and SF_6) in the atmosphere, temperature increase, a rise in sea level, a change in global and regional precipitation and an increase in extreme weather events are forecast. These climate changes affect ecosystems as well as **society** and the **economy** (LfU 2004). Rapid changes in climate may have, in particular, far-reaching impacts on biota and ecosystems. In addition, there are social and economic impacts such as those on regional production of foodstuffs and renewable raw materials and the threat to people and property though natural disasters (IPCC 2007b).

In the screening, the three main greenhouse gases (CO_2, CH_4 and N_2O) are considered with the respective CO_2-equivalent values (Table 2.5).

Table 2.5: Greenhouse gases and respective CO_2 equivalents taken into account in the screening (IPCC 2007a)

Greenhouse gas	**CO_2 equivalents (CO_2-e)**
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298

The aggregated indicator fulfils entirely the previously defined criteria:

- A **high relevance for sustainability** – in particular for politics,
- It has a **high functional relationship** to transportation,

- It has become more and more comprehensible by the public in the last decades (for example with the introduction of CO_2-emissions quote in marketing spots for cars (Belz & Pattie 2009)), and
- The availability and quality of data is considered as very good.

Fossil resource consumption

Human activities consume global and regional reserves of energy, water, soil/land and other raw materials. The available reserves of today's most important fuels, i.e., crude oil, natural gas and coal, as well as minerals (e.g., ores) are just as limited as agriculturally productive, fertile land.

Many pressure factors are associated with the resource consumption. These are caused by the energy sector, industry and commerce, households and transportation. Through the production of goods and services, the macroeconomic supply sector has a substantial influence on the use of natural resources. The environmental impacts are twofold: firstly, inefficient resource utilization combined with inadequate substitution or regeneration rates causes **regional and global resource shortages**. The economic, social and ecological implications are primarily associated with risks for future generations. Secondly, decisions concerning the use of environmentally relevant input materials and production processes always contribute to pollution of the environmental media. Carbon dioxide is released during the combustion of fossil fuels (e.g. coal, oil, and gas), leading to an increase in the atmosphere's CO_2 content and hence contributing to the anthropogenic greenhouse effect. Energy-related air pollutants of particular relevance include NO_x, SO_x, CO and dust. These impair human health (e.g. respiratory diseases) to an extent that is dependent on their concentrations. Deposition of NO_x and SO_x can lead to eutrophication and acidification of soils and water. These phenomena, in turn, can impact on ecosystems (e.g. forests) (LfU 2004).

Considering the high amount of indicators that relate to resource shortages (cf. Table 2.4), a choice has been made to exclude the material resource consumption and preferring the focus on **fossil energy resources** since the functional relationship to the system "urban mobility" is higher, the data availability is better and the comprehensibility for layperson is better. It is furthermore highly relevant for sustainability in regard to the future generations. Therefore, the following fossil resources are considered: crude oil, brown coal, natural gas and mineral coal. The scarcity values are converted into Crude Oil Equivalents (Detzel & Krüger 2006), which are themselves associated with conversion factors (Table 2.6).

Table 2.6: Crude oil equivalents of fossil resources considered in the screening (Detzel & Krüger 2006)

Fossil resources	Crude oil equivalent (COE)
Crude oil	1
Brown coal	0.0409
Natural gas	0.5212
Mineral coal	0.1836

Pollutant emissions

Road transport emissions of air pollutants decline in Europe. Nonetheless, a report from the European Energy Agency (EEA) has shown that they remain the primary source of nitrogen oxides and the second most important source of fine particulates (EEA 2008). Long-term and peak exposure can lead to a variety of health effects, ranging from minor irritation of the respiratory system to premature death. Particulate matter, a term used to describe a variety of tiny particles from sources such as vehicle exhausts and domestic stoves, affect the lungs. Exposure can harm people of all ages, but people with existing heart and respiratory problems are particularly at risk. According to the latest EEA data (2009), since 1997 up to 50 % of Europe's urban population may have been exposed to concentrations of particulate matter above the EU limit set to protect human health. Transfer of pollutants as NO_2 to sensitive, semi-natural habitats and their deposition there causes acidification and eutrophication processes, which can have negative impacts on the ecosystems (LfU 2004). **Especially urban areas** with heavy traffic are affected by high levels of nitrogen dioxide from vehicle emissions, which confers this indicator a high functional relationship to the topic.

Conversion factors supplied by the European Environmental Agency (Leeuw 2002) are used to quantify compounds such as sulphur dioxide (SO_2), nitrogen oxide (NO_x), non-methane volatile organic compounds (NMVOC) and ammonia (NH_3) as secondary particles (Table 2.7).

Table 2.7: PM10 equivalents of secondary particles considered in the screening (Leeuw 2002)

Particles components	**PM10 equivalents (PM10-e)**
Particles matter <10 mm (PM10)	1
Sulphur dioxide (SO_2)	0.54
Nitrogen oxide (NO_x)	0.88
Non-methane volatile organic compounds (NMVOC)	0.012
Ammonia (NH_3)	0.64

The aggregated indicator "Pollutant emissions" (PM10) completes the two other indicators GHG emissions and resource consumption thanks to its high functional relationship to urban mobility and its relevance to sustainability concerning the air pollution and its impacts on human health and ecosystems.

Environmental indicators framework

The European Environmental Agency developed a framework, so-called "DPSIR framework" (EEA 1999), which has been used and adapted e.g. by the Bavarian Environment Agency (LfU 2004). The DPSIR framework is useful in describing the relationships between the origins and consequences of environmental problems, and it reflects therefore a systems analysis view of the relations between the environmental system and the human system. The DPSIR framework classifies the environmental indicators:

- **Driving-force** indicators show which human activities cause the relevant environmental pressures.
- **Pressure** indicators describe which specific environmental pressures are caused by the various sectors.
- **State** indicators describe environmental quality, i.e. the state of environmental media and natural resources, which is affected by pressure factors.
- **Impact** indicators show the further effects and impacts of changes in environmental quality.
- **Response** indicators measure the efforts by society (e.g., politicians, decision-makers in the relevant fields of action) to respond to the changes in environmental quality and the impacts thereof.

Based on the DPSIR framework and on the effects structure of Bossel (1994), it is possible to elaborate an own framework with the environmental indicators with the different linkages that exist between the indicators and their impacts (Figure 2.7).

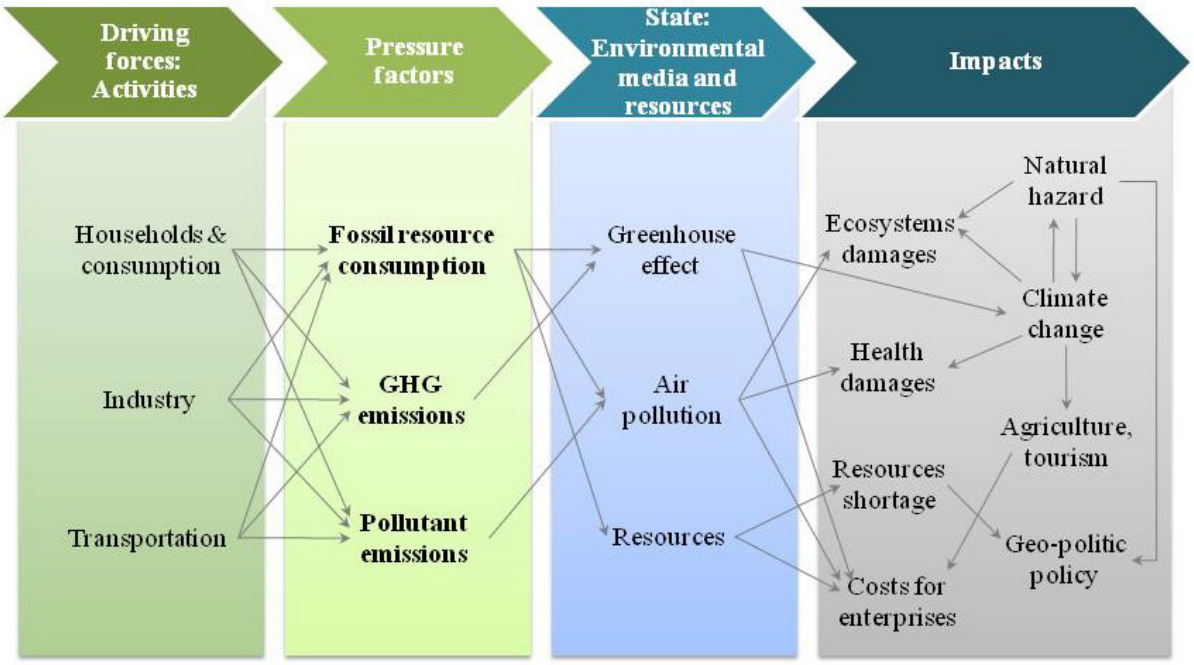


Figure 2.7: Environmental indicators framework from origin until impacts (own representation based on LfU (2004))

This framework of indicators confirms the choice that the **pressure indicators** fossil resource consumption, greenhouse gas emissions and pollutant emissions cover the main environmental aspects that occur within the system "implementation of a new idea for public transport". They embrace the **global and local impacts** of climate change, resource depletion and pollution, commonly at the centre of environmental sustainability studies; and they are therefore considered as **essential** and **sufficient** for the screening.

It confirms the fact that the **interconnections** are wide and that they merge actually more than the pure environmental consideration. Indeed, for example, "pollutant emissions" is an environmental indicator but it has effects on a **social level** by engendering health damages for the population. In the same vein, "fossil resource consumption" affects the **economy** since the scarcity of resources induce higher price on the market, and thus high costs for enterprises. Therefore, it encourages us to place the assessment of environmental impacts **at the focus of the screening**.

2.5.3 Social indicators: user's basic needs and user's wants

As previously noticed, the sustainability screening has the particularity to consider the consumer, i.e., in the specific case, the user of the new idea within public transport. The aim of the screening is to appraise **how useful** the idea is relating to the user needs and wants.

The human needs and direct satisfiers defined by Costanza et al. (2007) have been used in this research to identify the basic needs that are related to urban mobility, and especially to public transport (Table 2.8).

Table 2.8: Selection of human needs and direct satisfiers for the field of public transport (based on Costanza et al. (2007))

Human needs	**Direct satisfiers in relation with public transport**
Security	Security and safety
Understanding	Access to information
Identity	Status, recognition
Freedom	Freedom of mobility (Accessibility)

The direct satisfiers have been selected to represent the basic needs in the screening. Since the aim is also to identify the users' expectations and the reasons for choice of transportation modes, the list is completed with social factors for successful distribution, which had been identified by the help of scenario-oriented expert interviews and secondary analysis (Beck et al. 2009). Table 2.9 exposes the needs considered in the screening with a distinction between the **user's basic needs**, which reflect the general interest (cf. Table 2.8), and the **user's wants**, which reflect the individual expectations.

Table 2.9: Basic needs and individual wants considered in the screening (adapted from Beck et al. 2009; Costanza et al. 2007)

	Sub-indicators	
Indicators	**User's basic needs (reflect general interest)**	**User's wants (reflect individual expectations)**
Security	- Safety in transport and security of the transport	- Reliability (punctuality, familiarity)
Information	- Availability of information (access)	- Quality of information (actuality, comprehensibility)
Social acceptance	- Identity (Status and life style expression)	- Sustainability awareness
Distance	- Accessibility (Distance to the first mobility system)	- Number of transitions and barriers
Convenience		- Flexibility (alternative use of the journey, independence) - Comfort (privacy, force deployment, temperature, fun)
Costs		- Direct costs for travelling - Indirect costs
Time		- Travel time and waiting time - Preparation time

It is important to realize that some of the needs of Table 2.9 are overlapping and some are conflicting. For instance, comfort can be satisfied by the perception of security, which belongs to another indicator. Costs and time are closely overlapping, since it is common to attribute a monetary value to travel time (Crozet 2005). Moreover, sustainability awareness can conflict with comfort or perception of privacy (e.g., for the choice between driving a car or bicycle).

These indicators have a good comprehensibility, a high functional relationship to the system "urban mobility" and a high relevance for sustainability. This relevance to sustainability is high for two reasons: On the one hand, the **basic needs must be fulfilled**. They are indeed at the centre of the definition of sustainable development (WCED 1987) and it is the role of public transport to foster the general interest. Especially accessibility is a fundamental principle of sustainable transportation since it is the delivery of effective "access for all"

without discrimination as to income, physical ability, housing location, mode of travel or any other factor (Schaeffer & Sclar 1975). Accessibility, in other words, contributes to sustainability since it ensures options in activity participation (economic level), provides opportunities for everybody (social level) within crossing ecological boundaries (environmental level) (Wulfhorst 2010; Wulfhorst et al. 2011). Once more, the interconnection across the spheres of sustainability is obvious.

On the other hand, the satisfaction of the user's wants is necessary in order to **extend the diffusion** (i.e., the distribution) of the idea **on the market** and thus, makes active the positive effects of the new idea (Beck et al. 2009). However, there is theoretically no limits to user's wants (Stø et al. 2008), and for sustainability, this point is critical because there are physical limits to human activity (Meadows et al. 1972; Meadows et al. 2004).

Therefore, for the evaluation of an idea with the screening, the social impacts analysis is made for two reasons:

- On the one hand, the fulfilment of the basic needs is checked to see if the general interest is not corrupted according to the normative stance of sustainable development.
- On the other hand, the satisfaction of wants is investigated to forecast the diffusion of the idea on the market and to predict potential giving out of positive effects.

2.5.4 Economic indicators

In the official reports, the economic indicators of sustainability are usually linked with the development of the economy of the country (e.g., Gross Domestic Product per capita, inflation rate, places of employment) (UN 2007). Economic analyses are considered to be exact and objective, however, in the practice, there are problems of data availability, variety of costs (actual vs. planed costs), time-relative costs, costs influenced by the public authorities (subventions), assumptions about calculation of interest, etc. (Grießhammer et al. 2007; Rau 2010). In the screening, moreover, the connection between a new idea and the usual economic indicators is seen as non-reliably analyzable, because too many imponderable assumptions should be made. Nonetheless, an estimation of the global impacts on the economy of a country is indirectly considered within the environmental indicators framework (cf. Figure 2.7, indicators as resources shortages imply indirect economic impacts by inducing higher prices on the market).

Considering the goal and the boundaries of the system, the screening considers for the economic analysis the **value for the enterprise** linked with the implementation of the new

idea. This indicator is not at the focus of the evaluation and it has rather a role of **aspect to be checked**. We have seen in Chapter 1.3.3 that the main drivers for enterprises are benefit generation and risk management. Thus, the aim is to see if the implementation of an environmentally friendly and socially useful idea makes sense for the enterprise, i.e., if the enterprise will earn money with it and stays competitive on the market, or if it is unrealistic because the return on investment would be too low or non-existent.

Thus, in the screening, the value for the enterprise is the difference between the **costs needed to implement the idea** and the **earnings obtained from users' acceptance**. This indicator as a high functional relationship to the system, a moderate relevance to sustainability, it is comprehensible and data are available within the enterprise of the screening practitioner.

2.5.5 Summing-up of the indicators considered in the screening tool

Table 2.10 sums up the indicators that are considered in the screening.

Table 2.10: Overview of the sustainability indicators system of the screening tool (own representation)

Sustainability spheres	**Indicators of the screening tool**	**Sub-indicators**
Environment	Greenhouse gas emissions	▪ Carbon dioxide (CO_2) ▪ Methane (CH_4) ▪ Nitrous oxide (N_2O)
	Fossil resource consumption	▪ Crude oil ▪ Brown coal ▪ Natural gas ▪ Mineral coal
	Particle emissions	▪ Particles matter <10 mm (PM10) ▪ Sulphur dioxide (SO_2) ▪ Nitrogen oxide (NOx) ▪ Non-methane volatile organic compounds (NMVOC) ▪ Ammonia (NH_3)
Social	Security	▪ Safety in transport and security of the transport ▪ Reliability
	Information	▪ Availability ▪ Quality
	Social acceptance	▪ Identity ▪ Sustainability awareness
	Distance	▪ Accessibility ▪ Numbers of transitions and barriers
	Convenience	▪ Flexibility ▪ Comfort
	Costs	▪ Direct costs for travelling ▪ Indirect costs
	Time	▪ Travel time and waiting time ▪ Preparation time
Economic	Value for enterprise	▪ Costs to implement the idea ▪ Earnings from users' acceptance

Whereas goals are formulated in a general and very wide way within other sustainability indicators systems (Table 2.4), the aim of the sustainability indicators within the screening tool is to focus on the system "new idea for the public transport". The choice of indicators has been made by integrating Dubos's adage "Think Globally, Act Locally" since they reveal the **global impacts** of the implementation of a **local idea**.

It is important to notice that each sphere has a **different number of indicators**. This inequality is a result of the goal and scope of the present study, which **focuses** on the environmental and social aspects of sustainability. The results must therefore be carefully interpreted taking into account these considerations. It is, at last, part of the decision-making within the enterprise in charge of public transport to decide **which indicator or accordingly which aspect of sustainability is the most important for the evaluation**. Indeed, depending on the goal of the study (e.g. political instruction) and on the intended use of the results (e.g. comparison of variants of a given product), the **enterprise is free** to put the accent of the evaluation on specific indicators or even aspects of sustainability (for instance, on the social aspect). This point will be further discussed within the interpretation of the results (Chapter 3.8) concerning the weighting phase.

3 Modules of the screening tool

3.1 Configuration of the screening tool

Thanks to the identification of the variables (actors, activities, space and environment, mood and processes, Table 2.2) and the analysis of their properties within the system "implementation of a new idea for public transport" with the matrix of influences (Table 2.3 and Figure 2.5), the modules of screening tool are conceptualized (Table 3.1).

Table 3.1: Conceptualization of the modules of the screening tool (own representation)

Category of variables according to Vester (2002)	**Variables identified** (Table 2.2)	**Related modules in the screening tool**
Processes	Infrastructure	Description of reference and target scenarios
Space/Environment	Greenhouse gas emissions, pollutant emissions, resource consumption *(= environmental indicators)*	Environmental impacts' inventory analysis
Actors	User behaviour	Target users and related behaviour
	Enterprise, public authority	No direct consideration within modules
Mood	User's wants satisfaction, user's basic needs fulfilment *(= social indicators)*	Social impacts' inventory analysis
Activities	Profit, investment *(= economic indicators)*	Economic impacts' inventory analysis

These modules, as well as modules for the impacts assessment, the calculation of modal split and the results, constitute the **screening tool** (Figure 3.1).

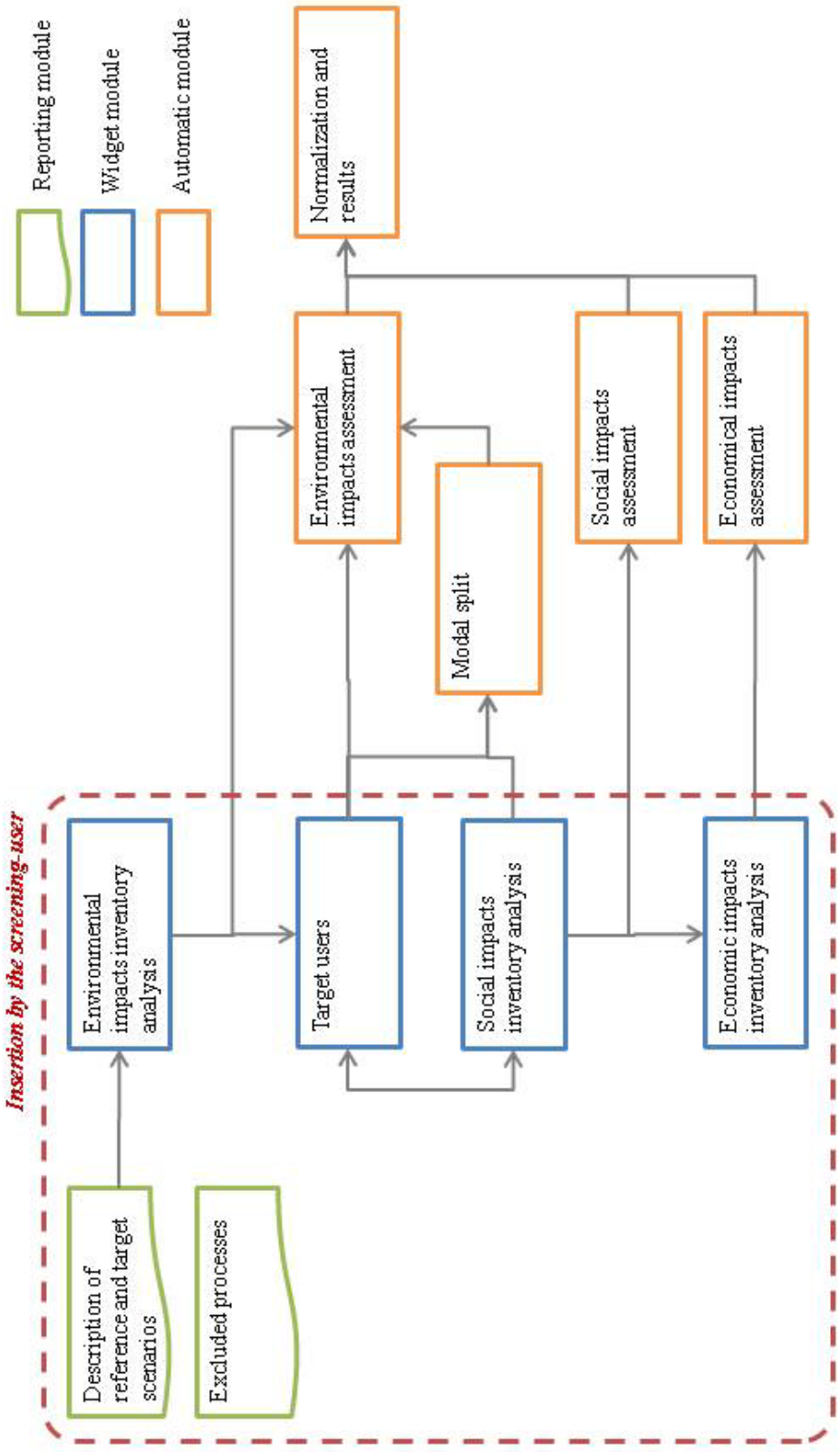


Figure 3.1: Modules of the screening tool and connections within it (own representation)

The screening runs from top to bottom and from left to right. However, the screening is built in order to enable a constant feedback control. Indeed, it provides a **trial-and-error process** (i.e., following the adage "learning by doing"), where entries can be modified, added or cancelled at any time.

The screening deals with different kind of modules (reporting, widget, and automatic modules). The screening tool is available for consultation on the annexe E.

Reporting modules

These modules are **filled by the screening practitioner** and they are useful to keep an overview throughout the screening process. Indeed, it is important to report and justify any assumption to ensure transparency (Guinée 2002) and support arbitrariness. Moreover, it simplifies the review process from a third part.

Widget modules

In the field of graphical user interface, a widget is a component of an interface that enables a user to perform a function or access a service. In the screening, diverse widgets are used, i.e., the interface with the screening practitioner can have three different forms:

- **Dropdown list**: The screening practitioner chooses items within a suggestion list,
- **Input box**: The screening practitioner inserts e.g. a number concerning a quantity with the predicated box,
- **Checkbox**: The screening practitioner clicks e.g. to answer yes or no to a question.

Within the screening, these modules are thematically divided between the environmental, social and economic impacts' inventory analyses and the target users. The widget modules are furthermore connected to the automatic modules.

Automatic modules

These modules are invisible to the screening practitioner and they are interacting in connection with the widget modules and the database in the background. These modules are acting as **calculators** and they give at the end a result, which is treated and eventually sent to another module. In the screening, the modules 'modal split', 'impacts assessments', and 'normalization and results' are automatic modules.

3.2 Modules 'Description of reference and target scenarios' and 'Excluded processes'

These modules are reporting modules, which means that they are filled by the screening practitioner.

Although the screening aims to be science-based, it involves a number of **technical assumptions and value choices**. An important role is played by the reporting modules, which helps to avoid arbitrariness. Indeed, it is important to make the assumptions and choices as **transparent** as possible.

These modules can be checked at any moment during the modelling process. As for the entire screening, the accent is put on "learning by doing", since the screening practitioner is able to come back to a previous step and to adapt the system to the findings he/she made. For this reason, reporting is essential and helps keeping in mind what is considered, compared and eventually excluded. The different modules can be consulted at the end of the evaluation in order to realize to which extend and with which assumptions the results are valid.

The screening tool starts directly with the request of formulating the new idea (i.e., the **target scenario**), its function, functional unit, and associated processes. After it, the screening practitioner is asked about the current idea(s) that the new idea will replace; it is the **reference scenario**. Description of excluded processes in the evaluation is optional, but recommended since it provides a valuable information support.

The reporting modules do not have any influence with the calculation within the screening. They are in form of input boxes, in which the screening practitioner takes **inventory** of the decisions and related assumptions he/she makes.

The first step is to **describe the new idea as concisely as possible**, i.e. the **target scenario.** It is important to document and justify in a transparent manner the "future" assumptions made since the systems selected potentially include systems that are yet to be developed or do not feature on the current market.

The second step is to define the **function** to be fulfilled by the idea. This step is correlated with the previous one and it is essential to provide a **comparison** with other ideas (i.e., other scenarios). The idea has to be seen as a system. Following the advice of Guinée (2002) for the methodology of a simplified LCA, it is necessary to identify, determine and describe the **functions** to be analyzed, and to formulate them in terms of the final use function(s). Additional functions are ignored; nevertheless, they are reported within the module

"excluded processes". After that, the screening practitioner defines the **functional unit**, i.e., he/she determines for which key parameters the system is functioning and in which unit they are expressed. He/she defines the function of the system in terms of these key parameters as accurately as possible and unambiguously.

In LCA, the practitioner takes an arbitrary amount of this function to quantify the amount of function analyzed. In the screening, the **time-scale is fixed to one day** and the screening practitioner may choose among 'trips per day', 'kilometres per day', 'persons per day' or 'pieces per day' for the comparison between the reference and target scenarios. It implies that the results are expressed related to one day.

The step 'function and functional unit' is essential since it enables to select after it **alternative products** that are meeting the requirements of the functional unit – in the present case, mainly products that are already implemented. These products represent the **reference scenario**. The screening practitioner has to justify and explain, if relevant, why certain product systems are considered while others have been omitted from the assessment, although they obviously fulfil the same function or service (**excluded processes**).

Figure 3.2 is a screenshot of the screening filled – as an example – for the idea "Mobile-phone ticket". The modules are available for consultation in the beta version of the tool (Annexe E).

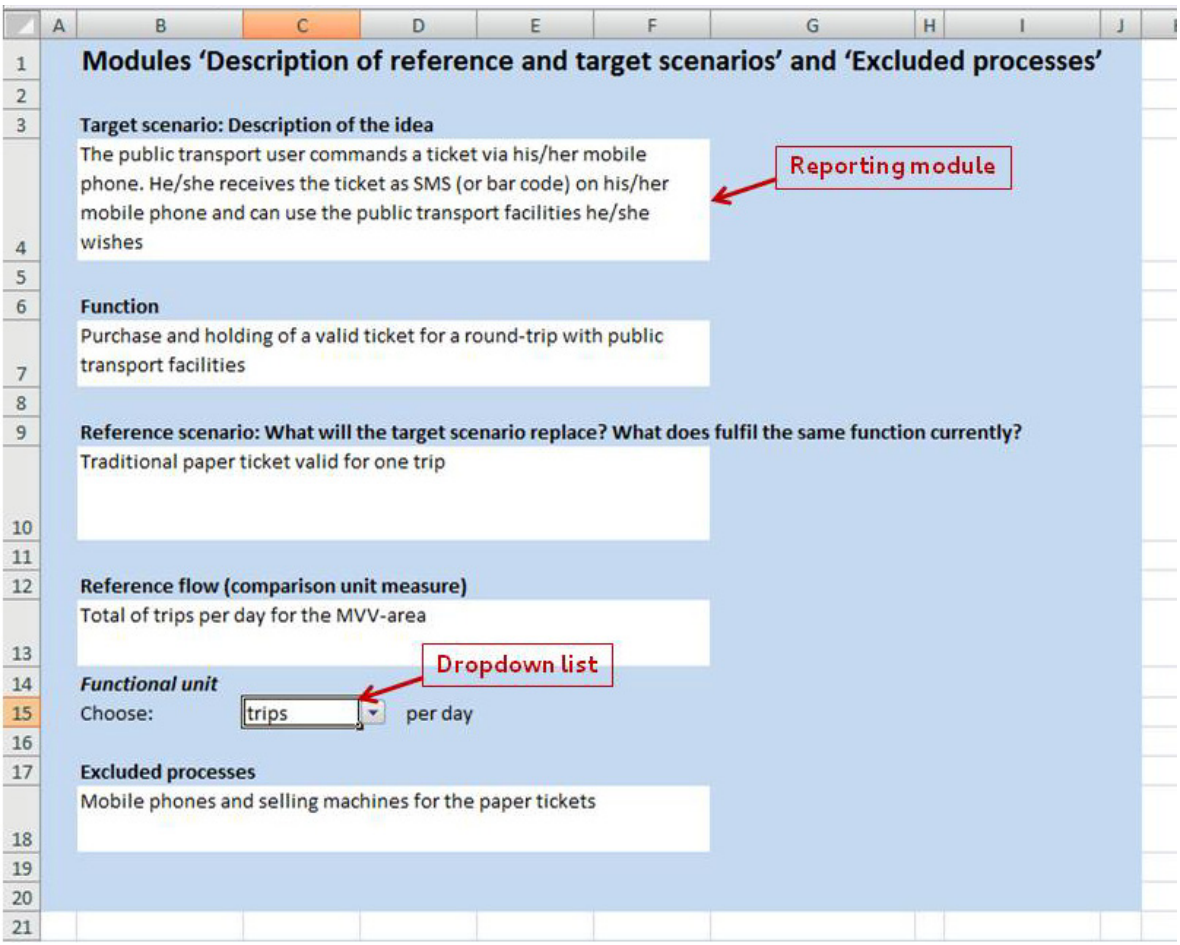


Figure 3.2: Screenshot of the module "Description of reference and target scenario" and "Excluded processes" for the idea "Mobile-phone ticket" (beta version of the screening tool, annexe E)

3.3 Module 'Environmental impacts' inventory analysis'

This module refers to the step 'data collection' of an inventory analysis of LCA. It is, however, simplified and adapted to the present procedure. In this module, the processes of the system are selected and weighted. According to the standard ISO 14040/14044 (2006), a process is "a set of interrelated or interacting activities that transforms inputs into outputs".

In principle, like for an LCA, the screening should track all the processes in the life cycle of a given product system, from the cradle to the grave. In practice, however, this action is impossible and a number of flows must be either **roughly estimated** or **cut off** and subsequently ignored.

Cut-off and data estimation for LCA (Guinée 2002, p.500)

"The root problem behind the cut-off issue is the lack of readily accessible data, implying disproportionate expenditure of funds and efforts on data collection. Cut-off can substantially influence the outcome of an LCA study, however, which means that "easy" LCA come at a price. [...] Cut-off is necessary mainly for reason of lack of data, in combination with lack of time and money. Cut-off is interpreted as more than simply ignoring certain parts. More importantly, the estimation of lacking data is an essential element [of the assessment]. The estimation can be made by approximation of the process by a similar process. If it is not possible, cut-off will be then achieved by putting flows explicitly to zero. For example, "the product xy has not been allocated, but just ignored for the sake of simplicity. This can be justified by acknowledging that x is negligible compared to y"."

These rules are applied to the screening methodology.

3.3.1 Selection of processes

Referring to the previous module 'idea description', the screening practitioner chooses in a list of available processes, the ones to model the target scenario and the reference scenario. As stipulated before, a small number of foreground processes have been gathered, i.e., processes for which primary data have been collected. Processes that exist in reference as well as in target scenarios and processes that are not modified through the idea are not considered. For example, infrastructure that is already implemented and not modified is not inserted in the screening.

The data collection was provided from the **Ecoinvent database v2.0** (2007) according to Frischknecht & Jungbluth (2007). The Ecoinvent database is the product of a long-term project and its roots go back to LCI experiences made in the late 80s and 90s in Switzerland (Frischknecht 2005). For the Ecoinvent database, almost all process datasets are transparently documented on a level of unit process inputs and outputs. The methodological approaches being applied show a high level of consistency throughout the database and thus guarantee a coherent set of Life Cycle Inventory data. Additionally, the level of data quality is reported quantitatively in terms of standard deviations of the amounts of input and output flows. All the datasets that appear in the database had to pass a standardized quality control procedure. Yet, it must be mentioned critically that a high level of transparency does not automatically imply a high level of data quality. It does allow an assessment and a personal

judgement of suitability and appropriateness of a dataset to a certain context (Frischknecht 2005). The study is focussed on the development of the screening tool; therefore, it does not deal with **primary data generation**.

Within the beta version of the screening tool (Annexe E), only few processes are available, but the list can be extended if necessary (Table 3.2).

Table 3.2: Processes of the screening (selection) and original name in the Ecoinvent database (Ecoinvent 2007)

Legend: RER/CH: geographic scope for Europe (RER) or Switzerland (CH) (Frischknecht & Jungbluth 2007)

Processes of the screening	**Processes' name in the Ecoinvent database**	**Unit**
Paper	Paper, wood-containing, LWC, at plant, RER	kg (kilogram)
Computer	Use, computer, desktop with LCD monitor, active mode, RER	h (hour)
Bus	Transport, regular bus, CH	pkm (person kilometre)
Car	Transport, passenger car, RER	pkm (person kilometre)
Road	Operation, maintenance, road, RER	ma (metre year)

In the Ecoinvent database, the processes are available mainly for Europe. Nevertheless, some processes are only available for Switzerland. For the screening tool, if these processes are similar in both countries (for instance, the process "Bus" in Table 3.2 is supposed similar in Germany and in Switzerland), the data for Switzerland are assumed valid for Germany.

Transport services are expressed in person kilometre (pkm). A person kilometre is defined as the transport of one person by a certain transport service over one kilometre. Average load factors as well as lifetime performance (i.e., life span) are taking into account in the database (Spielmann et al. 2007).

3.3.2 Reference flow quantification

According to (ISO14040/14044 2006), the reference flow is "a measure of the outputs from processes in a given product system which are required to fulfil the function expressed by the functional unit". Related to the screening, it means that the screening practitioner provides a quantification of the processes according to the function that he/she defined

before. Respecting the unit of each process, the measure of the outputs from each process is inserted in an input box.

In a next step, the screening practitioner is asked (Check Box: Yes or No) if the amount is dependent on the functional unit, which has been previously inserted. If yes, a connection is established with the module 'Target users' (Chapter 3.4). For instance, if the screening practitioner selects "Cars" as process and he/she wants to evaluate the environmental impacts for a specific population, he/she validates the box for the dependency to the functional unit and he/she inserts the number of kilometres per person or per trip for one day. Thus, the number of kilometres is calculated for this population for one day. On the other hand, if the process is independent from the functional unit that has been selected before, for instance a road, he/she just selects the referring process and the number needed per day.

Figure 3.3 is a screenshot of the screening filled as an example for the idea "Mobile-phone ticket". The module is available for consultation in the beta version of the screening tool (Annexe E).

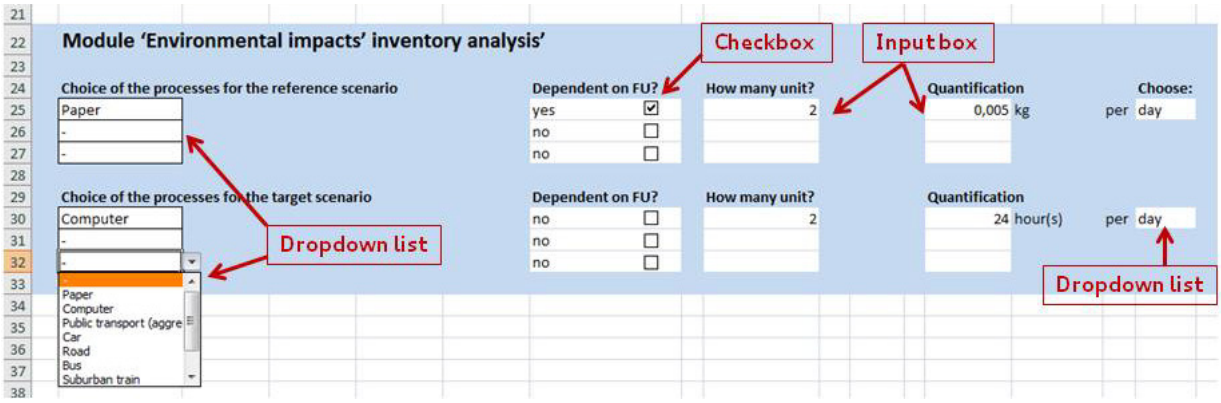


Figure 3.3: Screenshot of the module "Environmental impacts' inventory analysis" for the idea "Mobile-phone ticket" (beta version of the screening tool, annexe E)

3.4 Module 'Target users'

The aim of this module is to **quantify the diffusion** of the new idea on the market, since the diffusion has an impact on environmental and economic issues.

Target users are persons that belong to the system previously defined (Chapter 2.4) and that are susceptible to using the new idea once it is implemented. The identification of target users refers to the marketing technique of **segmenting the market**. Segmentation involves dividing the market into distinct and homogeneous groups of people with similar wants and

needs (Burnett & Baker 2001). Considering lifestyle segmentation, several institutes proposed their own framework. Inter alia, the Sinus-Institute has indentified basic values as well as attitudes to work, family, leisure, money and consumption for its Sinus-Milieu segmentation (Sinus-Institut 2011). The Institute of Social-Ecological Research (ISOE) has formulated mobility styles, which are defined as typical alliances of lifestyle, mobility orientation and traffic behaviour (Götz et al. 2002).

However, unlike marketing research, in which the market is researched in order to provide suitable products to specific user segments, the user segments are considered after that the product has been defined. Depending on the reference scenario, the aim is to quantify how many persons are susceptible to using the new idea. This quantification is linked with the appraisal of environmental impacts, since these impacts can be different according to the number of persons that use the idea.

In a first place, the screening tool has been developed for Munich and its area. Therefore, the data in the background of this module are for Munich. Nevertheless, the data can be adapted to other cities in Western Europe.

For the quantification of the target users in the screening, two methods of segmentation are possible: **MVV public transport user segments** or/and **socio-demographic segments**. The screening practitioner selects which segmentation is the most suitable to the idea, and then he/she chooses the user segment(s) that are susceptible to using the idea. Moreover, it is possible to combine both methods of segmentation.

MVV Public transport user segments

The Munich Transportation and Tariff Association (in German, Münchner Verkehrs- und Tarifverbund – MVV) published in 2007 the result of a marketing research, which identified market potential and target groups (Figure 3.4). This marketing research was based on interviews from around 5000 MVV-area inhabitants from 15 years old (MVV 2007a). According to the geographical boundaries and the time coverage, the study suits perfectly the screening for the case studies (Chapter 4) and it is therefore mainly used.

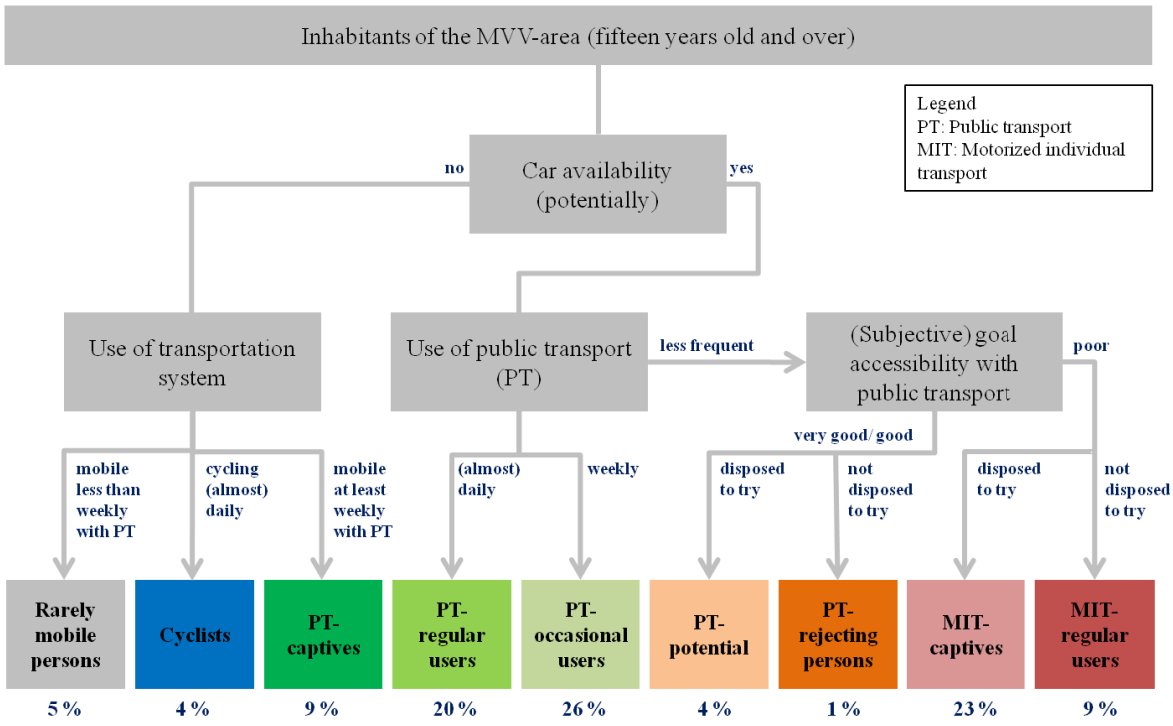


Figure 3.4: User segment depending on the availability of a car (translated from MVV (2007a))

This marketing research has been actualized in 2010 (MVV 2010b) with little modification of the segmentation. Since the detail of the calculation is only available for the first study (2007) and since the proportions are still comparable, the database of the screening refers to the first study of 2007.

Socio-demographic segments

Socio-demographic criteria, compared to other segmentation measures, are more readily available and can be applied to segmentation problems with relative ease (Diamantopoulos et al. 2003; Myers 1996). The following criteria can be chosen within the screening and are correlated with data from 2009 of the Statistical Office of Bavaria (in German, Bayerisches Landesamt für Statistik und Datenverarbeitung) (BayLfStaD 2010, 2011):

- Gender (women or men),
- Age (under different categories, for instance, from 15 to 18 years old or 65 years old and more),
- Location (MVV-area, Munich city or only suburban area of Munich).

The statistical office of Bavaria provides a sorting of the data per administrative districts of Bavaria. For the case studies, the database merge the data for the entire MVV-area, which spreads over the following districts: Freising, Erding, Dachau, Fürstenfeldbruck, Starnberg, Bad Tölz Wolfratshausen, Ebersberg, Munich (district) and the state capital of Munich (MVV 2007b).

For every MVV user segment, the number of trips and persons per transportation mode and per day is known. Therefore, a quantitative assessment about the spreading of the idea and the resulting modal split after the implementation of the idea (i.e., the new distribution of transportation modes) can be done. This module is flexible and can be used for simulations within the analysis of the robustness of the results. Indeed, beyond the appraisal of the spreading of the idea after implementation, it is possible to forecast what would be the environmental impacts for **diverse scenarios of spreading**. Each combination of demographic and user-segment restriction is indeed associated to a percent of population. For instance, by selecting 'men' between 15 and 30 years old in the entire MVV-area, the screening calculates the impacts for around 10% of utilization of the idea; and this consideration can be changed at any moment during the evaluation.

Figure 3.5 is a screenshot of the screening tool filled as an example for the idea "Mobile-phone ticket". The module is available for consultation in the beta version of the tool (Annexe E).

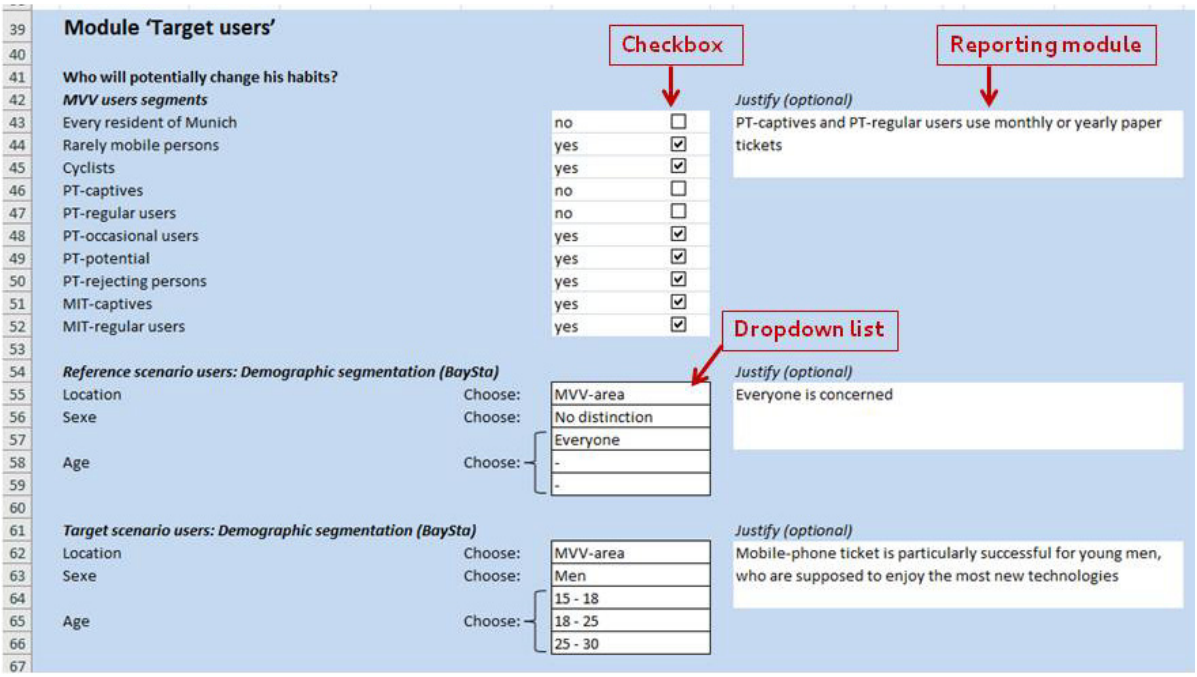


Figure 3.5: Screenshot of the module "Target users" for the idea "Mobile-phone ticket" (beta version of the screening tool, annexe E)

3.5 Module 'Social impacts' inventory analysis'

The aim of this module is to evaluate how the potential users will perceive the new idea. This evaluation is qualitative and refers to the social indicators described in the Chapter 3.1, i.e., it refers to the user's wants and needs. Therefore, this module estimates by extension if the idea will be successful on the market and widely used. Indeed, positive effects on the environment and the society cannot be achieved if the idea stays at the corner of the market or lacks user's expectation (Beck et al. 2009).

It is important to note that such procedure is by its very nature normative. There is no completely "objective" evaluation of needs and wants fulfilment because the satisfaction of needs is a **subjective concept**. There will inevitably be a disagreement among different individuals, but the point of the present research is to identify if an idea fulfils the needs and wants that occur in mobility behaviour for the most people in a Western European city like Munich.

It is delicate to handle with this module since the screening practitioner himself/herself has to assess the user perception. For the best validity of the results, interviews should be done with a representative number of potential users. However, such interviews could only be

subsequent to the implementation of the idea, once the users have tried it. The screening tool runs actually **before the implementation**, as "pre-feasibility" study. The screening practitioner, which comes from the enterprise that implements the idea, has to imagine himself/herself in the "user's shoes". The aim is, as for the entire evaluation within the screening, to stay as objective as possible in order to avoid a dispersion of the results when the screening practitioner changes. That part of the evaluation could be seen critically since each person might perceive every indicator differently; nevertheless, the description of the needs and of user groups helps to deal with subjectivity and provide a reproducible assessment.

Moreover, to improve the reliability and the uniformity of the results, the screening practitioner receives additional information about the **most common behaviours within the public transport**. That information could be used for example as control to be sure not to forget any consumer-type in the evaluation. The following profiles had been drawn thanks to interviews of experts and supported by literature. The interviewed persons were: Mr. Kesselring, sociologist at the Institute for Transportation from the Technische Universität München (Kesselring 2010); Mr. Price, transport planner at Nottingham City Council (Price 2010 by Rouse 2011); Mr. White, professor at the Westminster University and lecturer in Public Transport Systems (White 2010 by Rouse 2011).

- **Young people**: Their mobility is mainly between home and school. They expect to have fun, to show their lifestyle and to have an alternative use of the journey (Groß & Freyer 2001). They use mainly public transport with season tickets.
- **Elderly persons**: Their mobility is mainly outside the rush-hour traffic. For them, the comfort is most important; the time spent is not an important aspect (BMVBS 2010b).
- **Commuter**: Their daily mobility is between home and work. Time and costs are the most important factors for them. They travel mainly with a season ticket (AKOÖ 2009).
- **Business traveller**: Their mobility is different from the commuter's one, since they are travelling for their company to meet clients, for example. They are often not familiar with the city they travel in, have no precise knowledge of the public transport system and use often combined-mobility (e.g., train and taxi). They need to travel fast, efficiently and with the possibility to work during the travel (with the internet, phone).
- **Handicapped person**: Barrier-free transportation modes are for them a sine qua none condition (IAS 2009).

Once the most common behaviours are known and assimilated, the screening practitioner provides the **qualitative evaluation** of each need and each want, answering the question:

"Does the idea encourage the fulfilment of the need/want or does it restraints it?" For this issue, a ranking system has been developed (Table 3.3).

Table 3.3: Ranking system for the qualitative evaluation of the social indicators

Ranking	Related to each social indicator (i.e., user's need or want),
++	The idea contributes for **every** user to a better satisfaction of the need or want.
+	The idea contributes for **some** users to a better satisfaction of the need or want.
0	The idea has **no influence** on the need or want.
-	The idea corrupts for **some** users the fulfilment of the need or want.
--	The idea corrupts for **every** user the fulfilment of the need or want.

Figure 3.6 is a screenshot of the module within the screening tool filled as an example for the idea "Mobile-phone ticket".

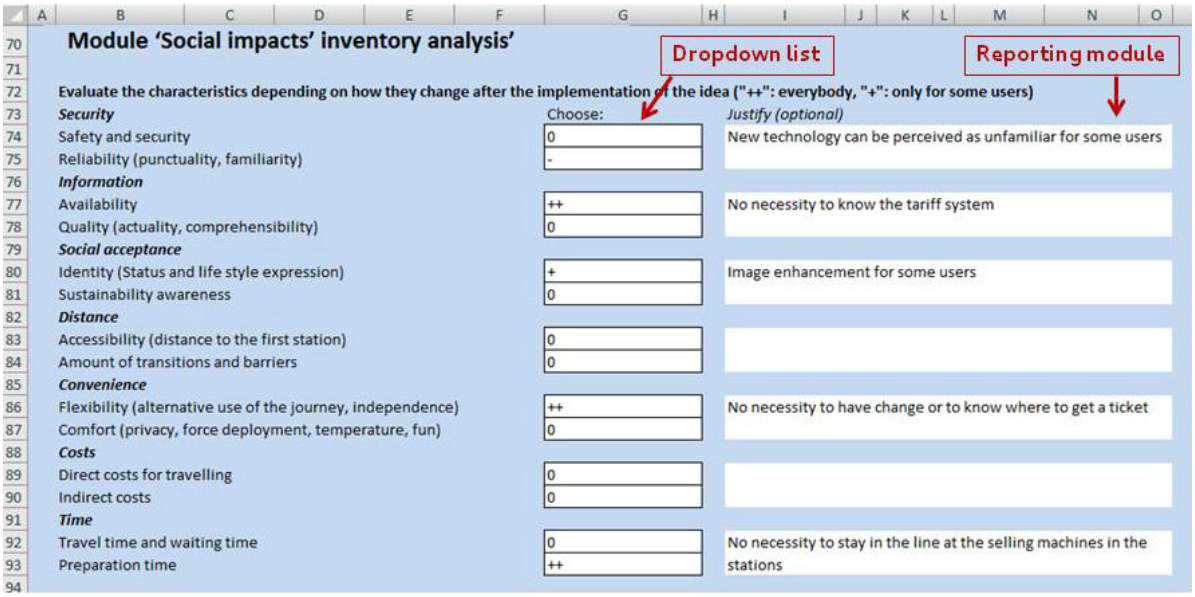


Figure 3.6: Screenshot of the module "Social impacts' inventory analysis" for the idea "Mobile-phone ticket" (beta version of the screening tool, annexe E)

3.6 Module 'Economic impacts' inventory analysis'

The aim of this module is to evaluate the economic indicator "value for the enterprise". Concordant with the definition of sustainability of the work, this module is complementary to the evaluation of environmental and social indicators, and, as noticed before, the environmental and social evaluations get more attention in the screening than the economic indicator. Indeed, it is assumed that **economic evaluations of products are "everyday business"** for enterprises, contrarily to socio-environmental evaluations.

As described in the Chapter 2.5.4, the value for the enterprise is in the screening the relation between the costs needed to implement the idea and the earnings gained from users' acceptance.

It is already admitted that economic evaluations are dealing – like any evaluation – with subjectivity with arbitrarily definition of boundaries, cut-off rules and data selection (Grießhammer et al. 2007). The aim is therefore to obtain an estimation of the value for the enterprise in a **transparent and traceable** way.

3.6.1 Costs for the implementation

In usual costs accounting for enterprises, it makes sense to monetize environmental aspects like resource consumption. In the screening, since these aspects are already considered in other modules, a monetization of the resource consumption and emissions would lead to a double accounting of the environmental impacts.

The screening practitioner must decide which costs are assumed by his/her enterprise, since some costs are for example endorsed by the public authority or by intermediary enterprises. With this information as well as his/her knowledge about other potential costs (e.g., work force, taxes, etc.), he/she is able to evaluate the costs endorsed by his/her enterprise for the implementation of the idea between high, medium and low.

3.6.2 Earnings from users' acceptance

Here also, it exist no precise methodology to forecast the exact earnings linked with the implementation of a new idea on the market. Especially in the case of public transport, it is almost impossible to know if a change in user behaviour is linked with the implementation of a new idea or with other factors (for instance, depending on the weather) (Fink 2009). Considering the reasoning of the previous module 'Social impacts' inventory analysis', it is

assumed that an idea can only be successful on the market (i.e., successful for the enterprise) if it is widely used, and, by extension, if it is improving the fulfilment of users' needs and wants. Therefore, to estimate the earnings linked with the user acceptance, the focus is on the user perception, which has been previously evaluated. It is supposed that a highly positive user perception leads to a high user acceptance, and consequently to high earnings for the enterprise (or respectively to medium and low earnings for the enterprise). This part of the module is connected with the module 'Social impacts' inventory analysis' and it establishes an **average value** for these social impacts. Above the average value, the earnings are considered are **high**. Respectively, under the average value, the earnings are considered **low**. If the social impacts are evaluated as equal to the average value, the earnings are **medium**. This part of the screening runs automatically and the screening practitioner has no direct influence on it.

3.7 Impact assessment

The following modules run automatically in the background of the screening and are therefore not visible in the main interface for the screening practitioner. Nevertheless, as every module in the screening, they can be consulted for information.

3.7.1 Module 'Modal split calculation'

The screening tool is suitable for the sustainability assessment of a wide range of ideas. Indeed, it can concern infrastructure projects like a new subway line as well as virtual measures like the improvement of the quality of information on the internet. Concerning the environmental impacts of these measures, a quick overview let suppose that highly resource-intensive infrastructure projects would induce more impacts than virtual projects (e.g., concerning the information). Nevertheless, since the entire system is under study, it is necessary to observe all the changes induced in it. Indeed, it is conceivable that a new subway line will be enough attractive for consumers so that they **switch from their private car to public transport**. Consequently, the environmental impacts linked with the construction of the new subway line could be compensated (or, at least, reduced) by the savings induced with the switch over of a part of the people from private car to public transport.

Therefore, the aim of the module "Modal split" is to calculate the environmental impacts induced by a **new modal split distribution** (so-called 'modal shift'). This new modal split

distribution results from a theoretical change of mobility behaviour of individual consumers once the idea has been implemented. The change of mobility behaviour is assessed thanks to the results of the modules 'Target users' and 'User perception' regarding the user basic needs and wants (Figure 3.7). This module runs automatically, i.e. the screening practitioner does not have direct influence on it.

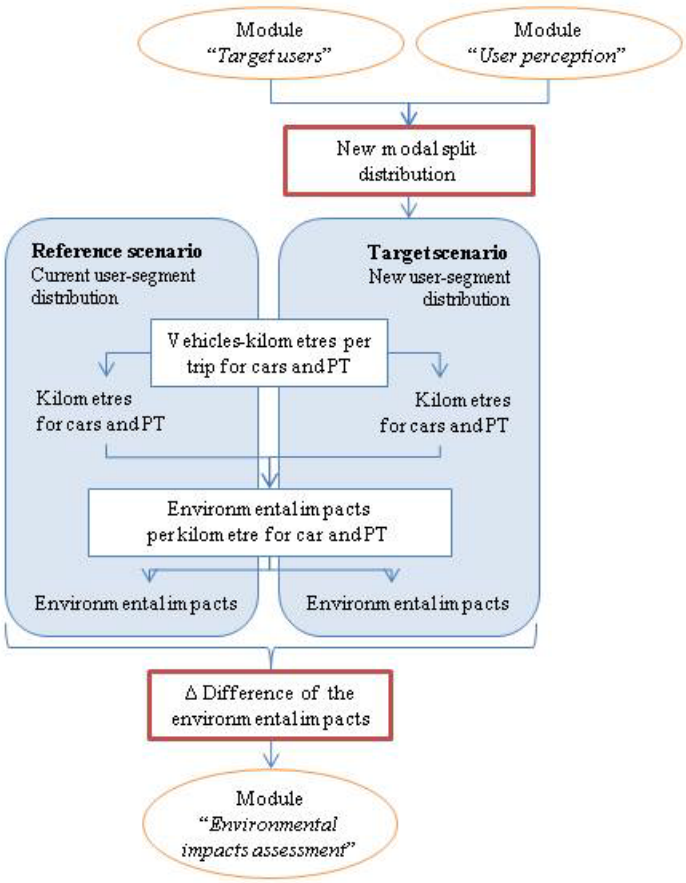


Figure 3.7: Structure of the module 'modal split' (own representation)

Calculation of a new modal split distribution

The screening tool has been developed for the city of **Munich** and its related public transport system. Therefore, data for Munich are used in the screening tool. The Munich Transportation and Tariff Association (MVV) determined public transport user segments (Figure 3.4) and a distribution of it for 2007 for the entire MVV-Network (Table 3.4).

Table 3.4: Public transport user segments and Modal split distribution for the MVV-Network (MVV 2007a)

Legend: Grey: Considered users in the modal split calculation (variables); PT: Public transport; MIT: Motorized Individual Transport, MVV: Munich Transportation and Tariff Association

				Modal share			
	Persons	Trips per day	Trips per person per day	PT	MIT	Bicy-cle	By foot
MVV-user segments	Variables		Constants	Constants			
Rarely mobile	47 000	131 000	2.8	21%	30%	8%	40%
Cyclists	77 000	228 000	3.0	32%	14%	38%	16%
PT-captives	158 000	428 000	2.7	69%	8%	4%	19%
PT-regular users	383 000	1 084 000	2.8	55%	27%	6%	12%
PT-occasional users	486 000	1 493 000	3.1	17%	53%	13%	17%
PT-potential users	65 000	200 000	3.1	5%	48%	23%	24%
PT-rejecting persons	10 000	34 000	3.4	0%	52%	13%	35%
MIT-captives	430 000	1 390 000	3.2	3%	74%	10%	13%
MIT-regular users	159 000	494 000	3.1	0%	83%	7%	10%
Sum	1 815 000	5 482 000					

According to MVV (2007a), three user segments are susceptible to changing their mobility behaviour, and are therefore at the focus of MVV marketing research: the **PT-occasional**, the **PT-potential** and the **MIT-captives**. Indeed, the other users have no reason to change their behaviour (e.g., the rarely mobile and the bicycle drivers) or are not disposed to change their behaviour (e.g., the PT-rejecting persons and MIT-regular users). For that reason, in the screening, a new modal split distribution can happened following three possibilities:

- PT-occasional users switch to become PT-regular users,
- PT-potential switch to be PT-occasional users,
- MIT-captives switch to become PT-occasional users.

A priority list was set by the MVV concerning the characteristics that are important for these user segments in function of the importance of the characteristic and of the current happiness (Figure 3.8 and Figure 3.9).

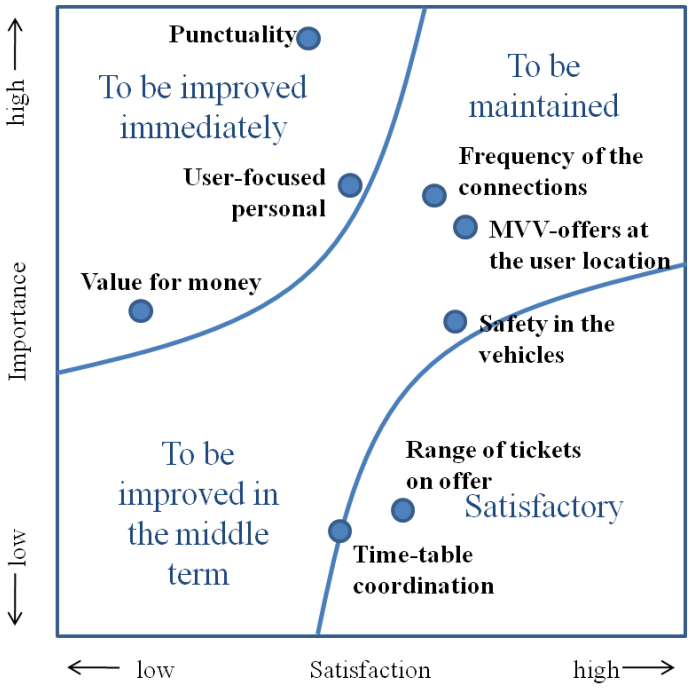


Figure 3.8: Portfolio of actions for PT-occasional and PT-potential users (translated from MVV 2007a)

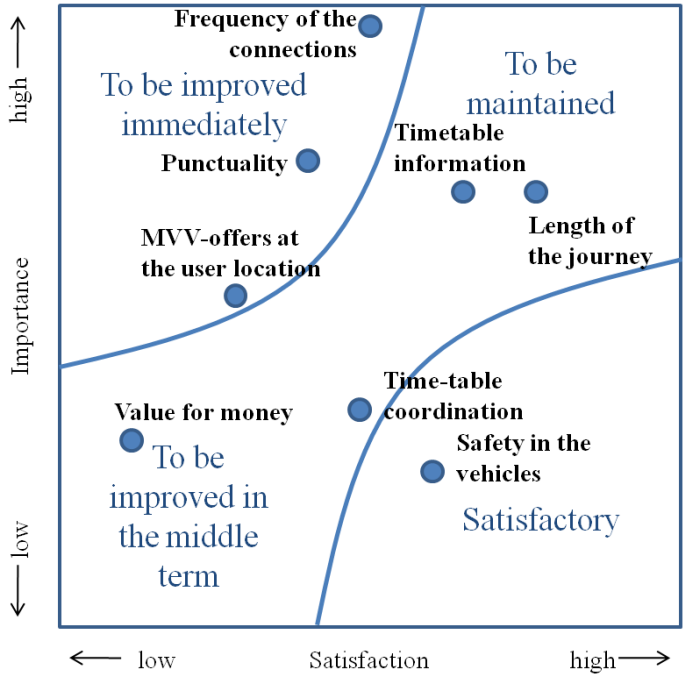


Figure 3.9: Portfolio of actions for MIT-captives (translated from MVV 2007a)

It is interesting to note that the characteristics from MVV are correlated with the social indicators previously defined for the screening (Chapter 2.5). In order to deal with a **uniform jargon**, the social indicators of the screening (i.e., the user's needs and wants) have been identified in the action portfolio of MVV (Table 3.5). A differentiation has been made between the characteristics of the field "to be improved immediately" and the field "to be maintained or improved in the middle term". The field "Satisfactory" of the Figure 3.8 and Figure 3.9 has not been considered since the characteristics of it have no influence on a new modal split distribution.

Table 3.5: Identification of the social indicators in the MVV portfolio of actions

	PT-occasional users and PT-potential users		MIT-Captives	
	Characteristics from the MVV (Figure 3.8)	Identification of the social indicator in the screening	Characteristics from the MVV (Figure 3.9)	Identification of the social indicator in the screening
To be improved immediately	Punctuality	Reliability	Frequency of the connections	Travel time and waiting time
	User-focused personal	- Availability of information - Quality of information	Punctuality	Reliability
	Value for money	Direct costs for travelling	MVV-offers at the user location	Accessibility
To be maintained or improved in the middle term	Frequency of the connections	Travel time and waiting time	Timetable information	- Availability of information - Quality of information
	MVV-offers at the user location	Accessibility	Length of the journey	Travel time and waiting time
	Safety in the vehicles	Safety in transport	Value for money	Direct costs for travelling

Since the calculation in the module has to be automatic, the aim was to **quantify** the qualitative analysis. For the Citivas Miracles project (EU 2008-2012), which has been co-financed by the EU, the aim was to improve the sustainability and efficiency of urban transport systems by reducing congestion, lowering emissions, and achieving a shift in the

modal split towards cleaner fuels and vehicles. A subproject has been carried by the Winchester City Council with the objective to contribute to an 8% public transport patronage in the city of Winchester (Wall & McDonald 2007). On this basis, two assumptions have been made for quantifying the switch of users to the upper user segment, which corresponds to an under value and an above value of a **realistic expected patronage** (i.e., 8%) by improving public transport:

- If a characteristic of the field "To be improved immediately" is enhanced thanks to the idea, **10% of the users concerned** (i.e., either PT-occasional users and PT-potential users or MIT-Captives) switch to the upper user segment.
- If a characteristic of the field "To be maintained or improved in the middle term" is improved thanks to the idea, **5% of the users concerned** switch to the upper user segment.

This switch is connected with the modules 'Target users' and 'User perception' for an automatic up-to-date. Thus, a **modal shift** (i.e., new modal share distribution) happens only if the user-segments 'PT-occasional', 'PT-potential' and 'MIT-Captives' are concerned. Furthermore, the new distribution is provided only in the described direction, i.e. when people switch to an upper user-segment category, which implies savings of environmental impacts. If a social indicator of the Table 3.5 is deteriorated with the implementation of the new idea, the modal shift is set to 0% for the considered user segment.

For the next subsections, the aim is to calculate the environmental impacts generated from the new user-segment distribution. Since the bicycle users and the pedestrians do not generate environmental impacts in comparison with the other modes, the car and the public transport are the only transportation modes considered in the following subsections.

Calculation of the savings regarding the environmental impacts

The new modal split distribution implies that the entire system and therefore the proportion of the different mobility behaviours of individual consumers have been modified. For example, the PT-regular users represent in the reference scenario 20% of the MVV-area population. After a new modal split distribution, depending on the evaluation of the social indicators, they could represent around 25% of the MVV-area population. The mobility behaviour (i.e., the relative use of different modes of transport) within the segment 'PT-regular users' stays nevertheless unchanged.

In order to provide the assessment of environmental impacts resulting from the different modes of transports, two figures are needed:

- The sum of kilometres realized in one day in the MVV-area with PT and MIT;
- The environmental impacts of PT (aggregated) and MIT per kilometre.

Sum of kilometres for one day in MVV-area with PT and MIT

In order to assess the sum of kilometres for the reference and target scenario, it was necessary to calculate the kilometres per trip for PT and MIT. The kilometres per trip depending on the transport mode are constant in the module. Thanks to the data of MVV (Table 3.4), it is possible to calculate that people travel – in average – three trips per day without distinction of transportation modes. Considering the modal share of Table 3.4, car is driven for an average of **45% of the trips** for all the MVV-user segments. Therefore, the number of trips realized per day with the car is **1.4 per person**. It is assumed that a car is driven in average 15.000 km/year (driving performance) (DIW 2008). With these considerations, **one trip with the car** is in the MVV-area **around 25 km**. On the other hand, considering the number of person-kilometres for the public transport (around 6 billion kilometres for the year 2006 (MVV 2007b)), the average distance of a travel with public transport is calculated; it is around **13 km per PT-trip**.

The sum of kilometres realized in one day in the MVV-area with PT and MIT is a variable within the module. This variable is function of the repartition of the population among the different user segments (previously calculated) and function of the kilometres per trip with both modes, PT and MIT. For example, in the reference scenario, around 67 millions of kilometres are driven with the car from the population of the MVV-area, and 16 millions of kilometres are provided with the public transport. In a hypothetical target scenario, where the social indicator ‘direct costs for travelling’ has been improved, the car is then driven around 65 millions of kilometres and the public transport around 17 millions of kilometres. The difference of kilometres has direct influence on the environmental impacts.

Calculation of the environmental impacts for PT and MIT per kilometre

The first step consisted in the aggregation of the different modes within the public transport. This aggregation is provided using the overall modal share within the public transport, assessed by MVV for 2006 and supposed unchanged for the screening (Table 3.6).

Table 3.6: Modal Share within the MVV public transport (MVV 2007b)

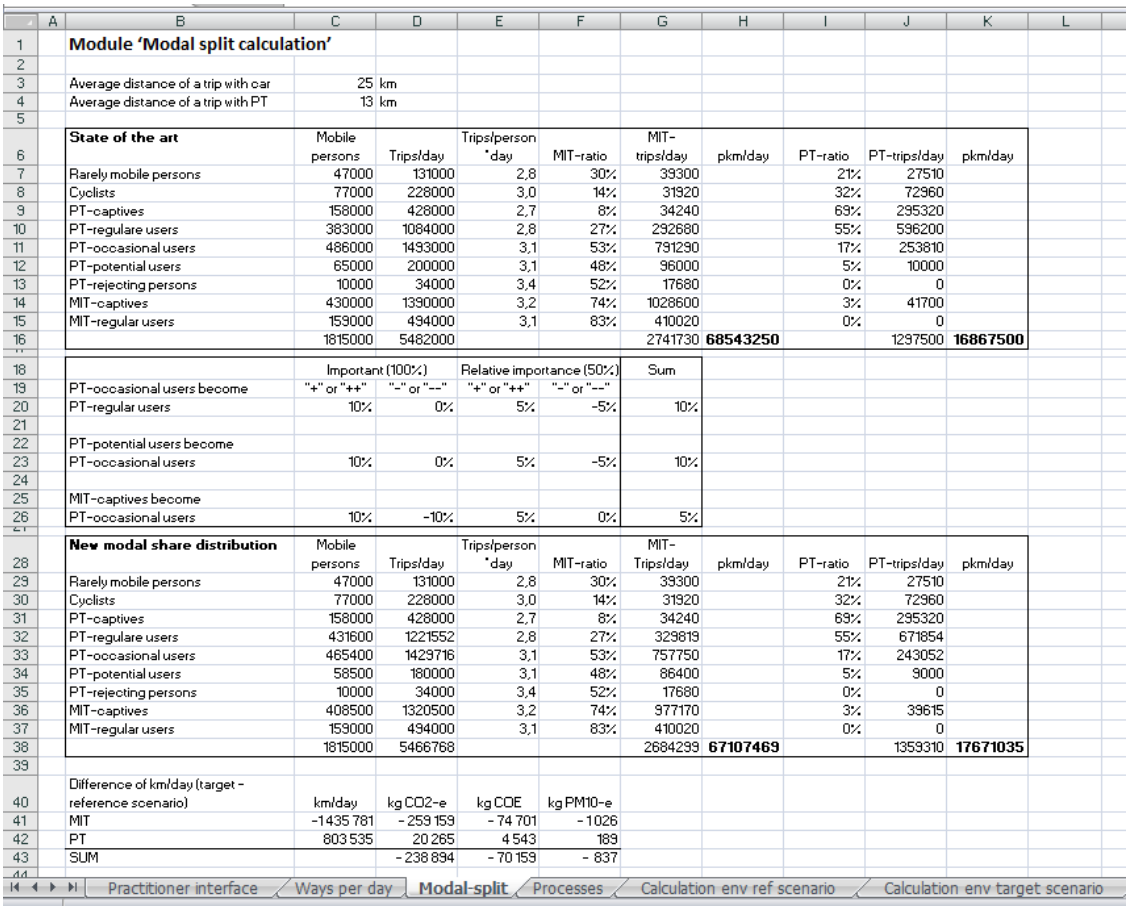
	Person-kilometre (in Million km) 2006	Share
Suburban train	3 566	60%
Metro	1 501	25%
Tramway	253	4%
Buses	664	11%
Sum	5 986	100%

The second step has been to identify the processes in the Ecoinvent database (Ecoinvent 2007) corresponding to the different modes. It has been assumed that metro and suburban trains have the same environmental impacts as regional trains. In the Ecoinvent database, the environmental impacts are expressed in person-kilometre considering different load factors of vehicles.

Finally, the environmental indicators (greenhouse gas emissions, resource consumption and pollutant emissions) have been extracted and aggregated with a weighting depending on the modal share of Table 3.6. Thus, for example, the aggregation of the greenhouse gas emissions for the public transport 'as a whole' has been calculated: **25 g CO_2-e are emitted per person-kilometre**.

With the sum of kilometres per day for the MVV-area and the environmental impacts per kilometre, the savings of environmental impacts resulting from a new modal split distribution are calculated per day. These savings are deducted from the final environmental impacts (or respectively added to the savings).

Figure 3.10 shows a screenshot of the module "Modal split calculation" within the screening tool.



Module 'Modal split calculation'

Average distance of a trip with car	25	km
Average distance of a trip with PT	13	km

State of the art	Mobile persons	Trips/day	Trips/person *day	MIT-ratio	MIT-trips/day	pkm/day	PT-ratio	PT-trips/day	pkm/day
Rarely mobile persons	47000	131000	2,8	30%	39300		21%	27510	
Cyclists	77000	228000	3,0	14%	31920		32%	72960	
PT-captives	158000	428000	2,7	8%	34240		69%	295320	
PT-regulare users	383000	1084000	2,8	27%	292680		55%	596200	
PT-occasional users	486000	1493000	3,1	53%	791290		17%	253810	
PT-potential users	65000	200000	3,1	48%	96000		5%	10000	
PT-rejecting persons	10000	34000	3,4	52%	17680		0%	0	
MIT-captives	430000	1390000	3,2	74%	1028600		3%	41700	
MIT-regular users	159000	494000	3,1	83%	410020		0%	0	
	1815000	5482000			2741730	**68543250**		1297500	**16867500**

	Important (100%)		Relative importance (50%)		Sum
	"+" or "++"	"-" or "--"	"+" or "++"	"-" or "--"	
PT-occasional users become					
PT-regular users	10%	0%	5%	-5%	10%
PT-potential users become					
PT-occasional users	10%	0%	5%	-5%	10%
MIT-captives become					
PT-occasional users	10%	-10%	5%	0%	5%

New modal share distribution	Mobile persons	Trips/day	Trips/person *day	MIT-ratio	MIT-Trips/day	pkm/day	PT-ratio	PT-trips/day	pkm/day
Rarely mobile persons	47000	131000	2,8	30%	39300		21%	27510	
Cyclists	77000	228000	3,0	14%	31920		32%	72960	
PT-captives	158000	428000	2,7	8%	34240		69%	295320	
PT-regulare users	431600	1221552	2,8	27%	329819		55%	671854	
PT-occasional users	465400	1429716	3,1	53%	757750		17%	243052	
PT-potential users	58500	180000	3,1	48%	86400		5%	9000	
PT-rejecting persons	10000	34000	3,4	52%	17680		0%	0	
MIT-captives	408500	1320500	3,2	74%	977170		3%	39615	
MIT-regular users	159000	494000	3,1	83%	410020		0%	0	
	1815000	5466768			2684299	**67107469**		1359310	**17671035**

Difference of km/day (target - reference scenario)	km/day	kg CO2-e	kg COE	kg PM10-e
MIT	-1435781	-259159	-74701	-1026
PT	803535	20265	4543	189
SUM		-238894	-70159	-837

Practitioner interface | Ways per day | Modal-split | Processes | Calculation env ref scenario | Calculation env target scenario

Figure 3.10: Screenshot of the module "Modal split calculation" for the idea "Tangential bus line" (beta version of the screening tool, annexe E)

3.7.2 Calculation method

Depending on the interactions between the modules, the environmental, economic and social impacts are calculated in the background of the screening. The method for the calculation is to provide a quantitative relation of the modules to one another and to scale the reference flows from the functional unit. Therefore, the calculation result within each impact calculation module is a set of linked and scaled processes, comparable with the inventory table as defined for LCA in the ISO 14040 (2006).

The calculation is provided with the utilization of a **spreadsheet application** (e.g., Microsoft-Excel 2007 as used for the development of the beta version of the screening tool available for consultation in annexe E).

3.7.3 Environmental impacts' characterization

In the characterisation step of LCA, the environmental impacts are quantified in terms of a common unit for the impact category, allowing aggregation into a single score: the indicator result (Guinée 2002). In the screening, only the environmental indicators are assessed in a quantitative way; therefore, the characterisation step only concerns the environmental impact assessment.

For the three environmental indicators 'greenhouse gas emissions', 'fossil resource consumption' and 'pollutant emissions', environmental profiles have been calculated by multiplying the interventions of inventory results by their concomitant conversion factors (Table 2.5, Table 2.6 and Table 2.7) and aggregating these multiplications for each category respectively in kg CO_2-equivalent, kg Crude Oil Equivalent and kg PM10-equivalent.

3.7.4 Normalization of the environmental impacts

Comparable to the phase of characterisation, normalization is only provided for quantitative assessments. Therefore, in the screening, it only concerns the environmental impacts.

ISO 14042 defines normalization as "calculation of the magnitude of indicator results relative to reference information". The reference information may **relate to a given community** (e.g., Germany, Europe or the world), person (e.g. a Danish citizen) or other system, over a **given period**. The main aim of normalizing the category indicator results is to better understand the relative importance and magnitude of these results for each product system under study (ISO14040/14044 2006).

In the LCA methodology, this step is optional (Guinée 2002). In the screening tool, normalization is necessary since it is used to check for inconsistencies and to prepare for the phase of representation of the results and interpretation.

For the screening, the indicator results of each impact category have been normalized into so-called "**resident-equivalents"** (REQs), which have been calculated for Germany (Detzel & Krüger 2006).

The normalisation factors are obtained by dividing the overall German loads per impact category with the number of residents in Germany. The results are statistical environmental impacts per resident (Table 3.7). The data have been calculated by Detzel for 2006; they are assumed to be valid for the time-scale of the work, since it is supposed that the **ratios**

between the inhabitants and the environmental impacts have been almost unchanged since 2006.

Table 3.7: Basic data for Germany for the year 2006 used to calculate resident-equivalents (REQs) (Detzel & Krüger 2006)

Legend: GHG: Greenhouse gas; COE: Crude Oil Equivalent

Indicators	Germany (2006)	Impact per inhabitant per year	Impact per inhabitant per day
Residents	82 532 000 persons		
GHG emissions (CO_2-e)	1 017 916 500 t	12 334 kg	33.79 kg
Fossil resource consumption (COE)	189 702 096 t	2 298 kg	6.30 kg
Pollutant emissions (PM10-e)	2 216 370 t	27 kg	0.07 kg

In the next step, the difference between the net indicator results of the reference scenario and the target scenario are divided by the respective impact per inhabitant per day, giving the contribution expressed in REQ for one day.

Hence, these REQs provide a **reference quantity** that allows the different indicator results to be converted into the same units and compared. It helps moreover for the comparison of the idea with other ideas. This case is useful for the screening in order to choose among several ideas. In the screening, the results in REQs provide indeed a descriptive representation of the results in the form of a **net result** for the entire population within the MVV-area for one day.

3.7.5 Net and relative results for grading colour attribution

This step is a central point of the screening tool since the results must be presented in a **simple way** to the screening practitioner. The aim of the screening tool is not to transmit quantities with margin of errors, but to give a support for answering the question: “Does the new idea improve or deteriorate the current situation in term of sustainability?” Therefore, the results are expressed in **percent**, i.e., ratio of the impacts of the target scenario compared to the impacts of the reference scenario. Negative percents represent savings and positive percent represent impacts. It is a **relative** representation of the results since it provides a

comparison of the scenarios, but does not give information about the **magnitude of impacts**.

Moreover, a **grading colour system** is applied for each indicator. Based on the representation system of the German Council for Sustainable Development (Nachhaltigkeitsrat 2008), the comparison between the current and the future situation is represented using red, yellow, light-green and green colours that symbolise a general indication of whether the idea is on track to achieve sustainability goals, or not. No colour means that there is no modification of the situation.

Environmental indicators

The attribution of the colours is made on the one hand, with the net result of impacts for the MVV-area for one day (i.e., in resident-equivalents), on the other hand, with the relative result of the impacts between the situation before and after the implementation of the idea (i.e., in percent) (Table 3.8).

Table 3.8: Attribution of the grading colour for environmental indicators (own representation)

Legend: x: Net result of the impacts in resident-equivalents (REQ), y: Relative result of the impacts (%)

Net result of the impacts (in REQ)	Relative result of the impacts (in %)	Grading colour attribution	
x > 4000	y > 0%		Impacts = Deterioration of the situation
2000 < x < 4000	y > 10%		
	0% < y < 10%		
0 < x < 2000	y > 10%		
	0% < y < 10%		
- 2000 < x < 0	- 10% < y < 0%		
	y < -10%		
- 4000 < x < - 2000	- 10% < y < 0%		
	y < -10%		Savings = Improvement of the situation
x < - 4000	y < 0%		

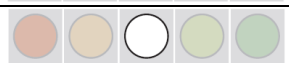
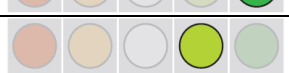
The decision to fix the limit between the grading colours has been decided accordingly to the goal of the study. In the present case, the screening has been modelled for urban areas in Germany. Considering that an agglomeration is allowed to be called “a town” in Germany **from 2000 inhabitants** (BMVBS 2010; Heineberg 2006), this amount symbolises the first

limit in resident-equivalents. By doubling this amount of resident-equivalents, the impacts or savings are correspondingly switching to the upper and lower grading colour. In the other hand, still according to the goal of the study, greenhouse gas emissions of the road and rail sectors in Germany are responsible for 14% of the entire greenhouse gas emissions (EU 2010). This number is rounded down (i.e., 10%) and is selected to represent a **symbolic border** for respectively high savings (if inferior to -10%) and high impacts (if superior to 10%). Nevertheless, these limits in percent and resident-equivalents are specific to the goal of the study and must be adapted if the screening is used for other case studies.

Economic indicators

The same process applies for the economic impacts (Table 3.9). One exception in the attribution of the colour is made if the earnings are high; the grading colour is automatically light green or green.

Table 3.9: Attribution of the grading colour for economic indicators (own representation)

Earnings	Investment	Grading colour attribution
Low	Low	
	Medium	
	High	
Medium	Low	
	Medium	
	High	
High	Low	
	Medium	
	High	

Social indicators

For the social indicators, each indicator includes **sub-indicators**, i.e. needs or wants. For example, the indicator ‘information’ is merging the basic need ‘availability of information’ and the want ‘quality of information’. The needs and wants are qualitatively evaluated with

plus or minus; however, in the final representation of the results, only the indicator is assigned with the grading colour.

Within each of the seven indicator categories, the number of plus or minus are added and grading colours are attributed depending on the sum (Table 3.10). The attribution of the grading colour is made independently from the consideration of needs and wants. A weighting for the results may underline that the needs could be considered as more important than the wants, and should have a higher influence on the results. In the current version of the screening tool, it is considered that needs and wants have the same importance since they are both anchored in the equity principles (human rights and individual freedoms) of sustainable development (see chapter 1.2.3).

Table 3.10: Attribution of the grading colour for social indicators (own representation)

Number of plus or minus	Grading colour attribution	
Two minus (--)		Deterioration of the situation
One minus (-)		
Zero (0)		
One plus (+)		
Two plus (++)		Improvement of the situation

Thus, it is possible to see at a glance the changes between reference and target scenario related to each indicators and to highlight for example non-intended effects.

3.8 Interpretation of the results

For the sake of transparency, it is good to separate analysis and opinion, and therefore, to have a separate step in which conclusions are drawn and recommendations are made.

The step of interpretation depends actually on the scope of the study. Indeed, it is optional for an internal use of the results (a short summary could suffice), but it is strongly recommended if the results of the screening are going to be published.

Comparable to LCA, the phase of interpretation is in the screening the phase in which the results of the previous steps and all choices and assumptions made during the course of the

analysis are evaluated in term of soundness and robustness, and overall conclusions are drawn (Guinée 2002).

The main elements of the interpretation phase are:

(1) An evaluation of results in term of **consistency and completeness**,
(2) An analysis of the **robustness of the results**,
(3) The formulation of the **conclusions and recommendations** of the study.

The aim of the first phase is to come back to the assumptions that have been made and to justify the factors that have been ignored. In the second phase, **simulations** are provided for the parameters that have been selected arbitrarily since no reliable data exists. The aim is to test the influence of these parameters on the results of the screening.

In LCA, the interpretation phase contains also an **uncertainty analysis**. Regarding the uncertainty of the database, the Ecoinvent database tries to deliver a quantitative estimate of the uncertainty of the data it provides, i.e. each data entry is defined with not only a mean value, but also as a lognormal distribution with a geometric standard deviation. However, the estimate of the degree of data uncertainty is largely subjective (it is defined using a pedigree matrix approach) and it only addresses statistical uncertainty in the data – not uncertainty in the system model itself (Münzing 2010). For this reason, the validity of data from the Ecoinvent database is not brought into question and is considered as valid for the screening.

The formulation of conclusions and recommendations is also correlated with the initial goal of the study and the reason the screening has been run. For answering the question “does the new product promote sustainable development?”, the **conclusion** is done by summarizing the significant issues of the evaluation, by observing the matrix of grading colours, by evaluating the results on the basis of the consistency and completeness check, and the analysis of the robustness of the results. A statement about the number of grading colours is not possible to conclude about the sustainability of the products since the spheres are containing different number of indicators. In LCA, the **weighting phase** helps to solve this problem by assigning numerical factors to the indicator results according to their relative importance (Guinée 2002). Weighting is based on value-choices for example monetary values or expert panel and it shall be consistent with the goal and scope of the study (ISO14040/14044 2006). For that reason, the phase of weighting has not been formulated in the methodology since the screening practitioner himself/herself has to decide the relative importance of each indicator. The screening tool provides therefore a support for decision-making but cannot replace the decision itself.

4 Case studies

Case studies have been provided to **test the screening tool** and to highlight its advantages and the aspects that still can be improved.

4.1 Selection of case studies

4.1.1 Ideas gathering

The input for the screening is a set of ideas, from which the environmental, social and economic impacts have to be evaluated. These ideas may come from enterprises (prototypes, for example). They can also come from politics or city planning stakeholders who want to evaluate quickly the legitimacy of measures relating to the mobility in a specific urban area. In addition, the ideas can also directly come from users, for instance by the mean of user integration in innovation processes, like for the case studies within the project "Encouragement of Sustainable Consumption by Integrating Users into Sustainability Innovations" (BMBF 2011). The user integration was performed in a series of two-day workshops supported by industrial partners. In Munich, where some of the case studies were taking place, the industrial partner was the enterprise in charge of public transport: the Munich Transportation and Tariff Association (in German, Münchner Verkehrs- und Tarifverbund – MVV). During the two workshops that have been organized with the MVV, the participants were asked to develop ideas in the field of 'sustainable mobility' using their daily experience with transportation in Munich. A short introduction were carried out about the notion of sustainability that included not only ecological, but also economic and social aspects (Cornet 2008-2009). The intention was to give the users a broader perspective and a deeper understanding of the complexity of sustainability.

As the ideas did not come from the industry and they were not developed by specialists, the level of details was low. Hence, the ideas were specified in adequacy to the territory where they would be implemented, namely the Munich transport network. Considerations of the infrastructure situation in Munich and interview of an expert from MVV (Fink 2009) have enabled to form these ideas into concrete mobility concepts and made possible a comprehensive evaluation. That step helped to build scenarios, which were used to quantify the amplitude of the implementation of the measures for the ensuing evaluation. The

reference scenario, in which the idea has not been implemented yet, has been compared with the target scenario, in which the idea is implemented.

The workshops' participants developed ideas as numerous as diverse. These ideas have been formulated in specific and concrete concepts (Cornet & Weber-Blaschke 2011) (Table 4.1).

Table 4.1: Description of the ideas (selection) (Cornet & Weber-Blaschke 2011)

Ideas from the workshops	**Formulation of concrete concepts**
Mobile-phone ticket	Ticket to be ordered and bought over the mobile phone
Tangential bus line	Bus line that connects the last suburban-train stations in the suburban MVV-area without stopping
Real-time information	Traffic information in real time, which is readable on the displays in the stations and on the internet
Camera surveillance	Camera surveillance in the stations and in the trains
Taxi sharing	Taxis travelling in the night and carry up to four passengers
Events supply	Combination of events with price reduction for public transport
Central service	Service staff at the main stations to answer customers' questions
E-cars, E-scooter	E-cars availability at the suburban-train stations for the last kilometres of the travel with the public transport (similar to car-sharing)

4.1.2 Ideas to test the screening tool

The goal of the case studies is to show the flexibility of the screening tool, and more precisely, to identify how the screening tool could be enhanced to cover **various ranges of ideas** for the topic of urban mobility. Therefore, a set of ideas has been considered that are different under the following aspects:

- Infrastructure projects, products and virtual services;
- Traditional (i.e., usual) ideas and innovative ideas;
- For diverse types of scenarios (competition with an existing idea or/and additional implementation to an existing idea).

With these considerations, ideas from the user integration have been selected to test the screening tool (Table 4.2).

Table 4.2: Selection of ideas and characteristics

Ideas	Type	Innovation grade	Implementation
Tangential bus line	Infrastructure project	Traditional project (comparable to any bus line)	Competition with car and suburban train
Mobile-phone ticket	Product	New for the city of Munich	Competition with standard paper ticket
Real-time information	Virtual service	New for the city of Munich (implemented in the meantime)	No competition
E-cars, E-scooters	Both product and infrastructure project	New for the city of Munich	Competition with private car

Thanks to the **diversity of the ideas**, it is possible to evaluate the screening tool itself, its performances as well as its weaknesses.

4.2 Tangential bus line

In some cities in Europe, for instance in Berlin, a subway line runs all around the city and enables the population to rise crosswise with public transport without having to reach the city centre and make a transition there. In Munich, there is for the moment no possibility to cross the landscape with public transport between two end stations of suburban train lines in a short time. Such a travel takes in average 45 minutes with the public transport for an average distance of 37 kilometres, whereas with car, there are only 18 kilometres between the two stations and it requires in average 20 minutes for the trip (Figure 4.1).

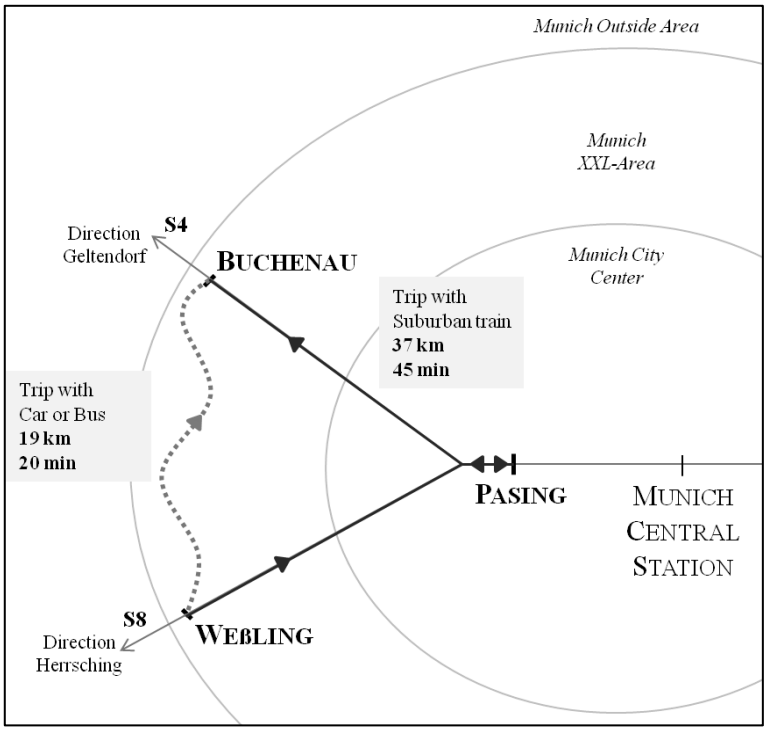


Figure 4.1: Simplified representation of trips between Weßling and Buchenau within the MVV areas with car, bus and suburban train (own representation)

The idea 'Tangential bus line' is evaluated with the screening in order to identify the environmental, social and economic impacts that could occur, as well as potential unintended effects.

4.2.1 Definition of function and functional unit

The first step is to define the reference scenario and the target scenario. The screening offers the possibility to begin directly with the description of the new idea, which helps to define the function that is fulfilled and the existing ideas that fulfil the same function in the reference scenario.

The new idea is a **bus** that drives across the landscape between last suburban train stations of the MVV XXL-area without stops.

Therefore, the function is the **commutation of persons between last suburban train stations of MVV XXL-area** and the reference flow is the number of persons in suburban area that travel either with car or public transport for their daily activity. The functional unit is consequently **persons/day**.

For the reference scenario, trips with **car and with suburban train** fulfil the same function. Thus, the impact assessment will compare the travel of persons, on the one hand, with car and suburban train (reference scenario), and, on the other hand, with the new bus line (target scenario).

4.2.2 Environmental impacts' inventory analysis

Processes

First, processes for the reference scenario are determined. For trips with car, the available process in the screening database is "Car", which is referring to the Ecoinvent process "**Transport, passenger car, RER**". This process is dependent from the functional unit and an average of 38 kilometres is achieved per person and per day (equivalent to a round trip for a single trip of 19 kilometres). For the reference scenario, the other possibility is to travel with suburban train. The process in the screening is "Suburban train", corresponding in the Ecoinvent database to the process "**Transport, regional train, SBB electricity mix, CH**". In the Ecoinvent database 2007, no process describes suburban trains on the European level. In the Ecoinvent database, this process has been defined based on the analysis of electric Swiss trains "RegioExpress" and suburban trains (Spielmann et al. 2007), which are used for suburban and regional traffic on the Swiss Federal Railways (in German, Schweizerischen Bundesbahnen – SBB) network. They are assumed comparable to any regional train across Europe. With the suburban trains, 74 kilometres are needed per person and per day for a round trip.

Relating to the target scenario, the process "Bus" is chosen in the screening to characterize the new bus line. It refers to the Ecoinvent process "**Transport, regular bus, CH**". In the Ecoinvent database 2007, no process describes buses on the European level. Nevertheless, the process refers to **standard diesel buses** comparable to any buses across Europe. To make a round-trip, the bus drives in average 38 kilometres on the same road than the car.

All the processes are expressed in person-kilometres and are dependent on the functional unit persons/day.

In a first place, maintenance of road is excluded from the calculation. Maintenance of road could be indeed higher with the implementation of new bus line since busses' traffic induces bigger damage to the road than the usual traffic with cars.

Figure 4.2 represents the system boundary as well as the excluded processes for the idea "Tangential bus line".

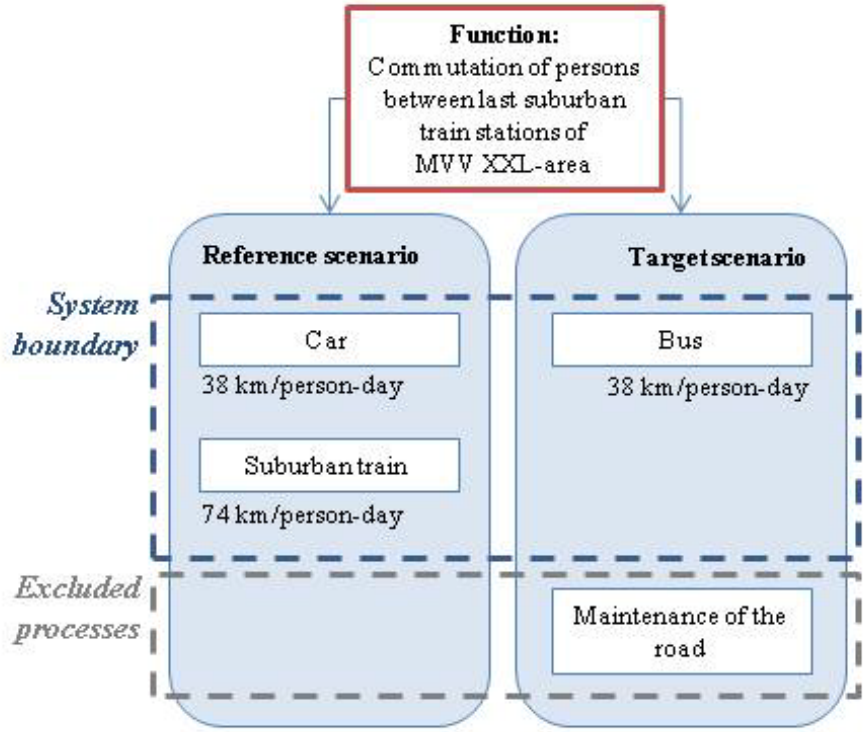


Figure 4.2: System boundary and excluded processes for the idea "Tangential bus line"

Users of reference and target scenarios

The users that are concerned with the implementation of the new idea are the **residents of the suburban area of Munich**. It represents for both reference and target scenario a restriction of 49% of the entire population of Munich (BayLfStaD 2011). A further restriction is that this population is using different modes of transports. Indeed, in the suburban area, the modal share distribution in 2008 is around 57% for the car and 10% for the public transport (MVV 2010b). It is supposed that, from these ratios, the persons are driving the average kilometres, respectively 38 kilometres with car and 74 kilometres with public transport, i.e., with suburban train.

From this number of persons, it is necessary to estimate how many persons are susceptible to changing their travelling habits in the target scenario. Thus, it is assumed in the first place that the bus line is especially attractive for the elderly, who represent around **21% of the**

population. In other words, it means that 21% of the previous concerned users of the reference scenario – car users and suburban train users – switch to the new bus line.

4.2.3 Social impacts' inventory analysis

In order to determine if the wants and needs of the people are encouraged or deteriorated by the idea, it is helpful to consider the users' profiles previously defined and their expectations. The business travellers are mainly travelling into the city centre and the utilization of bus for this category is very limited. Young people who are living in the suburban area are mainly travelling with school bus and are thus not directly concerned with the idea. The handicapped persons, the elderly as well as some commuters are going to be the most interested with this new idea. The focus is first on the persons who use the suburban train in the reference scenario. For the handicapped persons, the **number of transitions** is reduced since it is not necessary anymore to transfer in the city centre. The **comfort** is improved, especially for the elderly, who appreciate a low force deployment induced with fewer transitions, according to the definition of the users' profiles. For the commuters who travel crosswise with public transport, the **travel time** is improved since the bus line induces a reduction of half time for the travel, in comparison with the suburban train. For persons using the car in the reference scenario, the **direct and indirect costs** related to the possession of an individual vehicle are higher than for the utilization of public transport. In the present case, for instance, the costs (direct and indirect) linked with the fuel consumption, the insurance, the maintenance and the loss in value of the car – calculated around 0,35 €/km (ADAC 2010), corresponding of around 10.40€ for the considered trip – are higher than the use of the public transport – 7€ for a daily ticket (MVV 2010c). For car drivers who switch to the new bus line, **safety** is moreover improved (less accidents) as well as **sustainability awareness**. Nevertheless, for car drivers, **identity**, **comfort** and **flexibility** are deteriorated. Indeed, the utilization of private vehicle transmits a status symbol and an impression of privacy and independence, which are lost by the use of public facilities.

Relating to the evaluation in the screening, the choices available within the module are a double plus (++) if the indicator is improved thanks to the idea for all the users and a plus (+) if the indicator is improved thanks to the idea for one category of users. Respectively, a minus (-) and a double minus (--) are attributed for deterioration of the indicator with the same consideration regarding the users (Table 3.3).

In the screening, it is possible to provide the social analysis simultaneously for the different ideas that the new bus line replaces, i.e., car and suburban train.

Therefore, the sub-indicators ‘safety in transport’, ‘sustainability awareness’, ‘number of transitions’, ‘direct costs’, ‘indirect costs’ and ‘travel time and waiting time’ are improved with the implementation of the new tangential bus line. Since the improvement concerns only specific categories of users, the evaluation is with only one plus (+). The indicators ‘identity’ and ‘flexibility’ are deteriorated for car drivers and are therefore evaluated with a minus (-). The positive evaluation of comfort for the elderly is counterbalanced with the negative perception of car drivers and it is therefore set to zero.

The other indicators are not directly affected by the new idea and they are set to zero.

Table 4.3 sums up the social impacts’ inventory analysis.

Table 4.3: Summing-up of the social impacts’ inventory analysis for the idea “Tangential bus line”

Social indicators	**Sub-indicators**	**Ranking**	**Colour attribution**
Security	▪ Safety in transport and security of the transport	+	Light green
	▪ Reliability	0	
Information	▪ Availability	0	No colour
	▪ Quality	0	
Social acceptance	▪ Identity	-	No colour
	▪ Sustainability awareness	+	
Distance	▪ Accessibility	0	Light green
	▪ Numbers of transitions and barriers	+	
Convenience	▪ Flexibility	-	Yellow
	▪ Comfort	0	
Costs	▪ Direct costs for travelling	+	Green
	▪ Indirect costs	+	
Time	▪ Travel time and waiting time	+	Light green
	▪ Preparation time	0	

4.2.4 Economic impacts’ inventory analysis

The value for the enterprise is qualitatively estimated in the screening depending on the costs for the implementation of the new idea (investment) and the earnings linked with the user acceptance.

For projects in suburban area, MVV is working in cooperation with transport companies of the respective districts. These companies sign contracts with MVV as partners, and earnings are shared between MVV and the companies (Fink 2009). For the enterprise in charge of the public transport, here the MVV, the costs are **low** since they are borne by the different partners involved in the project, in this case the buses companies of the respective district.

As described previously in the social impacts' inventory analysis, the bus line does not induce a global improvement. It improves indicators only for specific categories of users. Therefore, the earnings linked with the user acceptance are **medium**.

4.2.5 Impact assessment

Environmental impact assessment

The results of the environmental impacts' analysis are shown in Table 4.4 for the processes of reference scenario and target scenario.

A modal shift is induced since the indicators "Travel time" and "Direct costs" are improved. Considering that "Flexibility" is deteriorated, the shift is counterbalancing for the different user segments. Finally, the resulting modal shift induces that:

- 10% of PT-occasional users become PT-regular users;
- 10% of PT-potential users become PT-occasional users;
- 5% of MIT-captives become PT-occasional users.

Table 4.4: Environmental impacts for reference and target scenario of the idea "Tangential bus line"

	Greenhouse gas emissions (kg CO_2-e/day)	**Fossil resource consumption (kg COE/day)**	**Pollutant emissions (kg PM10-e/day)**
Reference scenario	3 236 363	899 609	14 113
Target scenario	2 865 042	809 295	15 701

The processes extracted from the Ecoinvent database are expressed mostly in grams. Using these processes, the screening calculates the savings or impacts in grams too. Nevertheless, according to the diverse assumptions and restrictions that are considered, the **order of magnitude** of the results is the most important aspect.

After normalization, the results are converted into **resident-equivalents** to enable a comparison of the indicators. The resident-equivalents refer to the average impacts per inhabitant per day in Germany (Chapter 3.7.4).

For the representation of the results with the grading colour system, the focus is on the difference between the reference and target scenario in order to answer the question: "Is the idea improving or deteriorating the current situation?" Therefore, the difference between the impacts of the reference and target scenario is expressed in percent and in resident-equivalents (Figure 4.3). Negative percents represent savings and positive percent represent impacts.

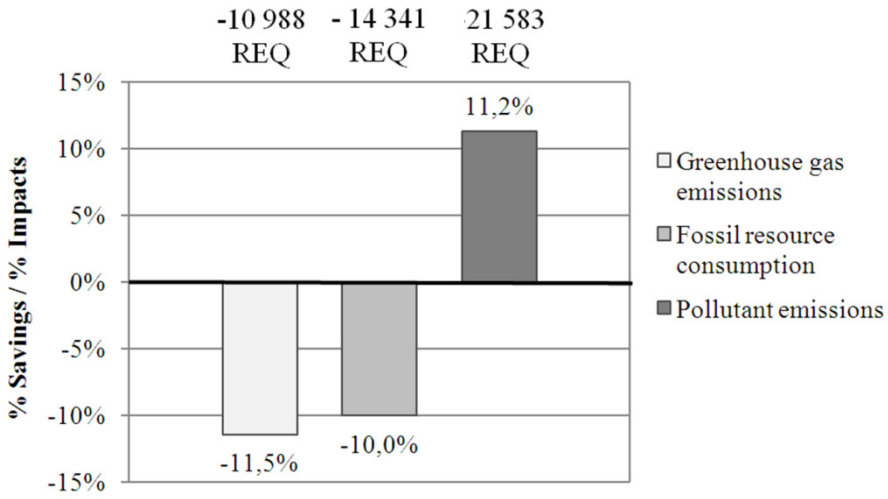


Figure 4.3: Environmental savings and impacts for the idea "Tangential bus line"

On the one hand, **savings** of greenhouse gas emissions and fossil resource consumption in the target scenario are observable in comparison with the reference scenario. On the other hand, the additional pollutant emissions are 11.2% higher in the target scenario than in the reference scenario with also high resident-equivalents. Buses have indeed higher pollutant emissions than cars, and therefore, their implementation induce higher pollutant emissions in the target scenario than in the reference scenario.

Relating to the grading colour system, the savings concerning greenhouse gas emissions and fossil resource consumption correspond to a **green colour**. The pollutant emissions are higher in the target scenario and are therefore marked with a **red colour**.

Social impact assessment

Relating to the attribution of grading colour, the indicator ‘costs’ is evaluated with a **green colour**. The indicators ‘security’, ‘distance’ and ‘time’ are evaluated with a **light-green colour**, since they are improved for some categories of users in the target scenario. ‘Convenience’ is critical since it is evaluated with one minus for ‘flexibility’, and there is no accordance for ‘comfort’ among the different users (zero). The corresponding grading colour is **yellow**. Similarly, ‘social acceptance’ is positive regarding the sustainability awareness but negative regarding the identity. It is therefore represented without colour.

The other indicators are not modified and therefore do not have any colour.

Economic impact assessment

In the screening, the value for the enterprise is not studied in detail since the screening runs within the enterprise itself, which implies that the screening practitioner has the best ability to assess this indicator. Concerning the value for the enterprise, the low costs are positive. However, associated with medium earnings linked with user acceptance, they are not enough to represent a positive value. The indicator is thus characterized with a **light-green colour**.

Recapitulation of the results for tangential bus line

The sustainability evaluation realized with the screening is summed up in Table 4.5.

Table 4.5: Summing-up of the results for the idea “Tangential bus line”

Spheres	Indicators	Tangential bus line
Planet	Greenhouse gas emissions	
	Fossil resource consumption	
	Pollutant emissions	
People	Security	
	Information	
	Social acceptance	
	Distance	
	Convenience	
	Costs	
	Time	
Profit	Value for the enterprise	

4.2.6 Interpretation of the results

The phase of interpretation of the results, comparably to LCA, contains an evaluation of the results in term of **consistency and completeness**, **robustness of the results** and the formulation of the **conclusions and recommendations** for the case study. The two first phases are mostly relevant for quantitative assessments; therefore, the environmental impact assessment is at the focus for them.

Consistency and completeness

The aim of consistency and completeness check is to **justify the choices** that have been made for the definition of parameters. It is a critical part of the screening since the aim is, first and foremost, to keep the evaluation **simple** for the screening practitioner and cut-offs have been necessary.

Consistency of the results

The consistency check is made regarding the choice of processes. In the screening, all the processes refer to the Ecoinvent database. This database has an international resonance within the scientific community. Therefore, the choice of the processes "bus" or "suburban trains" is considered as valid, since in both case, the **vehicles are similar across Europe**. Nevertheless, the exclusivity of the Ecoinvent database utilization poses a problem regarding **electricity consumption**. Indeed, the calculation for the energy consumption of the suburban train in the Ecoinvent database is done with Swiss electricity mix, which is different from other electricity mix across Europe. Especially for railways, the use of energy is proper to each country, which implies different environmental impacts (Figure 4.4)

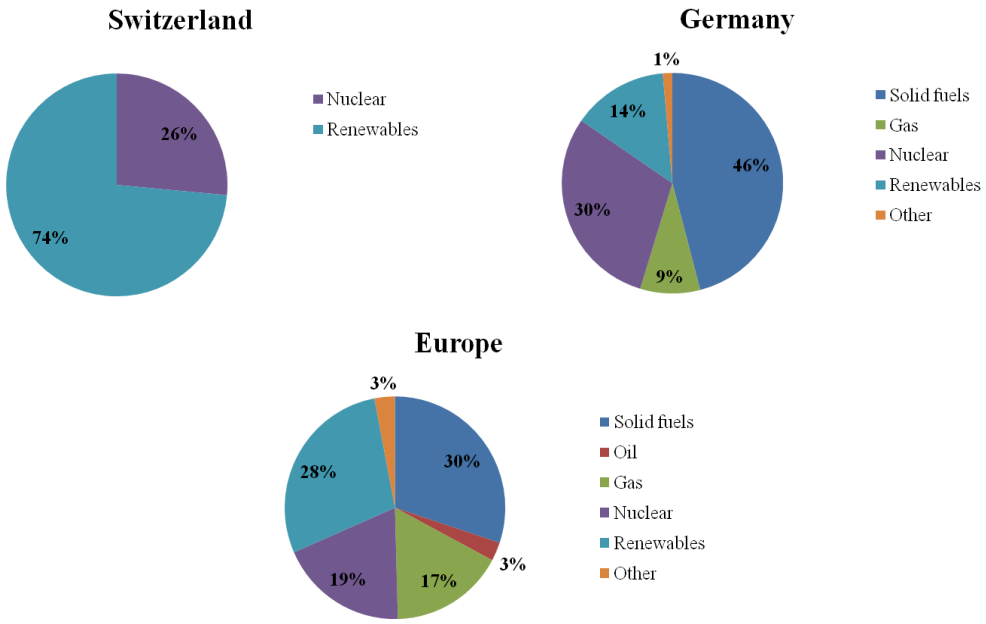


Figure 4.4: Energy split of electricity consumption used by railways in 2007 (IFEU 2010a)

In Switzerland, the energy used by railways is mostly from hydroelectric power. The issued emissions of greenhouse gas, for example, are therefore tiny. On the other hand, in Germany, almost half of the energy used by railways comes from solid fuels, which implies high greenhouse gas emissions.

Since the case study is made in the MVV-area, a simulation is made with the German electricity mix available in the Ecoinvent database. The electricity consumption of regional trains is **0.161 kWh/pkm** considering the entire life span (Spielmann et al. 2007) and is considered similar for German regional trains.

The results of the simulation show slight differences to the initial simulation (less than 5% difference with the initial assumptions), which does not affect the grading colour attribution. Indeed, even if the greenhouse gas emissions of German trains are six times higher than for Swiss train, the impacts of suburban trains with German electricity mix are low in comparison with those of cars and buses and do not influence the results.

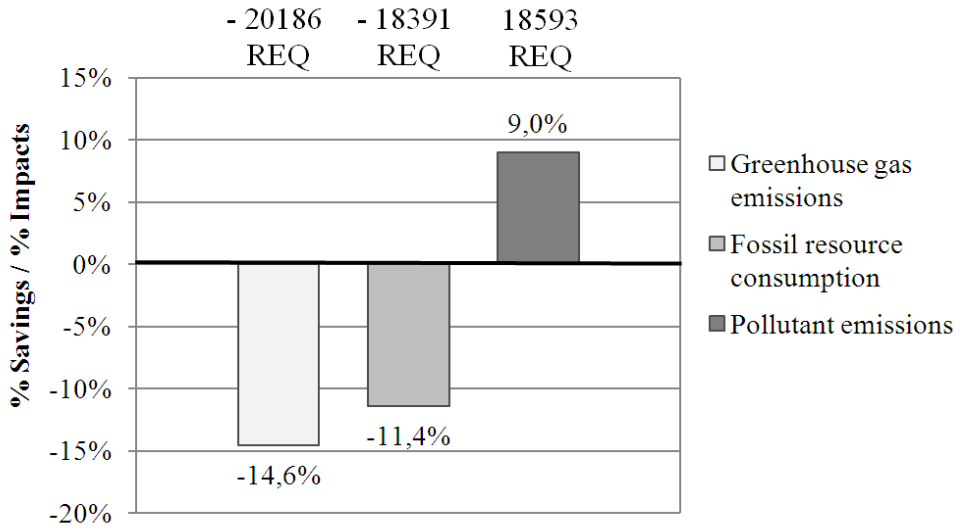


Figure 4.5: Environmental savings and impacts for the idea "Tangential bus line" – Simulation with German electricity mix for suburban trains

Completeness of the results

Regarding the completeness of the selected processes, the screening takes only into account changes between reference and target scenarios, i.e., processes that are not present in both scenarios or processes that are affected by the new idea. The infrastructure, for instance, is present in both scenarios and has been supposed unchanged, i.e., no road is built extra for the new bus line. In order to realize the amplitude of the influence of this assumption, the **alteration of the road by buses traffic** is now taken into account. The process "Road" in the screening refers to the Ecoinvent process "Road, construction and renewal, CH" in metre-year. It is supposed that the renewal of the 200-km road, which is concerned with the bus line, is made twice much often than in the reference scenario. In the Ecoinvent database, the process "Road" has a life span of hundred years with regular renewals throughout this life span. Therefore, considering the entire life span of a road with operation and regular renewals, it represents for the target scenario the replacement of **one complete road** and the attributed renewals.

There are more impacts than in a simulation without consideration of road degradation, but they are not significant in term of resident-equivalents and in percents (lower than 2% of difference with the results of the initial simulation) to change the attribution of the grading colour.

Robustness of the results

The analysis of the robustness of the results refers to parameters that have been fixed arbitrarily in the screening and it is provided in order to test the influence of these parameters on the results. For the simulation, the following parameters have been determined thanks to assumptions or qualitatively:

- the kilometres made by car in reference scenario,
- the demographic restriction,
- the occupancy of the buses,
- the evaluation of the social indicators.

In the screening, it is possible to vary the inputs and to observe the changes in the results.

Kilometres by car in reference scenario

The environmental impacts are mostly linked with the utilization of car in both scenarios. Therefore, a simulation is necessary to see the influence of the parameters that have been fixed about the car utilization. The supposition made in the first simulation was that all the people who use the car are driving the average distance separating two suburban train stations (i.e., 38 km for a round-trip). It suits to the reality if we consider that people are only travelling this route. For the travel with car in the reference scenario, the focus is now on the average distance made per person per day in Munich **56 km** (MVV 2007b). It is actually probable that the average distance by car in the suburban area is higher than the average distance in the entire MVV-area, since the density of activities is lower than in the city centre and more distance is needed to realize the same activities.

The simulation shows that the higher the kilometres by car in reference scenario, the lower the environmental impacts. For greenhouse gas emissions and fossil resource consumption, it means always savings in the target scenario and always a green colour. For the pollutant emissions, the average distance of 56 km with the car implies that the impacts are under 10% and under 4000 REQ in comparison with the reference scenario and thus, it would imply a **yellow colour** for this indicator. From 60 kilometres by car, pollutants emissions are under

2000 REQ and the indicator is marked without colour. From 65 kilometres, the savings of pollutant emissions in resident-equivalents are superior to 2000 REQ, and this would imply the attribution of a light-green colour for the indicator. Nevertheless, 65 kilometres is a high average distance and no European country is using the car that much. It is therefore considered that the maximum for this indicator is without colour.

Additional simulations with kilometres by car under 38 kilometres or with different kilometres for the suburban train are not realistic or do not have influence on the results.

Demographic restriction

In the initial simulation, it has been assumed that the idea is particularly interesting for the elderly, who represent around 20% of the population. By selecting different categories of target users, it is possible to observe the influence of the utilization of the bus line (i.e., the diffusion of the idea) on environmental impacts. The influences are following linear curves (Figure 4.6) and it shows that the higher the utilization rate of the bus line, the higher the savings for the greenhouse gas emissions and the fossil resource consumption. On the contrary, the impacts linked with a higher utilization of the bus line are higher for the pollutants emissions since additional buses are needed.

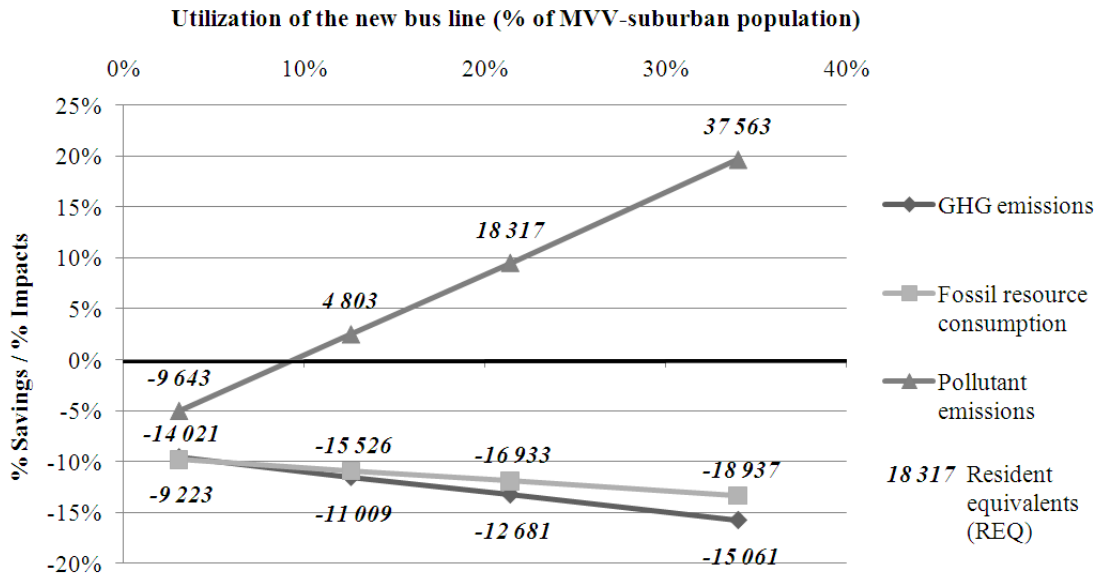


Figure 4.6: Simulation with different diffusion rates and resulting environmental savings and impacts for the idea “Tangential bus line”

For greenhouse gas emissions and fossil resource consumption, the simulation does not imply new grading colour. However, for the pollutant emissions, fluctuations are big and the attribution of grading colour varies **between green and red colour**.

Under 10% utilization of the bus line by the MVV suburban population, we observe a situation with **only savings for the environmental indicators**. It corresponds to a situation with very few buses, but still with occupancy of fourteen persons per bus.

The observation of the consequences of a low utilization of the bus line is not possible by setting the ratio to zero, since it would mean that there is no bus line in the target scenario. In order to observe the influence of a "**flop**" of the new bus line, it is necessary to act on the load factor of the buses, i.e. the occupancy.

Occupancy of the buses

In the screening, the load factors of the diverse modes of transport are fixed by the Ecoinvent database. For instance, buses have a fixed average load factor of fourteen persons (Spielmann et al. 2007). Nevertheless, it is possible to change this occupancy in the screening, for instance, in order to check the environmental impacts of a "**flop**".

Simulations are made with different load factors from two persons to twenty persons (Figure 4.7).

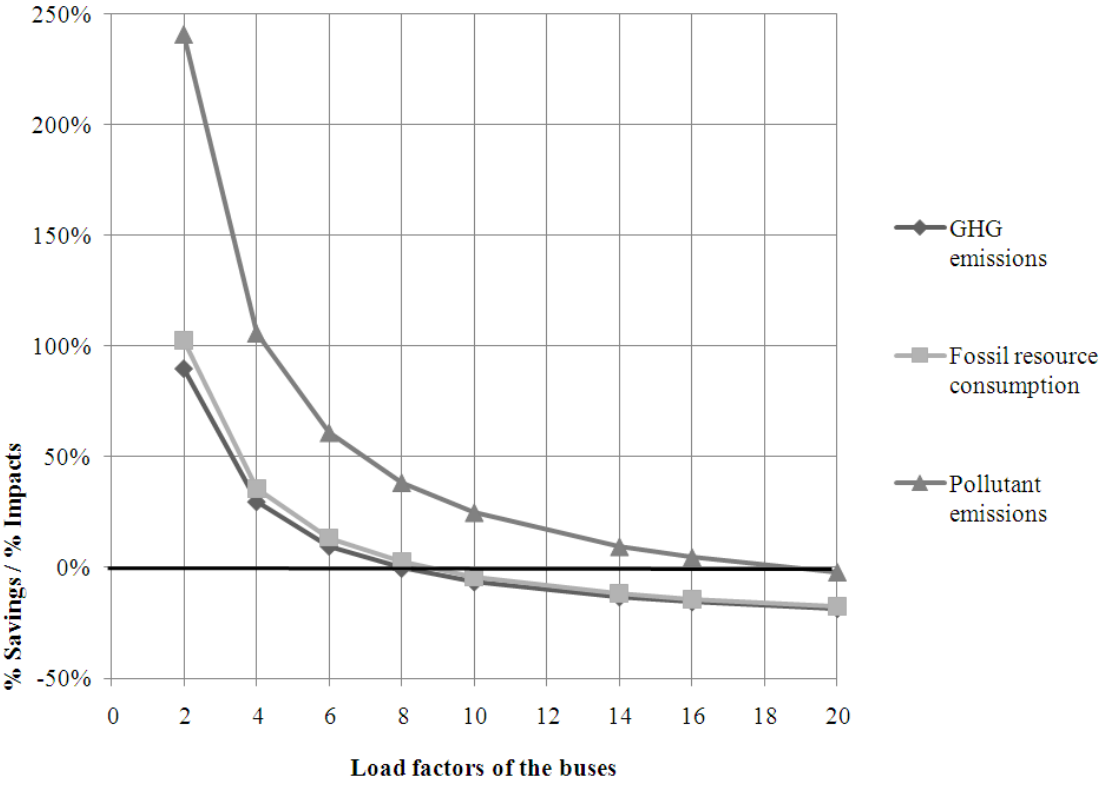


Figure 4.7: Simulation with diverse load factors and resulting environmental savings and impacts for the idea "Tangential line bus"

For higher load factors than the Ecoinvent average (i.e., load factors superior to fourteen persons per bus), greenhouse gas emissions and fossil resource consumption are marked with a green colour and pollutant emissions without colour. This situation is nevertheless not probable since buses are driving in the suburban area, and in this area, the occupancy of the vehicles is fewer than in the city centre. Therefore, the maximum occupancy in the simulation has been fixed to 20 persons. For lower load factors than the Ecoinvent database average, **brutal changes of the results** for all the indicators are observable. Greenhouse gas and fossil resource consumption are varying from **green to red**; and the impacts of pollutant emissions are crossing the 200% increase and more than 100 000 resident-equivalents in comparison with the reference scenario.

The parameter "occupancy of the buses" is thus **fundamental** for the results.

Social indicators

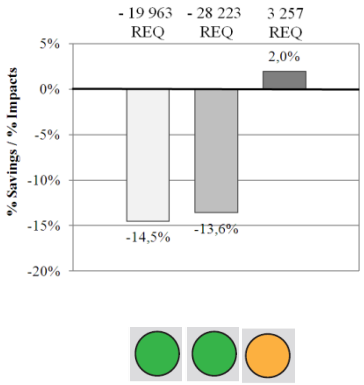
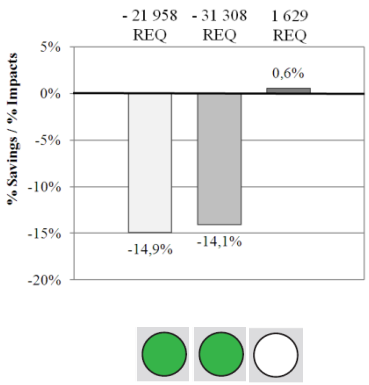
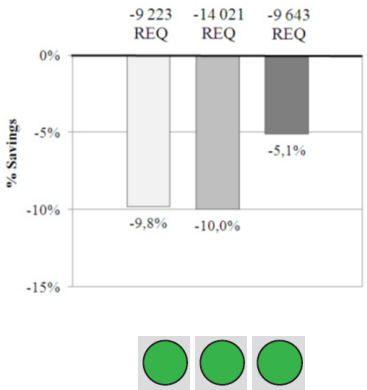
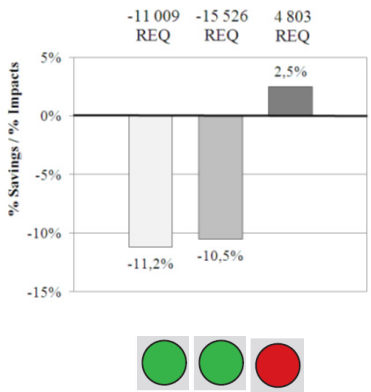
The social indicators have been chosen mainly with the help of literature and their evaluation reflects the direct consequences that would have a tangential bus line.

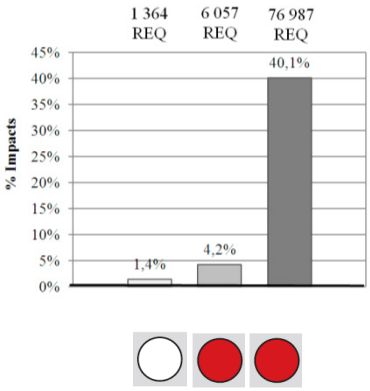
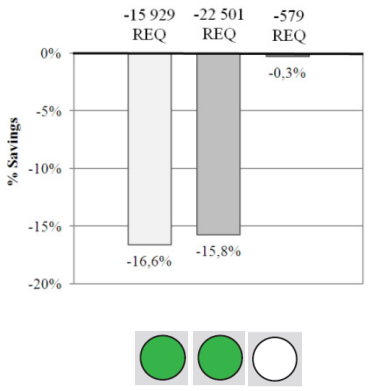
Relating to the modal shift and the associated environmental impacts, the simulation with variation of the social indicators does not change the attribution of the grading colour (green for greenhouse gas emissions and fossil resource consumption and red for pollutant emissions).

Table 4.6 sums up the analysis of the robustness of the results for the parameters related to the kilometres with the car, the demographic restrictions and the occupancy of the buses.

Table 4.6: Recapitulation of the analysis of the robustness of the results for the idea "Tangential bus line"

Legend: GHG: Greenhouse gas, COE: Crude Oil Equivalents, PM10: Particle Matter

Parameters	**Results with change of parameters and attributed colour**	
Kilometres with the car	56 km with the car	60 km with the car
Attributed colour for the environmental indicators (GHG, COE, PM10)		
Demographic restrictions	5,4% utilization of the new bus line	12% utilization of the new bus line
Attributed colour for the environmental indicators (GHG, COE, PM10)		

Parameters	**Results with change of parameters and attributed colour**	
Occupancy of the buses	8 persons per bus	20 persons per bus
Attributed colour for the environmental indicators (GHG, COE, PM10)		

Conclusions and recommendations

Table 4.7 sums up the results of the robustness analysis differencing "worst-case" scenario and "best-case" scenario.

Table 4.7: Summing-up of the consistency and robustness analysis for the idea "Tangential bus line"

		Tangential bus line	
Spheres	Indicators	Worst-case scenario	Best-case scenario
Planet	Greenhouse gas emissions		
	Fossil resource consumption		
	Pollutant emissions		
People	Security		
	Information		
	Social acceptance		
	Distance		
	Convenience		
	Costs		
	Time		
Profit	Value for the enterprise		

The evaluation of the idea “Tangential bus line” with the sustainability screening has shown that a decrease of car utilization is not always a synonym for sustainability. Indeed, replacing some cars by buses that have lower greenhouse gas emissions per person kilometre induces the side effect that the pollutant emissions increase. In fact, the buses selected in the Ecoinvent database are with **diesel motor** and emit twice more nitrogen oxide (NOx) than standard cars per person-kilometre. The first recommendation for the implementation of the idea is therefore the **use of particle filters** or other power engine for the buses (e.g. gas engines).

Concerning the social indicators, the bus line has the advantage that it does not present any red colour. Nevertheless, the results are mitigated and it is not possible to predict a good acceptance from users and consequently earnings for the enterprise in charge of public transport. In the present case, even if the costs for the enterprise are low, the earnings linked with the user acceptance are not high enough to generate profit.

Regarding the use of electricity mix, processes that involve electricity should be used carefully especially if their contribution to the entire impact is high. Indeed, in the case study, simulations have been made with different electricity mixes and the fluctuation of the results was low since the impacts of the suburban trains are low in comparison of those of cars and buses.

The analysis of the robustness of the results has shown that some parameters of the screening are highly sensible to changes. The most sensible are the diffusion of the idea and the occupancy of the buses. On the one hand, the simulation with utilization grades showed that a lower acceptance from the user means a reduction of the environmental effects for the pollutant emissions. On the other hand, a low occupancy of the buses affects negatively the results if it is under the average load factor of the buses.

As recommendation for the implementation, the enterprise should pay attention that, in average, the buses are driven with load factors equal or superior to fourteen persons, which can be made by **reducing the frequency of the buses**. A potential implementation would be **shuttle buses**, which are driving only few time per day (for instance, especially in the morning and in the evening for the commuters), but, with a high occupancy (superior to fourteen persons per bus).

To conclude, the regular tangential bus line is **not evaluated as sustainable product** if it is implemented as **normal bus line** with a 10 to 20 minutes frequency. The emissions of pollutants that it generates induce consequences outside the system, by damaging the

population health for instance. Furthermore, the social improvements are too low to generate a noticeable enhancement of the situation for the users.

On the contrary, a **shuttle bus is evaluated as sustainable product** since there is environmental savings in the target scenario and there is a higher value for the people (especially the commuters) and the enterprise.

In any case, the bus line has **several side effects**, since it is difficult to reduce the greenhouse gas emissions without endorsing the situation with further pollutant emissions. Furthermore, behaviour changes can occur in the long term. Indeed, by giving the people more speed between two suburban stations, the probability is increased that some pedestrians or cyclists will take the opportunity and use the new bus line. Such a behaviour change would be contrary to the stance of sustainability of the work.

4.3 Mobile-phone ticket

Throughout the workshops and during the diverse steps of the development process, the possibility to pay the public transport fare with the mobile phone was a recurrent idea that the participants formulated. Indeed, the mobile phone opened wide possibilities by its spreading to the community for data communication. Already in 2006, 104 mobile connections were available in Germany per 100 inhabitants (BITKOM 2008). With such a close-knit availability, it is expected to make the phone usable for public transport, such as for the timetable or for the ticket sales. Users sign up for one of the participating transport companies and can use in all participating regions public transport buses, trams, suburban trains, local trains and other public transport. This allows a user registered in Dresden to buy a ticket in Hamburg, Cologne, Nuremberg, and other cities and regions without having to get used to another method or tariff system (VDV 2010). The ticket sale machine is thereby the own mobile phone.

The idea “Mobile-phone ticket” is evaluated with the screening in order to identify the pros and cons related to sustainable development.

4.3.1 Definition of function and functional unit

The target scenario is in the present case as following: The public transport user commands a ticket via his/her mobile phone. He/she receives the ticket as SMS (or bar code) on his/her mobile phone and can use the public transport facilities he/she wishes.

The function to be fulfilled is **the purchase and the holding of a valid ticket for a round-trip** with public transport facilities.

The reference scenario refers to the existing ideas that fulfil the same function. In this case, the traditional paper ticket is fulfilling the same function. This paper ticket is supposed to be usable only for one trip and the monthly and yearly ticket are not considered.

The reference flow is the unit in which both ideas (mobile-phone ticket and paper ticket) are going to be compared. The time scale for the screening is fixed to one day; therefore, the reference flow will be "Total of trips per day for the MVV-area" and the functional unit **trips/day**.

4.3.2 Environmental impacts' inventory analysis

Processes

First, processes for the reference scenario must be determined. For the traditional paper ticket, the available process in the screening database is "Paper", which is referring to the Ecoinvent process "**paper, wood-containing, LWC, at plant, RER**". The weight of each paper ticket is around five grams. The process depends on the functional unit (i.e., it depends on the number of trips per day) and in order to fulfil the function, i.e., make a round-trip, the user needs two paper tickets.

Relating to the target scenario, the only processes needed are servers for the management and the monitoring of the selling system. These servers are comparable to computer, which are called in the Ecoinvent database "**Use, computer, desktop with LCD monitor, active mode, RER**". The servers run 24 hours a day and two are required to fulfil the function (one that calculates and one for security in case of breakdown) (Hesse 2011).

Excluded processes are the **mobile phones** themselves since it is considered that the user has already a mobile phone, independently of the implementation of the idea "mobile-phone ticket". Moreover, the **selling machines** as well as their installation, their use and their maintenance are not considered in the calculation since they are present in the reference scenario as well as in the target scenario. In a first place, indeed, the mobile phone does not induce a complete replacement of the paper-ticket system and selling machines stay in use.

Figure 4.8 represents the system boundary as well as the excluded processes for the idea "Mobile-phone ticket".

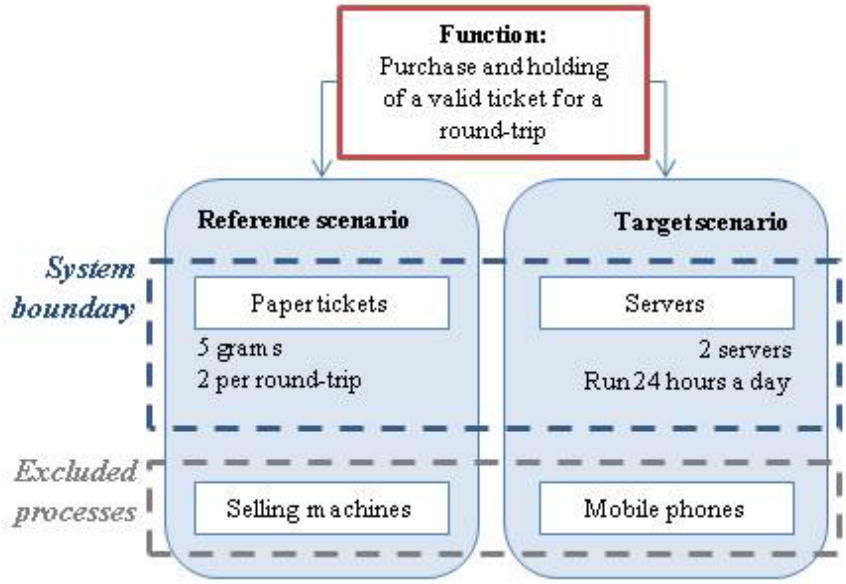


Figure 4.8: System boundary and excluded processes for the idea "Mobile-phone ticket"

Users of reference scenario and target scenario

The users of the reference scenario that are concerned with the implementation of the new idea are all the residents of Munich and its suburban area, excepting the regular users of public transport (PT-regular users) and the persons captives to the public transport (PT-captives), which have no other possibility to travel. These persons are travelling with monthly or yearly tickets that are not considered in the calculation.

From this number of persons, it is necessary to estimate how many persons are susceptible to changing their travelling habits in the target scenario, i.e., to estimate the diffusion of the idea on the market. It is supposed that the mobile-phone ticket is particularly successful for young men, who are supposed to enjoy the most new technologies (VDV 2010). Therefore, the focus has been restricted to the target users of **men from 15 to 30 years old**, which represent **10% of the population** in the MVV-area. In other words, it means that 10% of the previous considered users of the traditional paper ticket switch to the mobile-phone ticket.

4.3.3 Social impacts' inventory analysis

Relating to the social indicators, the indicators **'availability of information'**, **'flexibility'** and **'preparation time'** are improved thanks to the mobile-phone ticket. Indeed, the user does not need to know the tariff system anymore in order to buy a ticket (availability of

information) or to stay in the line at the selling machines in the stations (preparation time). Moreover, the user does not need to have change or to know where he/she can get the ticket (flexibility) (Fink 2009).

The **image** is improved for some users; especially at the beginning, the image enhancement is one of the main drivers for the introduction of mobile-phone tickets (VDV 2010).

The perception of the indicator '**reliability'** is deteriorated, since the technology is new and it can feel unfamiliar to deal with it for some users.

Thus, in the related screening module, 'availability of information', 'flexibility' and 'preparation time' are assigned with a double plus (++), Identity with a single plus (+) and 'reliability' with a single minus (-). The other indicators, for instance the costs, are not affected by the new system and are set to zero (Table 4.8).

Table 4.8: Summing-up of the social impacts' inventory analysis for the idea "Mobile-phone ticket"

Social indicators	**Sub-indicators**	**Ranking**	**Colour attribution**
Security	▪ Safety in transport and security of the transport	0	Yellow
	▪ Reliability	-	
Information	▪ Availability	++	Green
	▪ Quality	0	
Social acceptance	▪ Identity	+	Light green
	▪ Sustainability awareness	0	
Distance	▪ Accessibility	0	No colour
	▪ Numbers of transitions and barriers	0	
Convenience	▪ Flexibility	++	Green
	▪ Comfort	0	
Costs	▪ Direct costs for travelling	0	No colour
	▪ Indirect costs	0	
Time	▪ Travel time and waiting time	0	Green
	▪ Preparation time	++	

4.3.4 Economic impacts' inventory analysis

For the enterprise in charge of the public transport, it is important that costs stay under the current limit of 10% of the entire selling expenses. Following costs are expected for the implementation of the mobile-phone ticket (VDV 2010):

- The one-off costs for the integration of the mobile-phone ticket system in the entire system;
- The operating and maintenance costs;
- The communication costs (e.g. for SMS);
- The costs for the extension of the system.

After a pilot study, which was provided in several cities in Germany between 2006 and 2010, the Association of German Transport Companies (in German, Verband Deutscher Verkehrsunternehmen – VDV) evaluates that the costs for the mobile-phone ticket can stay in the middle term under 5% (VDV 2010). The investment for the implementation of the mobile-phone ticket is therefore considered as **medium**.

Regarding the several indicators that are improved thanks to the idea as well as the high topicality of the idea, the user acceptance is expected to be **high** and generate earnings for the enterprise.

4.3.5 Impact assessment

Environmental impact assessment

The results of the calculation of the environmental impacts for the reference scenario and the target scenario are shown in Table 4.9.

Concerning the modal shift, there is no change in the distribution since all the positive effects are counterbalanced with the degradation of the indicator 'reliability', which is an important criterion within the portfolio of action of the MVV.

Table 4.9: Environmental impacts for reference and target scenario of the idea “Mobile-phone ticket”

	Greenhouse gas emissions (kg CO_2-e/day)	**Fossil resource consumption (kg COE/day)**	**Pollutant emissions (kg PM10-e/day)**
Reference scenario	118	1 195	34
Target scenario	109	1 073	30

The emissions of greenhouse gas – mainly linked with the process ‘paper’ in both scenarios – are low since the raw material for paper production comes from trees, which use CO_2 for their photosynthesis (i.e., there is a CO_2-uptake during growth of trees).

After normalization, the results have been converted into **resident-equivalents** to enable a comparison of the indicators. Moreover, to facilitate the attribution of the grading colour, the results have been expressed in percent (Figure 4.9).

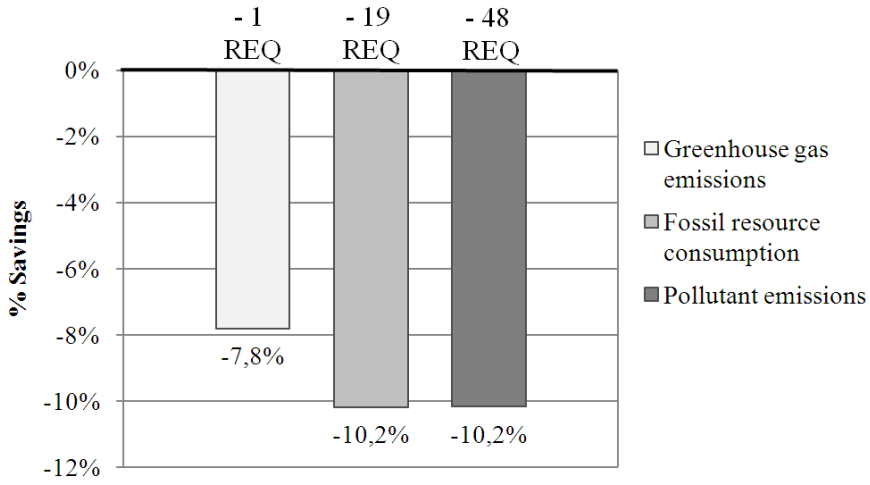


Figure 4.9: Difference in percent between target and reference scenario for the idea “Mobile-phone ticket”

The savings of the environmental impacts in the target scenario lay mainly on the reduction of the **paper-ticket utilization** when the mobile-phone ticket is introduced. Indeed, the impacts directly linked with the mobile-phone ticket system, i.e. the servers, are accounting for less than 5% of the impacts of the target scenario.

Relating to the grading colour system, the change between both scenarios relating to the greenhouse gas emissions is slight since inferior to 10% and these emissions represent only the equivalent of one resident; the situation is not modified and there is **no colour**

attribution. On the other hand, there is a slight improvement of the situation concerning fossil resource consumption and pollutant emissions, with a saving of 10.2% for both indicators, which corresponds to a **light-green colour**.

Social impact assessment

Relating to the social indicators, 'information', 'convenience' and 'time' are getting a **green colour** since their sub-indicators are improved for all the users with the development of the idea. 'Identity' is assigned with a **light-green colour**. The perception of distance and costs is not changing with the new idea (no colour attribution); nevertheless, the indicator 'security' is degraded for some users and is therefore evaluated with a **yellow colour**.

Economic impact assessment

A high fulfilment of user expectations implies – if the costs for the enterprise are medium or low – a green colour in the screening final evaluation (Table 3.9). Accordingly, the value for the enterprise linked with the implementation of the mobile-phone ticket is assigned with a **green colour**.

Recapitulation of the results for mobile-phone ticket

The sustainability evaluation realized with the screening is summed up in Table 4.10.

Table 4.10: Summing-up of the results for mobile-phone ticket

Spheres	Indicators	Mobile-phone ticket
Planet	Greenhouse gas emissions	
	Fossil resource consumption	
	Pollutant emissions	
People	Security	
	Information	
	Social acceptance	
	Distance	
	Convenience	
	Costs	
	Time	
Profit	Value for the enterprise	

4.3.6 Interpretation of the results

Consistency and completeness

Concerning the choice of the process ‘Paper’ in the Ecoinvent database, it was voluntary to take the most general process that can fulfil the function. Nevertheless, other processes were available to fulfil the function, for instance, ‘Solid bleached board, SBB, at plant, RER’. A simulation with this process instead of the process ‘Paper, wood containing, LWC, at plant, RER’ shows that the greenhouse gas emissions are higher in the target scenario than those of the reference scenario are (Figure 4.10).

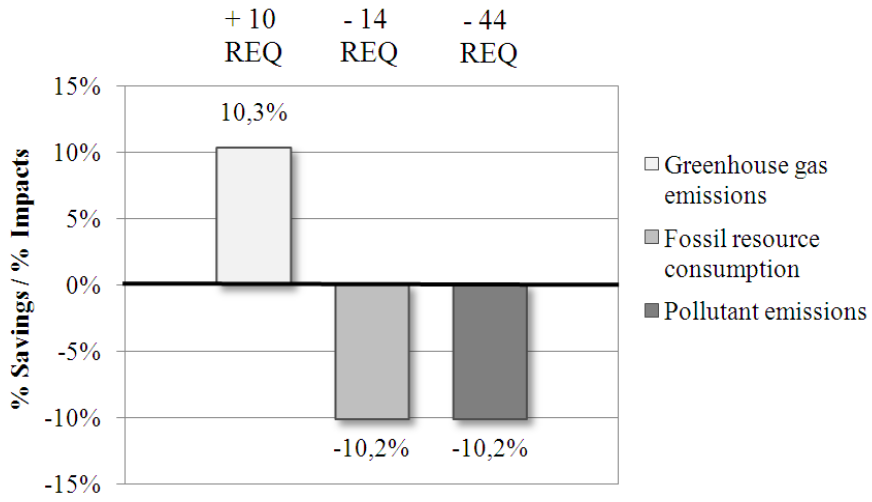


Figure 4.10: Simulation with "solid bleached board" process and relating environmental savings and impacts of the idea "Mobile-phone ticket"

The related attribution of grading colour for greenhouse gas emissions is a **yellow colour**. The attribution for the other indicators is unchanged. For the servers, the process referring to the use of a computer (i.e., with a desktop and a LCD display) has been chosen to fulfil the function in the target scenario. Nevertheless, a server has theoretically lower energy consumption than a normal computer since it has no display. A weighting should be therefore conducted to subtract the emissions linked with the display. However, the results have shown that the impacts are mainly due to the process 'paper' and that the impacts of the servers represent less than 5% of the entire impacts. Thus, a simulation with a new process for the computer is not necessary.

Regarding the completeness of the data selected, the ignored processes (selling machines and mobile phones) have been already justified by their presence in both scenarios.

Concerning the economic indicators, the value for the enterprise reposes mainly on the costs for the implementation engendered by the new idea. Nevertheless, enterprises must carry other costs, like – in the case of tickets – running costs for selling machines. In Munich, the mobile-phone ticket is not implemented yet because these running costs will not be reduced. Indeed, the mobile-phone ticket does not imply a substitution of the current selling machines. It means that for the Munich Transport Corporation (in German, Münchner Verkehrsgesellschaft – MVG) the implementation of the mobile-phone ticket does not have economic advantages (Fink 2009). However, these considerations are only valid in the middle term since in the long term, the mobile-phone ticket should replace the paper ticket

and the number of selling machines should be reduced. The Association of German Transport Companies (in German, Verband Deutscher Verkehrsunternehmen – VDV) speaks about a replacement of the "old" and "expensive" distribution channels, i.e. the selling machines and the points of sales (VDV 2010). Therefore, the green colour is justified for this indicator.

For the other parameters that have been fixed qualitatively, like the social indicators' evaluation, the evaluation has been proceeded on the most objectively way with support of literature and expert interview. In doubt, the values have been taken on the lowest level to be sure that the impacts are not underestimated.

Robustness of the results

The following parameters have been chosen either arbitrarily under the "common sense" logic or qualitatively with expert support:

- Number of paper tickets needed for a round-trip (the public-transport user buys a daily paper ticket instead of a one-time ticket);
- Weight of the paper ticket (from 3 to 10 grams);
- Number of servers needed (from one to four servers);
- Demographic restrictions (not only young men from 15 to 30 years old);
- Social inventory analysis (reliability is set to zero).

The simulations with diverse demographic restrictions represent the progressive implementation and diffusion of the idea on the market, from a short-term view – when the idea is not well known – to a more long-term scenario with more users.

After simulations on the screening tool by varying the four first parameters, it is noticeable that fossil resource consumption and pollutants emissions have a similar and stable behaviour, whereas the greenhouse gas emissions fluctuate more when the parameters change. Therefore, the analysis of the robustness of the results is separated between the fossil resource consumption and pollutants emissions on the one hand; and the greenhouse gas emissions, on the other hand.

The social inventory analysis and the related modal shift are treated separately since the analysis influences the three environmental indicators.

Fossil resource consumption and pollutant emissions

As noticed before, the process “Computer” generates low impacts in comparison with the process “Paper”; this is especially true for the fossil resource consumption and pollutant emissions, which are always under 1% of the impacts linked with the paper ticket – independently from the assumptions made.

For the indicators fossil resource consumption and pollutant emissions, the difference between reference and target scenario is directly linked with the utilization of paper ticket, i.e. with the number of target users that uses the new mobile-phone ticket instead of the paper ticket. Therefore, the savings for these indicators are ranged between **no colour** (diffusion of 6%) and a **light-green colour** for all the other diffusion possibilities.

Greenhouse gas emissions

The greenhouse gas emissions are linked to two main factors: On the one hand, they are dependent on the assumptions made about the paper ticket (weight and number needed to realize a round trip), which is used in both scenario since the mobile-phone ticket does not replace entirely the paper ticket. On the other hand, the emissions are dependent on the percent of the population that will use the mobile-phone ticket in the target scenario.

Regarding the assumptions made about the paper ticket and its constitution, it was underlined that the CO_2 emissions are low since there is a CO_2 uptake during trees’ growth. These emissions are even lower if – in both scenarios – the ticket is lighter (three grams instead of five) and if the people are using a daily ticket instead of two unique tickets for the round trip. In this case, the servers in the target scenario are playing a role that is not negligible anymore and the greenhouse gas emissions are superior to the emissions of the reference scenario (1.8% supplementary impacts). Nevertheless, these impacts represent 35.56 kg CO_2-e/day, which is corresponding to one resident-equivalent for the entire MVV-area, and thus, really slight (still no colour attribution). If in both scenarios the paper ticket is heavier (ten grams) and the people use two tickets for the round trip, the servers do not play a role anymore in the whole emissions, and there are slight savings in comparison with the reference scenario (-9%), which still implies no colour attribution.

Regarding the assumptions made about the target users, simulations have been provided with different ratios of population using the mobile-phone ticket. Since the utilization of the mobile-phone ticket and the decrease of utilization of the paper ticket are linked directly with the ratios of population concerned, greenhouse gas emissions decrease proportionally (Figure 4.11).

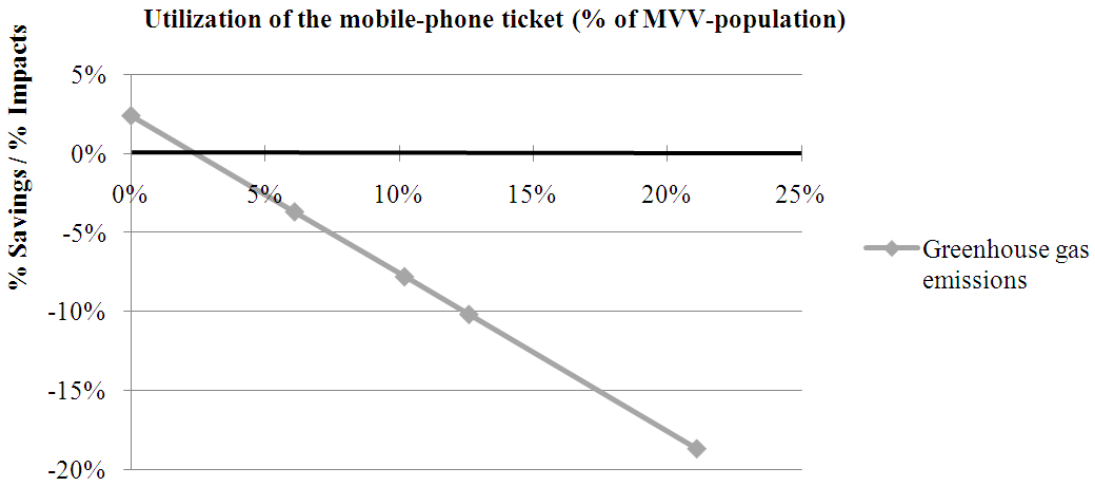


Figure 4.11: Simulation with different diffusion rates and resulting greenhouse gas emissions savings and impacts for the idea “Mobile-phone ticket”

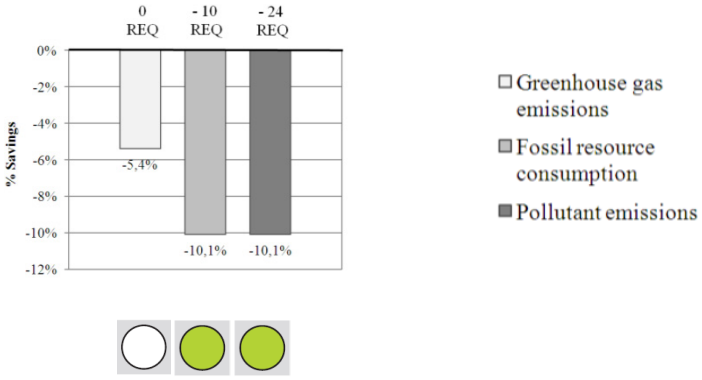
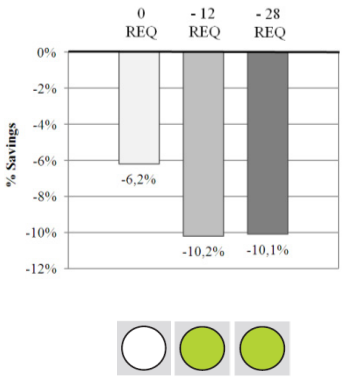
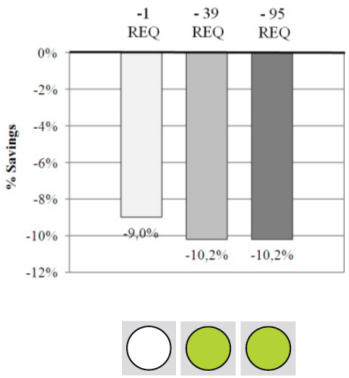
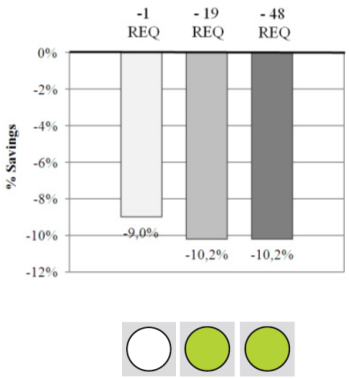
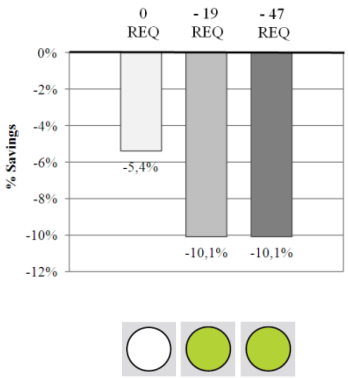
If no public-transport users utilize the new mobile-phone ticket, the emissions are those of the servers and they are 2.4% superior in the target scenario than in the reference scenario. At 2.4% of the MVV-population using the mobile-phone ticket, greenhouse gas emissions are equal in both scenarios. Up to 2.4% utilization, there are savings of greenhouse gas emissions in the target scenario. From 13% utilization, the savings are superior to 10% but still with low resident-equivalents.

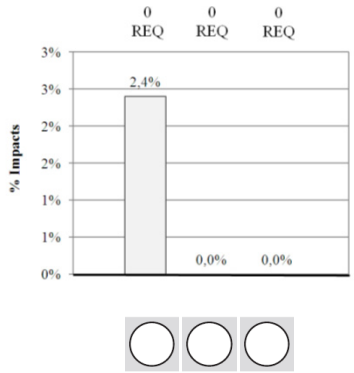
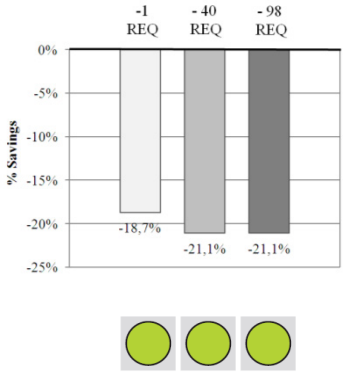
In any case, it is probable that the utilization is superior to 2.4% of the population; therefore, the greenhouse gas emissions are oscillating between **no colour and light-green colour** for the implementation of mobile-phone ticket.

Table 4.11 sums up the analysis of the robustness of the results for the parameters related to the ticket, to the servers and to the demographic restrictions.

Table 4.11: Recapitulation of the analysis of the robustness of the results for the idea “Mobile-phone ticket”

Legend: GHG: Greenhouse gas, COE: Crude Oil Equivalents, PM10: Particle Matter

Parameters	**Results with change of parameters and attributed colour**	
Number of tickets *Attributed colour for the environmental indicators (GHG, COE, PM10)*	One paper ticket for a round-trip 	
Weight of a paper ticket *Attributed colour for the environmental indicators (GHG, COE, PM10)*	3 grams 	10 grams 
Number of servers *Attributed colour for the environmental indicators (GHG, COE, PM10)*	One server 	Four servers 

Parameters	**Results with change of parameters and attributed colour**	
Demographic restrictions	No users of mobile-phone ticket	21% of PT-users switch to mobile-phone ticket
Attributed colour for the environmental indicators (GHG, COE, PM10)		

Social indicators and related modal shift

Concerning the evaluation of the social indicators, the positive aspects regarding the availability of information is counterbalancing with the deterioration of reliability for some users. Therefore, there is no new modal split distribution in the target scenario. However, if one of these two aspects is modified, it generates a new modal split distribution. For example, it is possible to simulate a scenario where **reliability is set to zero** (inducing no colour anymore for the indicator), i.e., there is no lack of familiarity for the user to deal with the mobile-phone ticket.

As described before, the module 'Modal shift calculation' calculates automatically the modal shift depending on the social factors that are affected during the social impacts' inventory analysis (Chapter 3.7.1). Reliability is an important factor for the MVV-target user segments PT-occasional users and PT-potential users, and a relatively important factor for the MIT-captives. Thus, a new modal share distribution occurs and:

- 10% of PT-occasional users become PT-regular users;
- 10% of PT-potential users become PT-occasional;
- 5% of MIT-captives become PT-occasional.

Consequently, an **important decrease** of the environmental impacts is observable in the target scenario. Around 200 tonnes CO_2-e/day, more than 60 tonnes COE/day and 800 kg PM10-e/day are saved in the target scenario, what is more than 6000 resident-equivalents for

greenhouse gas and more than 10000 resident-equivalents for fossil resource consumption and pollutant emissions (**green colour**).

Other simulations with changes of value for the social indicators are technically possible but not realistic.

Conclusions and recommendations

Table 4.12 sums up the results of the consistency and robustness analysis differencing "worst-case" scenario and "best-case" scenario.

Table 4.12: Summing-up of the consistency and robustness analysis for the idea "Mobile-phone ticket"

		Mobile-phone ticket	
Spheres	Indicators	Worst-case scenario	Best-case scenario
Planet	Greenhouse gas emissions		
	Fossil resource consumption		
	Pollutant emissions		
People	Security		
	Information		
	Social acceptance		
	Distance		
	Convenience		
	Costs		
	Time		
Profit	Value for the enterprise		

The results of the difference between the target and the reference scenario are **positive regarding sustainable effects** since there is no red colour and a majority of green and light-green colours for the considered indicators. Moreover, the worst-case scenario combines all the assumptions that lead to a deterioration of the situation, whereas the best-case scenario is correlated with the amelioration of only one indicator: the reliability.

On the environmental side, the **dematerialization of the ticketing system** (immaterial thanks to the mobile phone) leads to a reduction of the paper production, which is – in spite of low greenhouse gas emissions regarding the entire life cycle – energy intensive. That is supported by the analysis of the robustness of the results for a simulation with lower paper consumption that implies a reduction of fossil resource consumption and pollutant emissions. Concerning the greenhouse gas emissions, the idea has only little influence on it since the resident-equivalents are fluctuating between -161 and 4 REQ/day for the diverse simulations on the processes' parameters.

On the social side, two **basic needs** 'availability of information' and 'identity' are positively affected by the implementation of the mobile-phone ticket. A statement about the identity criterion is nevertheless delicate since relatively subjective and it depends on each individual. On the contrary, the mobile-phone ticket **improves globally the perception of availability of information** and does not deteriorate any other basic needs, which is positive regarding the present normative stance about sustainable development. The wants positively affected by the idea (flexibility and preparation time) – even if they are counterbalanced by the deterioration of the reliability – let suppose an acceptance of the product on the market, particularly if the use of the new system is simple enough for the user. Thus, a diffusion of the positive environmental effects can be expected, but it is not possible to take any conclusions about the time needed for it.

Regarding the economic aspects, even if the screening does not focus on it, it is assumed that the high topicality of the thematic 'paper-free ticket' linked with the increasing mobile-service society will lead to **growing expectations** from the users and will encourage the enterprise to invest in this new system.

The analysis of the robustness of the results and the respective simulations have shown that the **positive effects are strongly dependent of the utilization of the new mobile-phone ticket** in the future. Therefore, the assertion that positive sustainable effects will be active only if people utilize the new idea is true in this case. As a result, the enterprise that will implement the mobile-phone ticket is strongly encouraged to develop, on the one hand, a user-friendly product and, on the other hand, efficient marketing actions for a wide diffusion of the idea.

4.4 Real time information

The real-time information began in Germany in 1994 with the transmission of lateness and drive cancellation to central information services (MVV 2007b). In Munich, “dynamic” information – contrarily to “static” information of timetable, for example – was established in 1997 for a tramline as prototype within an European research project Tabasco (Telematics Applications in Bavaria, Scotland and others) (MVV 2007b). The static information delivered by timetable was amended with announcement of traffic disturbances. Since 2003, the Association of German Transport Companies (in German, Verband Deutscher Verkehrsunternehmen – VDV) proposed a recommendation, called VDV 453, to help for a uniform implementation of real-time information within public transport among various transport authorities (VDV 2008). Since 2009, the VDV 454 is used by transportation companies to provide the exchange of real-time data for updating the schedule information with current data (VDV 2009).

In Munich, the government of Upper Bavaria (in German, Oberbayern) encourages the modernisation of real-time information within the suburban train network since 2008 with the project DEFAS (Integrated Electronic Passenger Information System and Schedule Synchronisation, in German “Durchgängige elektronisches Fahrgastinformations- und Anschlusssicherungssystem”) (MVV 2007b).

Beyond the announcement of disturbances, the aim of real-time data is to inform the public-transport users about actual data on the one hand and, on the other hand, to indicate to them new ways to achieve their journey in case of troubles. The system can furthermore indicate the number of available Park & Ride places and the operational status, such as a broken lift in a station, which is important information for handicapped persons.

For the implementation of real-time information, the position of vehicles must be referenced and sent to a data pool. The data-pool system collects, prepares and sends the information to the public transport users through the displays in stations or in internet (VDV 2009). The referencing of vehicles already exists with the MVV and the Deutsche Bahn, but it has posed a problem for the traceability of lateness for the involved transportation companies, which have blocked the transmission of information to a central data pool (Fink 2009). Nevertheless, the Free State of Bavaria ordered that the companies make the data available for the users, without financial sanctions in case of lateness.

The idea is in the framework of the screening since the aim of real-time information is to improve the attractiveness of public transport. Nevertheless, contrarily to the previous ideas,

this idea does not enter in competition with other ideas, since it represents an amelioration of the system and not a replacement of an existing idea. Therefore, a comparison between reference and target scenario is not possible. The screening is used here only to indicate the absolute impacts linked with the implementation of the idea.

4.4.1 Definition of function and functional unit

The purpose of real-time information in public transport is to **inform public-transport users about the current situation** of the following items:

- Actual schedules and prediction time of arrival of buses, trams, suburban trains and metros,
- Operating conditions regarding lifts and escalators,
- Disturbances of the traffic.

The information is visible on displays in the stations and available on the internet.

Since the people are not active with the idea, the impacts cannot be expressed per persons or per trips. There is no functional unit related to the idea, and, therefore, the impacts are expressed per day.

4.4.2 Environmental impacts' inventory analysis

Processes

In the target scenario, servers are required for the management and the monitoring of the information system. These servers are comparable to computers, which are called in the Ecoinvent database "**Use, computer, desktop with LCD monitor, active mode, RER**". The servers run 24 hours a day and three of them are required to fulfil the function (two that calculate and one for the security in case of breakdown) (Hesse 2011).

Excluded processes are the paper placards, which fulfil almost the same function (static information instead of dynamic). The number of these placards could be reduced in the stations, but in a first place, the static information stays identical and the process is not considered within the screening calculation. Concerning the modes of transportation, cars as well as public transport facilities **are present in both scenarios** and are therefore not considered in the screening.

Figure 4.12 represents the system boundary as well as the excluded processes for the idea "Real time information".

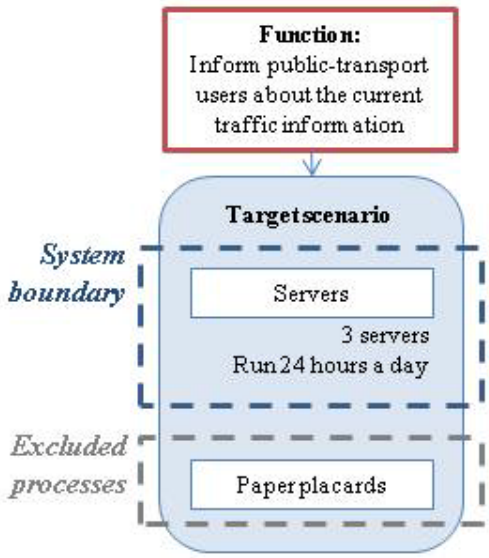


Figure 4.12: System boundary and excluded processes for the idea "Real time information"

Target users

There are no specific target users for the idea since every inhabitant has access to it and is susceptible to using it.

4.4.3 Social impacts' inventory analysis

Relating to the social impacts, the idea improves generally the **quality** (exactitude and actuality) and the **availability** (e.g., on the displays) **of the information** for all the users (++). The **waiting time** is reduced since it is possible to know exactly when the first mode of transport is travelling (i.e., no need to wait at the bus station) or to use an alternative route or mode of transport if a problem occurs during the travel. This sub-indicator is also marked with a double plus (++). The perception of **reliability** on the system thanks to more accurate information, the **flexibility** and the reduction of **preparation time** induced with the possibility to travel spontaneously are also improved for specific situations and are therefore marked with only one plus (+).

The other sub-indicators are not concerned and they are therefore set to zero (Table 4.13).

Table 4.13: Summing-up of the social impacts' inventory analysis for the idea "Mobile-phone ticket"

Social indicators	Sub-indicators	Ranking	Colour attribution
Security	▪ Safety in transport and security of the transport	0	Light green
	▪ Reliability	+	
Information	▪ Availability	++	Green
	▪ Quality	++	
Social acceptance	▪ Identity	0	No colour
	▪ Sustainability awareness	0	
Distance	▪ Accessibility	0	No colour
	▪ Numbers of transitions and barriers	0	
Convenience	▪ Flexibility	+	Light green
	▪ Comfort	0	
Costs	▪ Direct costs for travelling	0	No colour
	▪ Indirect costs	0	
Time	▪ Travel time and waiting time	++	Green
	▪ Preparation time	+	

4.4.4 Economic impacts' inventory analysis

The implementation of the idea is financially promoted by the Free State of Bavaria. Moreover, the costs are divided among the diverse enterprises in charge of public transport. Therefore, the **investment is low** for the enterprise.

On the other side, through the high topicality of real-time information and the positive aspects highlighted in the social analysis, the expectations of the users are high, and it is probable that the attractiveness of public transport is improved, which links to **high earnings** for the enterprise.

4.4.5 Impact assessment

Environmental impact assessment

Relating to the modal split induced with the implementation of the idea, real-time information enhances improvement of important factors for the user segments susceptible to changing their behaviour. Indeed, the improvement of 'availability and quality of

information' and the reduction of 'travel time and waiting time' generate a new modal share distribution and:

- 10% of PT-occasional users become PT-regular users;
- 10% of PT-potential users become PT-occasional;
- 10% of MIT-captives become PT-occasional.

Since the idea does not replace anything but it is **additionally implemented**, it is not possible to compare reference and target scenario as for the previous idea. In the screening tool, the impacts are expressed only for the target scenario in an descriptive way, i.e., in resident-equivalents (Table 4.14).

Table 4.14: Environmental impacts for target scenario of the idea "Real time information" as presented in the screening tool

Target scenario	**Greenhouse gas emissions**	**Fossil resource consumption**	**Pollutant emissions**
In kilograms	-456 236 kg CO_2-e/day	-133 682 kg COE/day	-1 624 kg PM10-e/day
In resident-equivalents	-13 501 REQ	-21 228 REQ	-22 079 REQ

The impacts are due to the new modal share distribution; indeed, the servers are not directly influencing the results.

The attribution of grading colour requires the expression of the results in percent (comparison reference and target scenario) and the expression of the net result of the impacts (in resident-equivalents). Since the comparison of both scenarios is not possible, the grading colour attribution relies only on the descriptive results. Since the impacts for the three environmental indicators are superior to 4000 REQ, a **green colour** is attributed to the three environmental indicators.

In order to obtain a comparison of both scenarios, it is possible to 're-model' the system with the help of the results calculated by the primary assessment. Within the modal-split module of the screening tool, the modal share distributions related to car and public transport are calculated for the reference and target scenarios (Table 4.15).

Table 4.15: Person-kilometre per day for reference and target scenarios for the idea “real time information”

Legend: MIT: Motorized Individual Transport, PT: Public Transport, pkm: person-kilometre

	MIT (pkm/day)	PT (pkm/day)
Reference scenario	67 207 473	16 400 400
Target scenario	64 491 861	17 745 680

Therefore, a new system is modelled (Figure 4.13).

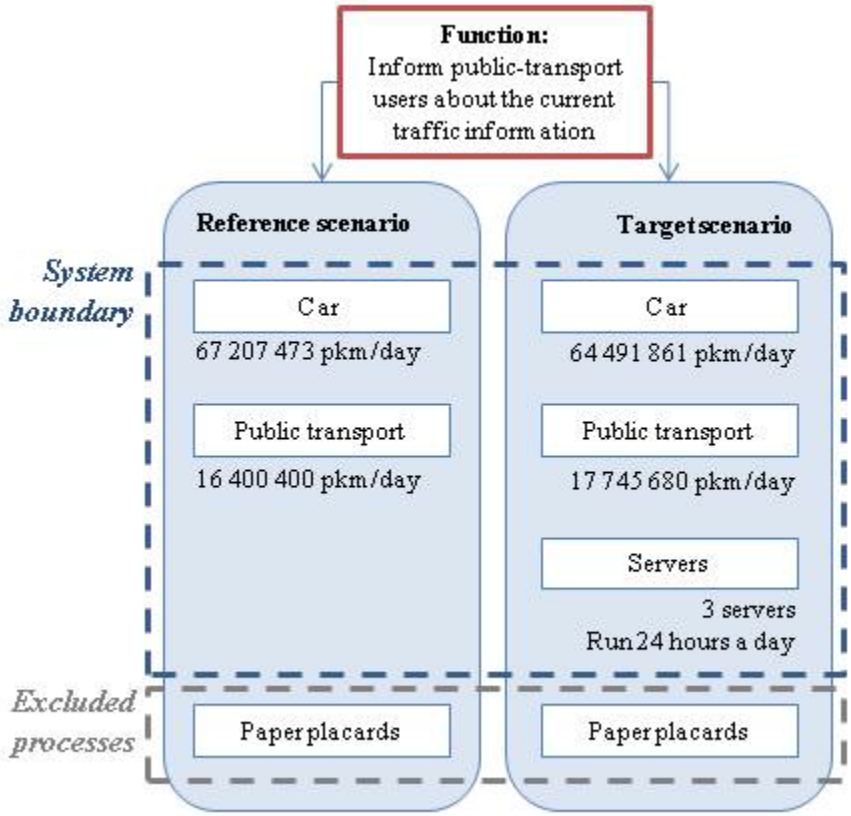


Figure 4.13: Extra modelling of the system boundary and excluded processes for the idea “Real time information”

In this way, it is possible to visualize in the screening the difference for the emissions in the reference and target scenarios (Table 4.16).

Table 4.16: Environmental impacts for reference and target scenario of the idea “Real time information” (extra modelling)

	Greenhouse gas emissions (kg CO_2-e/day)	**Fossil resource consumption (kg COE/day)**	**Pollutant emissions (kg PM10-e/day)**
Reference scenario	12 544 591	3 589 400	51 903
Target scenario	12 088 355	3 455 717	50 279

Thus, it is possible to represent on a graphic the net result of the impacts (in resident-equivalents) and the comparison in percent of reference and target scenario (Figure 4.14).

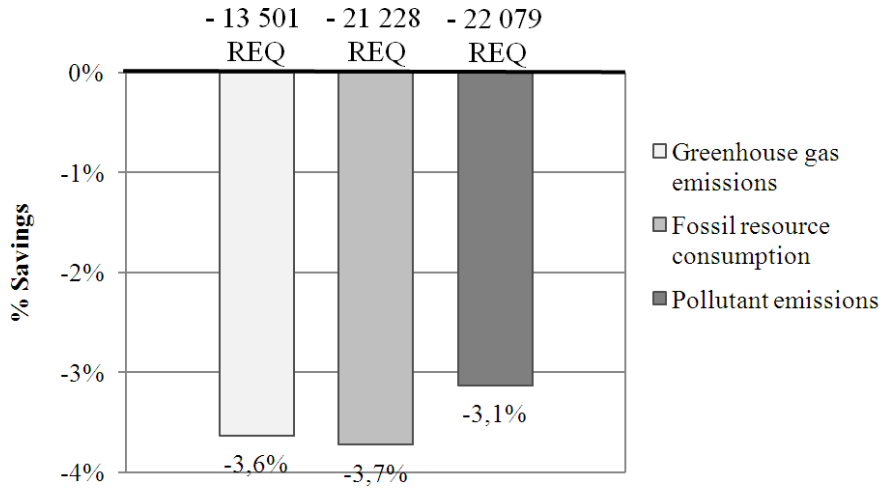


Figure 4.14: Difference in percent between target and reference scenario for the idea “Real time information” (extra modelling)

Still, since the impacts for the three environmental indicators are superior to 4000 REQ, a **green colour** is attributed to the three environmental indicators.

Social impact assessment

Regarding the social impacts, the perception of information and time is explicitly improved for the user, which correspond to a **green colour**. Some sub-indicators of ‘security’ and ‘convenience’ are improved, which corresponds to a **light-green colour**. The other indicators are not modified and are therefore not marked with any colour.

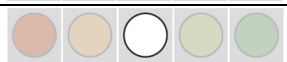
Economic impact assessment

For the enterprise(s) in charge of public transport, low investments and high earnings correspond to a **green colour**.

Recapitulation of the results for real time information

The sustainability evaluation realized with the screening is summed up in Table 4.17.

Table 4.17: Summing-up of the results for the idea “Real time information”

Spheres	Indicators	Real-time information
Planet	Greenhouse gas emissions	
	Fossil resource consumption	
	Pollutant emissions	
People	Security	
	Information	
	Social acceptance	
	Distance	
	Convenience	
	Costs	
	Time	
Profit	Value for the enterprise	

4.4.6 Interpretation of the results

The aim of the interpretation phase is to evaluate the consistency and completeness of the results, to make simulations with other assumptions for the analysis of the robustness of the results and to formulate conclusions and recommendations for the implementation of the idea.

Consistency and completeness

Only one process is included for the evaluation of the idea and it has no influence on the results. Simulations with parameters about the computers are therefore unnecessary.

In a first place, the process of paper placards with static information has been excluded. A simulation is made where the half of the thousand paper placards is moved up since the users have access to dynamic information. After simulation, the emissions linked with the paper are insignificant in comparison with the savings induced by the modal shift and thus, it does not influence the results and the attribution of grading colour.

Robustness of the results

The first supposition was that three servers are needed for the data management. Changing the number of servers is not influencing the results, since – like in the case of paper placard – the impacts are insignificant in comparison with the savings induced by the modal shift.

Concerning the social impact assessment, a simulation is made with an amelioration of the information (quality) only. The other social (sub-)indicators are set to zero. The resulting modal shift is lower than in the initial simulation, but still, the savings are superiors to 4000 resident-equivalents and the grading colour attribution stays unchanged.

Conclusion and recommendations

The idea real-time information is evaluated as **sustainable** with the screening. On the environmental side, the low impacts of the implementation and the savings induced by a probable modal shift show possibilities to reduce emissions of greenhouse gas and pollutant as well as resource consumption. On the social side, information is a central point for the utilization of public transport and the improvement of it leads to more satisfaction of the users. Information merges furthermore a **basic need** (availability of information) and a want (quality of information), which are both improved. For the enterprise, the high topicality of real-time information and the relatively low costs of implementation are good arguments for the implementation and the generalization in all the stations for all the public modes of transport. Virtual services have the advantage to minimize the use of material and their implementation in usual modes of transport, information systems or transaction systems follows the “natural” development of the society.

The idea is comparable to every improvement of infrastructure, for instance, the renewal of metro stations. The users do not interfere with it, but it improves the general impression of public transport and thus, the attractiveness.

The idea could be amended with a new function: Commuters that travel every day on the same way could sign up for free travel alert service and set up personalised SMS alerts and emails warning them of service delays. This function would act like a guardian angel, since the user receives a travel alert before starting the journey, like in Transport of London (Transport_for_London 2011).

4.5 E-Car Sharing and E-Scooter Sharing at public transport stations

During the workshops, participants have wished for their future utilization of public transport the **availability of electric vehicles** at the public transport stations. The idea is similar to running projects of car sharing, for example, in Munich, the project "STATTAUTO" in cooperation with the MVV is running since 1999 with price reduction for PT-users and common marketing actions (StattAuto-München 2010). The Research Centre for Energy Economics (in German, Forschungsstelle für Energiewirtschaft e.V. – FfE) is considering within the project "Leuchtturm E-Mobilität Bayerisches Oberland" (in English, Lighthouse E-Mobility Bavarian Upper Land) the implementation of electro scooters at the proximity of rail stations between Munich and Garmisch-Partenkirchen for commuting persons (Ffe 2010a). In both cases, the aim is to **provide the last kilometres of mobility** – after the use of public transport – with vehicles available for sharing.

The idea is useful for diverse users and in diverse situations. For instance, it is valuable for areas with low density of public transport facilities (i.e., in suburban area), but also as replacement of own vehicle in the city centre where it is difficult to find a parking place. Thus, the idea suits the focus of the screening since, in cooperation with the enterprise in charge of public transport, it fosters the use of public transport and it leads to a reduction of car utilization (MVV 2007b).

In order to respect the idea of the participants, the screening is run for the implementation of E-cars or E-scooters as Car Sharing facilities for public transport users.

4.5.1 Definition of function and functional unit

With the new idea, people have the possibility to **rent an electric car or an electric scooter** for the last kilometres of their mobility with public transport facilities. This rental is comparable to Car Sharing with an annual subscription.

The function to be fulfilled is the travel between two places.

In the reference scenario, people are using their **own car** to achieve their activities.

The reference flow is the persons that travel within the MVV area and the functional unit is therefore **persons/day**.

4.5.2 Environmental impacts' inventory analysis

Processes

In the reference scenario, the only process is "Car", which corresponds in the Ecoinvent database to the process "**Transport, passenger car, RER**". The people are driving the daily average kilometres **(25 kilometres)** per person with Motorized Individual Transport (MIT) in Munich.

In the target scenario, this travel with car is replaced with the utilization of public transport facilities for the daily average kilometres (12 kilometres) per person with MIT in Munich and the rest is achieved with the E-Cars or the E-Scooters of the Car Sharing program. The first process needed in the screening is **Public Transport (aggregation)**, which merges the different ratios of utilization of metro, suburban trains, trams and buses in one process. The second process is **either E-Car or E-scooter for 13 kilometres** per person and per day. These processes are based on data used for the update of the Ecoinvent database v2.2 2010 (Leuenberger & Frischknecht 2010a, b) with the German mix of electricity. In these reports, the energy demand has been calculated for the entire life span of electric vehicles (525 W/pkm for an electric car and 194 W/pkm for an electric scooter).

In a first place, parking places are not considered in the calculation. Indeed, in the city centre, arrangement has to be made with municipalities and firms in order to share parking places (for example in car park). The electric scooters are placed on Park&Ride areas of the public transport stations and therefore, they do not need extra infrastructure (Ffe 2010a).

Furthermore, the installation of the charging infrastructure is not considered since evaluated as negligible. Indeed, the required electricity is paid by the user and the impacts of the installation and the maintenance of the charging machine are considered low.

Figure 4.16 represents the system boundary as well as the excluded processes for the idea "E-Car sharing".

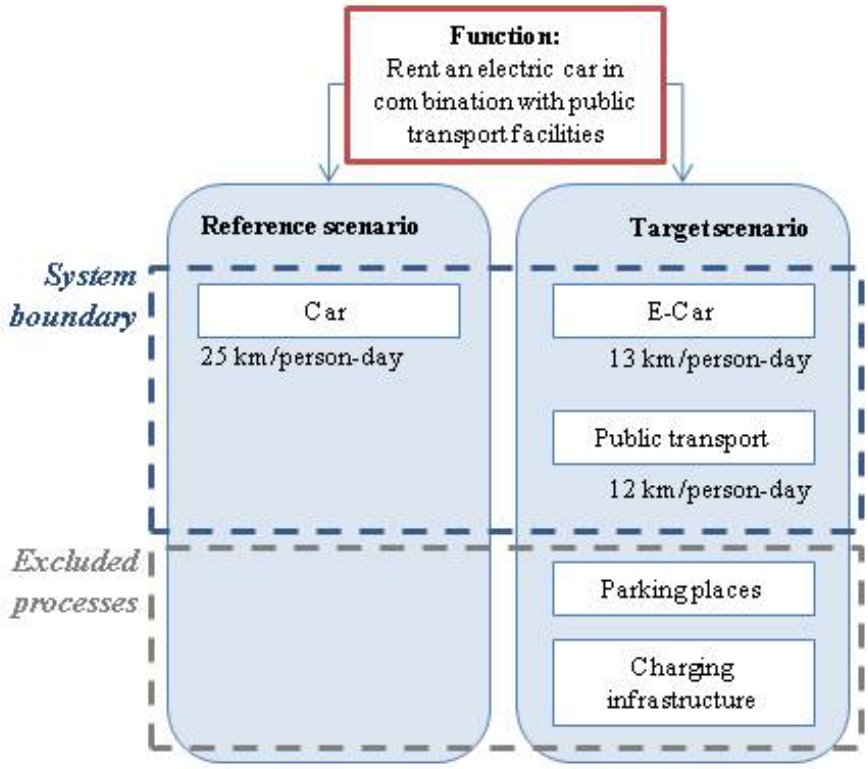


Figure 4.15: System boundary and excluded processes for the idea "E-Car sharing"

Users of reference and target scenarios

For the use of Car Sharing facilities, the user segments are wide. The Car Sharing is often used as second vehicle by private persons for punctual activities like bulk buying (Ffe 2010b). On this basis, the persons concerned with the idea are the persons who have a high share of Motorized Individual Transport (MIT) in their daily mobility. In other terms, it means that the rarely mobile, the cyclists and the PT-captives are not concerned with the implementation of the idea.

To estimate the diffusion of the idea, i.e. how many people change their habits and use the new idea, it is considered in the first place that the idea is attractive for people between 25

and 30 years old. It is indeed supposed that this category is the more receptive to innovation and experience of new concept, like electric mobility (Ffe 2010b). This category represents **8.5% of the population** in MVV area. This consideration is supported with actual data, since in 2002, in spite of the bad economic situation, 8.8% of the population of Munich tried diverse Car Sharing concepts (Landeshaupstadt_München 2003).

The screening is calculating in the background with these entries how many electric cars or electric scooters are needed considering the occupancy of these vehicles (1.6 persons per car and 1.1 persons per scooter).

4.5.3 Social impacts' inventory analysis

For the social impacts' inventory analysis, the focus is on the users that change their habit, i.e. in the present case on the people that are not using their own car anymore but a combination of E-Car or E-Scooter and public transport facilities. Thus, E-Car Sharing is not considered in an absolute way but **comparatively** to the situation that it enters in competition with. In this case, factors that are improved for all the considered users are **indirect costs and sustainability awareness** (++). Indirect costs are lower in comparison with the owning of a car since there are no maintenance costs, no insurance and taxes for Car Sharing. In addition, the **direct costs for travelling** are lower with the utilization of Car Sharing and public transport facilities (regular PT-users get moreover a price discount if they own a season ticket). Since it depends however on the initial utilization of the car and how often it is used, it is characterized in the screening with one plus (+). For instance, for someone that is driving around 15000 km per year with his/her car, the costs are 0.35€/km and with Car Sharing, the costs are 0.14€/km (StattAuto-München 2010). Moreover, the use of electric vehicle instead of combustion engine and public transport facilities is improving the feeling of travelling on an environmentally friendly way (Ffe 2010b).

Comfort is also improved since it is not necessary anymore to maintain the car with tire change and car wash (+). **Identity** is improved (+) since electric mobility, as a new tendency, which is often correlated with new design vehicles, is perceived as an expression of lifestyle (Ffe 2010b).

As negatively perceived factor, **preparation time** is for a switch from the own car to Car Sharing susceptible to being longer since a registration is necessary (-).

Relating to the charging of E-Cars and the autonomy that has a car once charged, a deterioration of reliability is for some cases expected. Nevertheless, this situation concerns

however private E-Cars, and for Car Sharing, since only short distances are covered, 'reliability' is not affected.

The other factors are not modified with the idea and thus, they are set to zero (Table 4.18).

Table 4.18: Summing-up of the social impacts' inventory analysis for the idea "E-Car sharing"

Social indicators	**Sub-indicators**	**Ranking**	**Colour attribution**
Security	▪ Safety in transport and security of the transport	0	No colour
	▪ Reliability	0	
Information	▪ Availability	0	No colour
	▪ Quality	0	
Social acceptance	▪ Identity	+	Green
	▪ Sustainability awareness	++	
Distance	▪ Accessibility	0	No colour
	▪ Numbers of transitions and barriers	0	
Convenience	▪ Flexibility	0	Light green
	▪ Comfort	+	
Costs	▪ Direct costs for travelling	+	Green
	▪ Indirect costs	++	
Time	▪ Travel time and waiting time	0	Yellow
	▪ Preparation time	-	

4.5.4 Economic impacts' inventory analysis

Since the utilization of Car Sharing is mainly made during people's free time, the users are not travelling with public transport during the rush hours. This induces for the MVV that there is no charge related to encumbrance of the vehicles during the rush hours (**low investment**) (MVV 2007b). The other costs are supported by the Car Sharing organisation.

Related to the earnings linked with user acceptance, they are attended to be **high** since many social factors are improved. Moreover, for the enterprise in charge of public transport, cooperation with car sharing organisations induces a better image for the public and politics (VDV 2004).

4.5.5 Impact assessment

Environmental impact assessment

For the E-Car or the E-Scooters, a modal shift is induced since the indicator 'direct costs for travelling' is improved. This factor is an important factor for the user segments PT-occasional and PT-potential (10% switch to the upper segment), and a relative important factor for the MIT-captives (5% switch to the upper segment).

The results of the calculation for the reference scenario and target scenario with the implementation of E-Car Sharing and E-Scooter Sharing are shown in Table 4.19.

Table 4.19: Environmental impacts for reference and target scenario of the idea "E-Car Sharing"

	Greenhouse gas emissions (kg CO_2-e/day)		**Fossil resource consumption (kg COE/day)**		**Pollutant emissions (kg PM10-e/day)**	
Reference scenario	3 824 621		1 102 426		15 145	
	E-Car	E-Scooter	E-Car	E-Scooter	E-Car	E-Scooter
Target scenario	3 702 486	3 431 635	981 406	956 321	13 946	13 418

For the attribution of grading colours, the results are represented in percent (comparison between both scenarios) and in resident-equivalents (Figure 4.16).

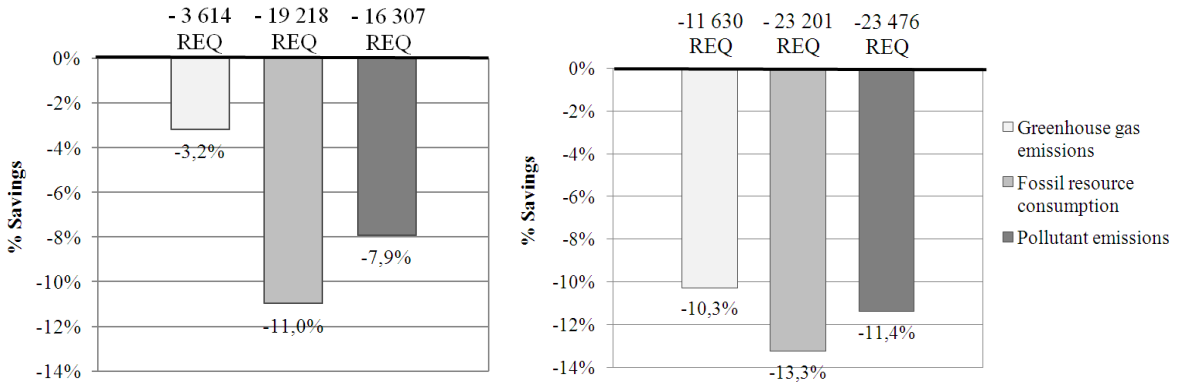


Figure 4.16: Environmental savings and impacts for the idea "E-Car Sharing" and "E-Scooter Sharing"

Relating to the scale previously defined for the colour attribution, the greenhouse gas emissions are characterized with a **light-green colour**, and the fossil resource consumption and the pollutant emissions with a **green colour** for the idea "E-Car Sharing".

For the idea "E-Scooter sharing", the three environmental indicators get **a green colour**. In spite of a lower occupancy of Scooter (1.1 person per scooter) in comparison with Car (1.6 person), the emissions per person are lower for two-wheel vehicles (e.g., half for greenhouse gas emissions).

Social impact assessment

For the social indicators, there is no difference if using an E-Car or an E-Scooter. In both cases, the indicators 'costs' and 'social acceptance' get a **green colour**. Convenience is partly improved and is evaluated with a **light-green colour**. Time is partly deteriorated and it is therefore getting a **yellow colour**. The other indicators are not concerned with the new idea and they have no colour attribution.

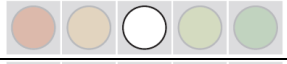
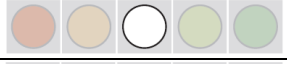
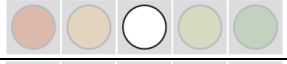
Economic impact assessment

On the one hand, the investment is low and, on the other hand, the earnings are expecting to be high. Value for the enterprise is therefore getting a **green colour**.

Recapitulation of the results for the ideas "E-Car Sharing" and "E-Scooter Sharing"

The sustainability evaluation realized with the screening is summed up in Table 4.20.

Table 4.20: Summing-up of the results for the idea “E-Car Sharing” and “E-Scooter Sharing”

Spheres	Indicators	E-Car	E-Scooter
Planet	Greenhouse gas emissions		
	Fossil resource consumption		
	Pollutant emissions		
People	Security		
	Information		
	Social acceptance		
	Distance		
	Convenience		
	Costs		
	Time		
Profit	Value for the enterprise		

4.5.6 Interpretation of the results

For the phase of interpretation, the diverse assumptions considered in the screening are reviewed and simulations are made to evaluate the robustness of the results, especially in the present case, the validity of the grading colour attribution.

Consistency and completeness

Assumptions about processes and excluded processes

This phase is focusing mostly on the assumptions about the processes. For the calculation of the impacts of E-Cars and E-Scooters, technical information was extracted from reports for the Ecoinvent database v2.2 (2010) (Leuenberger & Frischknecht 2010a), but it was necessary to adapt the situation to a German environment since the production of electricity is different in both countries. As underlined before for the suburban train, the mix use of electricity is emitting much more greenhouse gas in Germany than in Switzerland. This is mainly due to utilization of brown coal and mineral coal in Germany, whereas in Switzerland, hydropower is the biggest contributor to energy demand. Nevertheless, in

Germany, the government is encouraging strongly the utilization of renewable energy and therefore, the emissions are going to be different in few years from now (Bundesregierung 2011).

In the Ecoinvent database 2007, the available electricity mixes are current electricity mixes of several West European countries and the database does not contain mixes for future scenarios. The Bavarian Energy Concept for 2021 (BayStREG 2011), with a share of 50% renewable energy for electricity, would represent an interesting energy scenario to test the ideas. Nevertheless, this energy concept is not inserted within the Ecoinvent database. Therefore, a simulation is made with a different electricity mix in order to observe the changes in the results. The electricity mix of Switzerland has been chosen since the mix is without solid fuels and without gas use. The simulation is made for the E-Cars and the E-Scooters; the rest stays unchanged. The results show higher savings than with German electricity mix for E-cars and E-scooters with around 10% reduction and the resident-equivalents are superior to 10 000 REQ. Thus, it changes only the attribution of the greenhouse gas emissions for the E-Car from light green to **green**.

Concerning the ignored processes, in this case study, the **parking places** required for **Car Sharing** in suburban areas have been ignored in the initial calculation. A simulation is made to see the influence of this supposition on the results. In the screening, the corresponding process is Road referring to the Ecoinvent process “Road, construction and renewal, CH”. For the parking places, 15 metres of road are considered for the 92 suburban stations outside the middle ring road of Munich with a life span of 50 years. It affects the target scenario of 30 tonnes CO_2-e/day more and leads to a diminution of the savings for the greenhouse gas emissions, which are thus **without colour**. The other indicators are still with green colour. Nevertheless, the calculation has been done with the German electricity mix of 2007 and it is probable that the greenhouse gas emissions of the energy supply are going to be reduced in the future. With the Swiss mix of electricity, in spite of the impacts of the road, there are still savings with green colour for the three environmental indicators.

Moreover, for these stations and for the stations in the city centre – independently if E-Cars or E-Scooters are considered – the **charging infrastructure** can also be added to the calculation. In order to keep the procedure simple, it is assumed that the implementation is similar to the installation of computers. The results show that – even with a high amount of computers (e.g., 10000) – the impacts are still **negligible** in comparison with the impacts linked with the transportation system (cars, E-cars, and public transport facilities).

Scenarios definition

In the initial simulation, the reference scenario is that the people are using their own cars. They are travelling 25 km/day. With the implementation of car sharing, public transport facilities are more attractive, therefore, 8.5% of them use for the same distance partly public transport (12 km), partly E-Car Sharing (13 km). The idea E-Car Sharing enters in this case directly in **competition with the private car**. Therefore, the target users are the people with a high share of MIT in their daily mobility.

Beyond the choice of processes, another scenario is now supposed: The idea does not enter in competition with the private car, but it is seen as an **amendment of public transport** (as often quoted in marketing actions, cf. MVV 2010a). Thus, the idea is used for the last kilometres of mobility that are – otherwise – done mainly with the bus.

A simulation is made with the process **Bus** in the reference scenario and the process E-Car in the target scenario, for the same distance (13 km). The target users are the people with a high share of public transport in their daily mobility, i.e., the rarely mobile, the cyclists, the PT-captives, the PT-regular users and the PT-occasional users. The segmentation is the same (people from 25 to 30 years old, i.e., 8.5 % of the population). However, the social impacts' inventory analysis is redone since the comparison is now with the bus instead of with the private car.

In this case, the indicators that are improved for all the users are **'flexibility'** (more independence), **'comfort'** (more privacy and more fun) and **'travel time and waiting time'** (faster mode of transportation and suppression of waiting time for the bus) (++). For some users, **'identity'** (life style) is improved, as well as **'accessibility'** (depending on the location place) (+). Deteriorated factor is **'preparation time'**, similarly to the comparison with the car since a registration is needed (-).

The evaluation of the economic indicators stays unchanged.

Consequently, the modal shift is different from the initial simulation since 'travel time and waiting time' is improved. It is a relative important factors for PT-occasional and PT-potential (5% switch to the upper segment) and an important factor for the MIT-captives (10% switch to the upper segment). The resulting savings and impacts relating to the environmental indicators are similar to the initial simulation (Figure 4.17); nevertheless, the savings of greenhouse gas are negligible and thus **without colour**.

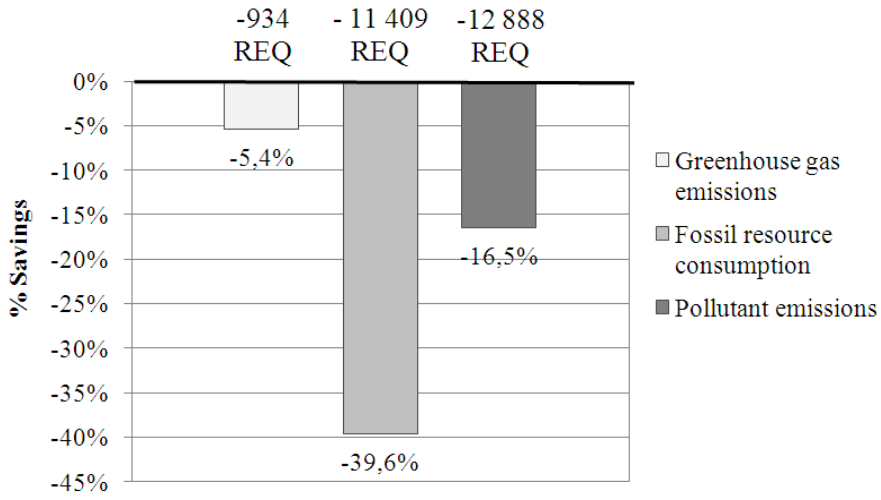


Figure 4.17: Environmental savings and impacts for the idea “E-Car Sharing” (competition with bus)

In absolute, the savings of pollutant emissions are not that high than in the initial scenario since buses are considered and they have higher NOx emissions than cars. The savings of greenhouse gas are – comparatively and in net result – lower in the present simulation since buses have lower GHG emissions than cars. Thus, the resulting colour attribution differs from the initial simulation, especially for the social aspects (Table 4.21).

Table 4.21: Summing-up of the results for the idea “E-Car Sharing” (competition with bus)

Spheres	Indicators	E-Car
Planet	Greenhouse gas emissions	
	Fossil resource consumption	
	Pollutant emissions	
People	Security	
	Information	
	Social acceptance	
	Distance	
	Convenience	
	Costs	
	Time	
Profit	Value for the enterprise	

This simulation shows that the social impacts’ inventory analysis cannot be made in an absolute way and it is necessary to define clearly the two situations to be compared by answering the question: “What is going to be replaced and what are the consequences for the users?”

Robustness of the results

The aim of the analysis of the robustness of the results is to test the robustness of the results in correlation with the assumptions that have been made arbitrarily. In the present case study, the kilometres driven with E-Cars have been fixed arbitrarily, as well as the target users’ selection and the evaluation of social indicators (and resulting modal shift).

Nevertheless, a detailed analysis of the robustness of the results is here not necessary since it follows a simple rule: The more the E-car is driven, the less the savings for the three environmental indicators. This is due to the high impacts of the German electricity mix with data of 2007. If the Swiss mix of electricity is considered, the results and accorded colour are not sensible to change of parameters.

Conclusion and recommendations

The evaluation of the idea “E-Car Sharing” and “E-Scooter Sharing” with the sustainability screening has shown good potential for the idea in matter of sustainability, especially if the vehicles operate on **renewable energy** with low emissions and resource consumptions. This stays anyway in the development program of the city of Munich according to the goals of the Federal Government of Germany relating to Electric Mobility (Bundesregierung 2009). Coined in the adage of Alphonse Allais “we should build the cities in the landscape, because the air is purer there!” (In French, “on devrait construire les villes à la champagne, car l’air y est plus pur!”), the utilization of E-Car without renewable energy is only **moving the problem** from one place (the combustion engines) to another one (the power plant).

Despite the fear of the municipality to induce an increase of the individual mobility in the city (Ffe 2010b), E-Car in form of Car Sharing can be seen as an **amendment to public transport for multimodal mobility**. The idea satisfies different categories of users for diverse reasons and for diverse situations. Beyond the utilization by private persons, the idea can be used by enterprises for their employees for example.

Inevitably, **unintended effects** are expected and they concerned the pedestrian and cyclists that are susceptible to changing also their behaviour by using E-Cars or E-Scooters.

5 Discussion

The discussion is divided between the facts that have been brought to light by the case studies and the more general points about the screening itself that have been found out during the entire development process.

5.1 Case studies discussion

5.1.1 Are ideas that improve the attractiveness of public transport sustainable?

Basic understandings

Relating to the ideas that have been evaluated with the screening, the first finding is that **no idea is revolutionary in term of sustainability**, and the evaluation of the other ideas that have been developed during the workshops leads to the same conclusion (Cornet 2010; Cornet & Weber-Blaschke 2011). Infrastructure projects are expensive and need to be supported by the community or the government. They stress moreover the environment with high landscape utilization and material consumption. The tangential bus line has been modelled without new infrastructure, but it is nonetheless the idea with the higher environmental impacts excluding the modal shift. Considering the idea E-Car Sharing as an electrification of standard Car Sharing concept, it is clear that overall current "fashion" and intense marketing actions from car industry about E-Car (e.g., "Elektro-Smart", "Audi e-tron") have influenced the participants. Electric mobility is otherwise nothing new since, within the public transport sector, metro and tram have operated on electricity in Munich since the 60's. Correlated to the current origin of electricity in Germany (i.e., with a share of around 60% fossil energy (RWE 2010)) electric cars will not make a significant contribution to solve the urgent problems of climate change and resource depletion in a conceivable period (Leipner 2010).

Despite the non-radical impacts on sustainability of the ideas, the screening has highlighted the utility of virtual services within public transport. On the one hand, the **dematerialization of services**, like ticketing or information, is almost without impacts for the environment and associated to low costs for the enterprise. On the other hand, more quality of the services induces a modal shift, which has positive impacts on the environmental side.

In any case, the leitmotif of public transport companies and associated public policies to present themselves as an **environmentally friendly alternative to MIT** in the city (among others Kenworthy & Laube 1996; Land_Berlin 2007; MVV 2007b; Schade 2011) is corroborated by the results of the screening. In dense urban areas, public transport is also described as the only way to improve accessibility comparatively to MIT (Crozet 2009). Indeed, the modal shift from car to public transport is for the evaluated ideas an important – if not the most important – source of savings in matter of environmental aspects.

Green energy necessary

The screening supports the assertion that **energy with a high share of renewable energy (i.e. green energy) is essential** for the implementation of services linked with electric supply. For instance relating to E-Cars, the usage of electric energy from fossil sources (viz. coal, oil and gas) just relocates the fuel tanks and exhaust pipes from the car to power plants – producing roughly the same quantity of emissions somewhere else (BMU 2008). Such an approach would certainly reduce locally generated emissions from some cities. Nevertheless, it causes negative ecological effects somewhere else, which, after all, are equally spread over the world anyway (SRU 2011). Therefore, no matter if we speak about E-Car, suburban train or any other electric supply, their implementation and diffusion needs renewable energy, since it is considered as the only ecologically worthwhile solution (BayStREG 2011; Holden & Høyer 2005; Le_Monde_diplomatique 2009).

Rebound effect

One of the aims of the screening is the early identification of unintended effects. Indeed, ideas for the improvement of attractiveness of public transport are **not *per se* sustainable** since the evaluations of the ideas have shown yellow and red lights. It reveals that – in spite of the will to develop sustainable ideas – the participants have focused on some aspects of sustainability, whereas other aspects have been deteriorated. This could also happen within development division of an enterprise that would focus for instance on the reduction of greenhouse gas emissions since the debate on climate change is taking centre stage (Münzing 2010) on political level since the Kyoto Protocol (UN 1998) and within the public opinion. Therefore, it is necessary to look at the different levels of sustainability (Cornet & Weber-Blaschke 2011) by considering for sure the most “popular” indicators but also the “hidden” ones, like the actual consumption of fossil resources or the social aspects, which

have been until now underestimated by the diverse evaluation methods (see Chapter 1.3 and following point).

The improvement of the attractiveness of public transport can lead to another relevant rebound effect, namely the **global increase of the quantity of travel**. As pointed out with the tangential bus line, the amelioration of public transport facilities can lead to a shift from cyclists and pedestrians to public transport (instead of a shift from private car to public transport). This phenomenon was observed directly in practice in the modal share of the city of Freiburg before and after strong measures in favour of public transport (Schade 2011). This aspect is not considered in the screening since it considers only the shift from car to public transport and no function forecasts the unintended switch from cyclists and pedestrians to public transport facilities.

This phenomenon is explained by the fact that people tend to use what timesaving they do gain to **travel further** (Whitelegg 1993). Even if the travel time budget (i.e., quantity of money and time that people invest to travel) per person is constant, those who are mobile reinvest in travel the time that they save through speed (Crozet 2009) and consequently distance. This leads undeniably to increase of transport, overload of vehicles, congestion, etc. Globally, too much travel is being generated to achieve a certain level of socio-economic benefit or welfare, and this travel results in **higher – environmental – costs** (Givoni & Banister 2010). In fact, the aim of sustainable mobility (and a public transport that integrates it) is not only to improve the efficiency of travel, but also to reduce the quantity of travel (Givoni & Banister 2010). Beyond choice of transportation modes, sustainable products **must replace other products or services** and not increase in general the entire consumption or utilization of services (Cornet & Weber-Blaschke 2011; Paech 2010; Stø et al. 2008). With these considerations, Car Sharing concepts support this understanding since it leads to a renunciation of owning a car. Nevertheless, the screening as a tool focuses mostly on the evaluation of the efficiency of transportation and not directly on the reduction of the quantity of travel.

5.1.2 Choice of indicators

Sustainability indicators: Amount and quality problematic

In every sustainability evaluation methods – and thus for the screening, the choice of indicators is critical (Meadows 1998). Bossel (1999) underlines the difficulty to capture vital aspects of sustainable development with indicators, since they condense the enormous

complexity of the world into a manageable amount of meaningful information, into a small subset of observations informing our decisions and directing our actions. An unintended effect is that if we follow the wrong signals, we get confused or misled, **responding inappropriately**, against our intrinsic interests and intentions, going in a direction in which we do not want to go. Moreover, the choice of indicators is an **expression of values** (Meadows 1998) that can be seen as a **communicative process** (Devuyst 2000) and it always reflects the specific expertise and research interest of their authors (Bossel 1999). They are overly dense in some areas (multiple indicators for essentially the same concern), and sparse or even empty in other important areas. This is visible in the screening, where the number of indicators within the spheres is inevitably non-homogenous, since the environmental and the social spheres have been selected to be at the focus. Here, as well as during the development process of the screening, the question of arbitrariness comes out.

In the screening's scope, it was voluntary to keep the evaluation simple in the use, but also **simple in the comprehension of the results**. Achievement of policies' objectives is facilitated through the use of indicators that have been chosen because they are **meaningful to the public** and reflect an understanding of their values and objectives (Shields et al. 2002). Therefore, the environmental indicators have been limited to three aggregated indicators, namely greenhouse gas consumption, fossil resource consumption and pollutant emissions. Nevertheless, reducing the number of indicators and using only aggregated indicators induce **loosing information** (visible by other assessment methods, for instance by the use of ecological footprint, which is the aggregation of the results in one indicator (Fiala 2008)). For example, it was visible in the case study "Tangential bus line" that pollutant emissions were high for buses but the screening did not show for which pollutants. A closer look in the database revealed that especially nitrogen oxides are higher for buses than for cars. Thus, the utilization of aggregated indicators must be done carefully since it may hide serious deficits in some sectors, which actually threaten the overall health of the system (Bossel 1999).

Planet and People in the foreground

The screening stance regarding sustainability was to consider the "strong" sustainability, i.e. environmental-focussed sustainability, where the planet is in the foreground fixing the boundaries of people actions. This supports the position of the German Advisory Council on the Environment (in German, Umweltrat – SRU) in opposition to a "weak" sustainability, in which every sphere has the same importance (SRU 2002). In the screening, as well as

pointed out by Weber-Blaschke (2009), humanity and its economy is indeed **part of the environment**, which must be preserve as livelihood. Certainly, more indicators for measuring progress toward sustainable development are necessary. Still, the currently available indicators in the screening tool can track progress regarding **social and ecological minimum conditions** for sustainable development (Moran et al. 2008).

Regarding the system in which the screening tool behaves, i.e., urban areas, Camagni et al. (1998) underline that cities are by nature open systems, impacting intensively on other areas and on the earth as a whole. In fact, although a wide part of environmental problems of cities are felt at the local level (pollution, congestion, noise, decay of the visual environment), many effects exist that have a trans-border nature (e.g. waste water flows, waste disposal) or a global one (contribution of traffic and heating emissions to greenhouse effect and global warming) (Camagni et al. 1998). Since the Club of Rome's Limits to Growth (Meadows et al. 1972), global trends have been drawn and economy and ecology have been considered in a greater, overarching perspective, defining ecology as **long-term economy** (Lubbers 2005). Thus, the screening tool, like other impact assessments made for the local level (Devuyst 2000), enables the appraisal of global impacts from local actions.

Environmental indicators

Considering the risk to have an **overlapping of indicators**, greenhouse gas emissions and fossil resource consumption appear often as strongly related. Indeed, most of the time, high fossil resource consumption implies high greenhouse gas emissions. It is true for most of the situations, but in the case of ideas for which paper is used, for instance the idea Mobile-phone ticket, the separation of greenhouse gas emissions and fossil resource consumption have highlighted interesting aspects. Low greenhouse gas emissions do not always mean low fossil resource consumption since, considering the entire life cycle of paper, greenhouse gas emissions are low because of the CO_2-uptake during growth of trees. However, looking at the entire life span, the paper industry has a high consumption of energy, which leads to a disagreement with the sustainability goals in spite of low greenhouse gas emissions.

Social indicators

Even if it is not always the case in many sustainability evaluations (see Chapter 1.3), sustainable indicators must be more than environmental indicators (Meadows 1998). The screening showed a first insight of **potentials** in evaluating social indicators, more precisely needs and wants related to mobility.

Regarding the social impacts' inventory analysis, the case studies have shown that it is important to define what is being compared. Regarding qualitative aspects like needs and wants, it does not make sense to pretend to provide an absolute evaluation of welfare. For example, E-Car Sharing does not present the same advantages depending on which situation it is implemented (e.g., as replacement of the car or bus). Often, in marketing actions, **arguments are mixed up**, for instance for Car Sharing arguing that flexibility, sustainability awareness and costs are improve simultaneously (MVV 2010a), which can lead to confusion for the users.

In addition, from the user perspective, the evaluation is made for the overall journey, considering all the elements that are involved in travelling from the origin to the destination. In most assessments, the weakest part of the journey, or the most difficult one, is often outside the main mode used (e.g. getting to or from the rail station) (Givoni & Banister 2010). Factors implied in mode change, for instance accessibility or comfort, are indeed considered in the screening.

Furthermore, most of the evaluations consider only time and costs as social factors. It is for the category of commuters definitely true that these indicators are the most important one. However, although timesavings provide the principal economic justification for new road schemes, the expansion of the road network and the increase in traffic does not seem to have given people more free time. This is because pedestrian time is not evaluated and because cars are deceptively time-consuming (Whitelegg 1993). Travel time is often perceived as wasted time (Banister 2011) and other aspects like fun or alternative use of the journey are neglected. Indeed, the workshops showed that time and costs are not the only relevant factors for the choice of transportation (MVV-Innovationsworkshops 2009). This assertion is supported by the results of experts' interviews (e.g. White 2010) and it reveals the importance to consider a wide range of social factors.

5.1.3 Exclusivity of the Ecoinvent database

For the ecological part of the screening, the assessment database is the Ecoinvent database used for life cycle assessments. In principle, the application of this database should work for many products and services, as it is currently one of the most reputable and comprehensive data sources. However, as modelling a system depends on the availability of data sets, problems might be entailed with the data acquisition for newly developed systems, as the modelling data will not be available immediately (Kronthaler 2011). Actuality and availability of the databases (and monetary funds for the licenses respectively) are a crucial

point. For instance, for the screening of E-Car, the available database did not contain the required data to model a simplified version of an electric car.

In addition, there is a risk that the evaluation is made only on the basis of data availability. The restriction to some available category leads to one-side results and eventually to wrong decision-making (Weber-Blaschke 2009). The results of a survey about data quality and availability for LCA (Vigon & Jensen 1995) showed that industrial practitioners were most likely to comment on upstream or downstream data as being more of a problem while the consultants, universities and government practitioners lacked manufacturing facility-specific access in many cases. The screening tool, integrated to the enterprise, may be enhanced with data for specific process.

5.2 Screening tool discussion

5.2.1 Screening tool adapted to stakeholders

Is the screening an incomplete evaluation?

There is a point at which complexity for complexity's sake offers only marginal benefits (Graedel & Klee 2002). Users of the screening tool (and those of the results respectively) should keep in mind that they are dealing with a **simplified assessment method**. It is within the responsibility of the screening practitioner to estimate how representative the outcome actually is (Kronthaler 2011). When doing the assessment, care has to be taken, not only to avoid comparing apples with oranges, but also to take a representative range of these apples into consideration. The 'measuring scale' for sustainability of the analysed systems is set with this defined range – contrariwise implying that the 'absolute most sustainable' solution, under certain circumstances, might be omitted from this range. This aspect is illustrated in the screening by the fact that behaviour of cyclists and pedestrians – and especially modification of behaviour – is not taking into account.

Participatory process

For the environmental evaluation, the broad scope of analyzing the complete life cycle of a product can only be achieved at the expense of simplifying other aspects. In this state of affairs, the screening does not replace decision-making but it is **part of the decision-making** process (Cornet et al. 2010). The issues must be prioritised (Hartlin 2011), i.e., the screening

practitioner has the responsibility to allocate a weighting to the environmental, economic and social impacts of the evaluated ideas according to his expectations and goals.

It is, moreover, important to have evaluation methods where indeterminate effects can be placed in a whole-system context of trends, projections, goals and targets, like in the Sustainability Solution Space for Decision-making (SSP) (Wiek & Binder 2005) designed as a concise guideline for sustainable decisions to make decision-makers aware of the synergistic and contradictory effects of their decisions. In surroundings where procedures are missing, whereas staff and financial resources are limited, the screening tool is situated at the interface between two kinds of tools: Those for easy scenario-building within a city or a region, like the Integrated Sustainable Cities Assessment Method (ISCAM) (Ravetz 2000) and those that facilitates communication between stakeholders, like the ecoWheel® management and communication tool (Seidel et al. 2011).

Quantitative and qualitative assessments

As expressed by Guinée (2002) about LCA, an assessment is, as far as possible, quantitative in character; where this is not possible, **qualitative aspects** can – and should – be taken into account, so that as complete a picture as possible is given to the environmental impacts involved. Therefore, the screening did not renounce to evaluate aspects that cannot be quantitatively assessed. Indeed, qualitative approaches to sustainability assessment may already be sufficient in encouraging people to think about and consider more sustainable scenarios to reach their goals (Devuyst 2000). Moreover, the evaluation of social aspects, which are intrinsically qualitative aspects, can be improved with the screening by the application of appropriate **empirical social research methods**, for instance quantitative data acquisition in the form of public surveys (Kesselring 2010; Ravetz 2000; Schnell et al. 2005).

In fact, assessments may begin with a method useful for conceptual understanding. This may be followed by approaches that are more comprehensive and empirical analyses or simulation modelling (Smit & Spaling 1995). In any case, a **mix of methods** is recommended within decision-making (so-called “Toolbox”) (Cornet & Weber-Blaschke 2010; Valdivia et al. 2011).

5.2.2 Objectivity versus subjectivity

Since only one person executes the screening, the results can be influenced because the **subjectivity of the screening practitioner** may interfere during the modelling of reference and target scenarios, as well as during the social impacts inventory analysis. Guinée (2002) highlights the fact that a technically excellent assessment without a transparent and unambiguous report will be of very limited value. All issues should be reported in a transparent way and explicitly.

In addition, the definition of scenarios suffers of subjectivity problem. The screening has a twofold approach: the tool looks **backward** for the definition of the reference scenario and **forward** for the definition of the target scenario. These both aspects are relevant for assessing future sustainability patterns. Even if they can be represented in an objective way, alone retrospective tools are not enough for gauging longer-term sustainability since they have been developed for analyzing the past. Forecasting with prospective tools have been designed for example to help reveal impacts, benefits, risks, vulnerabilities, etc. resulting from some system change at a variety of temporal scales (Ness et al. 2007). Nevertheless, prospective tools have the disadvantage that they are **more subjective** in nature – often making it more difficult for decision makers to accept their credibility.

Also for the colour scale definition, the limit from one colour to the next one has to be validated by the screening practitioner in relation to the goal of the study. Weber-Blaschke (2009) underlines how important it is to choose carefully the evaluation method according to the goal and scope of the study, and to define precisely the system to be studied, among other things **for transparency reasons**. The screening is dealing with this aspect since the reporting modules encourage the screening practitioner to take note of all the decisions he/she makes and this ensures the **transparency of the evaluation process**. This reporting is also relevant if the results of the evaluation are going to be published.

5.2.3 Power-balance among stakeholders: Users, businesses and politics

The screening is at the interface among users, businesses and government. The enterprise provides the evaluation with the screening taking into consideration the users' needs and wants, and thereby, the fulfilment of general interest, which is also supported by politics. In this state of affairs, the challenge for a sustainability evaluation is to **keep powers in balance** (Ravetz 2000). Thus, it is necessary to look at how to ensure a reasonable balance of power in the triangle of individual consumers, government and businesses, where now

business sometimes seems to overpower consumers via advertising, and sometimes has much influence on government via lobbying, election support and so on (Tukker et al. 2008). Indeed, as previously illustrated with the rebound effect linked to behaviour changes of users, the main challenge in the future will probably be on the **consumption side**, and it can be successful only if individuals are mobilized in their roles as both consumers and voters in a bottom-up approach (Stø et al. 2008).

Furthermore, considering sustainable products and services – in the present case for the improvement of public transport attractiveness, they must have more than technological and economic dimensions as usual products, and inevitably **complex political, institutional and cultural dimensions** (Ekins 2010). The myth to think that technology can solve the environmental problem is out-of-date since it is evident that the humanity will never be able to haul up to the level of complexity of the regulations existing in the biosphere (Bourg 1996). On the consumption side, the support of public opinion and the responsibility of individual are essential for accompanying the development of sustainable products (Ekins 2010; Weber-Blaschke 2009). With these considerations, evaluation methods need to be devised that can assess to what extend sustainable products are implemented. Evaluation methods that take the multidimensionality of sustainability as well as the variety of stakeholders into account are especially useful for the field of urban mobility and urban planning since the current sustainability debate is younger than the infrastructure planning (Banister 2011).

5.2.4 Meaning of sustainability

The screening is based on the axioms of sustainability, which allows a reasonable and wide perspective on the examined system – in the sense of the true meaning of the term ‘sustainability’. A fact that cannot be taken for granted, when looking at examples from common practice, where the term is sometimes used for marketing reasons (Belz & Pattie 2009). Indeed, the term ‘sustainability’ recently has a **high marketing potential** – with the mobility and transport sector not being an exception (Grober 2010a, b; Kronthaler 2011).

The term sustainability and its definition occupy fields of actions as numerous as diverse. From philosophical debates to industrial applications, there is still **no consensus** of what is sustainability (Graedel & Klee 2002). Moreover, sustainability as a practical definition is surrounded with assumptions and value judgements (Ravetz 2000). Economists define economy as the instrument of humanity to deal with the resource shortage and the satisfaction of all its needs (Musolino 1997), which remains the definition of sustainability

of the Brundtland report. For Tukker (2008), reflexion about sustainability leads to a debate on the **meaning of life** and the question of what production and consumption should deliver for humanity. Should sustainable products enhance the quality of life in a hedonic sense, and hence "satisfaction" or "happiness"? Or should it provide spiritual growth? Regarding the quality of life, people will not give up what they already have (Banister 2011) and especially for public transport systems: people tend not to notice when things are working better (Fink 2009), but only when something is getting worse (MVV-Innovationsworkshops 2009). With these considerations, the screening practitioner is responsible for fixing the boundaries of what is necessary from what is superfluous considering sustainability. It shows that sustainability is very hard to operationalize or to interpret when it comes to actual planning, development and governance of the transport system (Givoni & Banister 2010).

5.2.5 Urgent need for solutions

Sustainability and its assessment is a highly inter-linked and cross-connected topic – with ecological impacts influencing the social sphere and having certain economic effects and reciprocally (Ravetz 2000). Analysing – not to speak of finding and recuperating – a sustainable balance among every single influence of a considered product or service is virtually impossible. However, the screening is not designed for being a panacea. Considering on the one hand the vast variety of products and services, which ought to be analysed for their ecological, social and economic effects, and on the other hand, the ticking clock of global challenges, it makes clear that a feasible and pragmatic method has to be used in order to make a determined progress (Herrmann et al. 2010; Meadows 1998).

On the order of magnitude scale, even the simple sustainability measurements herein provide guidance toward reasonable targets to achieve more sustainable ends (Graedel & Klee 2002).

Even if one concludes that the creation of a set of meaningful and simple Indicators for Sustainable Production (ISP), applicable to any organization, is not possible, the exercise of trying to do so is not in vain. The very fact of focusing on the issue heightens companies' awareness about sustainable production, promotes organizational learning and improved measurement practices (Cornet et al. 2009; Veleva & Ellenbecker 2001).

6 Conclusion

The sustainability screening gives a first insight about positive and negative effects of products, services or infrastructure projects in the field of public transport on sustainability. The significance of the **screening tool is twofold** since it evaluates on the one hand the **direct impacts** of an idea on the environment, the economy and for people, and, on the other hand, it evaluates the **indirect impacts** linked to a new modal split distribution. It provides therefore a helpful tool within the decision-making process in order, for instance, to identify among diverse ideas or diverse variants of an idea, the one with the best sustainability potential. In other words, the screening provides a **'pre-feasibility' study** with the early identification of unintended side effects of products and services.

It has been shown that a sustainability assessment is not necessary complicated, since the screening tool can be used by a non LCA-expert in a simple and fast way. Consequently, the results of the screening reveal an order of magnitude with a grading colour system that helps for drawing conclusions and for the comparison of the ideas. The sustainability indicators cover the main issues of the problematic of sustainable development on a local level, considering the people (more specifically, the public transport users) at the centre of the evaluation and the planet as boundary. The pros and cons of the screening have been identified thanks to case studies in which four ideas designed to improve the attractiveness of public transport have been evaluated.

6.1 Ideas to be evaluated and methodology of the screening tool

Regarding the products that can be evaluated with the screening, a **low level of detail** is acceptable for the modelling. Reporting throughout the modelling ensures **transparency** for the assumptions that are taken for the scenarios definition.

In its utilization, the screening is **simple and highly flexible**. Contrarily to other methods in which the focus is on precise results, the particularity of the screening is the revelation of order of magnitude for diverse scenarios and the possibility to "play" with the tool in order to realize with only few clicks sensitivity analyses. This provides **overview** about cause-effects relationships and supports decision-making processes. Indeed, the flexible arrangement of data **highlights strong and weak points** of the idea that is evaluated, and helps for **developing specific implementations** with the highest utility for all the stakeholders – and by extension for sustainability.

From infrastructure projects to virtual services, the range of products and services that can be evaluated with the screening is **wide**. The screening is also suitable for ideas that are not directly used by public transport users, like information or renewal of stations.

Relating to the validity of the results of the environmental impacts, the screening does not give precise results but rather **order of magnitude**. Still, these results give an **descriptive insight** about the impacts of the idea on the environment in kilograms, which can be compared with other studies when the assumptions considered are similar. The conversion in resident-equivalents provides a **better understanding** of the impact within the environmental sphere. Moreover, a **comparative representation** of the results in percent supports the decision-making by answering the question: "Is the idea improving the current situation or is it deteriorating it?" A grading colour system has been developed with a colour scale. It merges descriptive and comparative results and provides a summary of the assessment **at a glance**.

6.2 Sustainability indicators for urban mobility

Respecting a system approach, indicators have been developed by analysing the system urban mobility and the interactions of its variables. The indicators cover the **main issues** of the system 'urban mobility' and of current sustainability discussions.

The strong sustainability stance has been used and the indicators reflect the fact that the planet fixes the boundaries, the people behave within and the economy is an instrument for the management of activities. Since the evaluation is done by the enterprise, which is in the best position to evaluate the validity of the idea in adequacy with its economic goals, the economic aspect has not been at the focus of the indicator set.

6.3 Actors of the sustainability evaluation

The screening has been developed to assist enterprises in charge of public transport (or enterprises working with such enterprises) during decision-making process. It can help for instance for the identification of obstacles. Within a business environment, the screening is valuable since it is **fast**, what means for the enterprise, that is **not expensive**. Furthermore, the screening can be used by **non-LCA expert**, which is also synonym of costs savings for the enterprise.

The screening is an **integrated assessment** method since the enterprise does not only receive the evaluation but it is provided by the enterprise itself. It ensures the quality of the data and thus the validity of the results. Furthermore, it suits the definition of sustainability as **participatory process** with the opportunity to **educate stakeholders** and shape their views about the causes-and-effects relationships within the environmental sphere but also about needs and wants of the user.

Beyond the use on a project basis, the scope of the screening can also be widened by using it rather as a **management tool** on a more continuous basis (i.e., ongoing monitoring of the management process, benchmarking). Combined with other tools (e.g., Life Cycle Costs Analysis), the screening can be a valuable component in a set of sustainability instruments, which offers further opportunities for different types of analyses for long-term goal.

6.4 Case studies to test the screening tool

In order to identify the pros and cons of the screening tool, case studies have been run. The case studies were based on ideas that have been developed by public transport users of the city of Munich. Therefore, the screening tool contains demographic and statistical data for Munich, which may be adapted for the application to other West European cities.

Four ideas have been selected to show the flexibility of the screening tool, and more precisely, to proof that the screening tool is appropriate doe the evaluation of a wide range of ideas for the topic of urban mobility. From infrastructure projects to virtual services, ideas have been considered that are more or less innovative, in competition with existing products or not. Thus, a tangential bus line that drives all around Munich has been assessed as sustainable idea if particle filters are used for the buses. Running the screening tool for the idea “Tangential bus line” showed that it is possible to **identify the best implementation** of the idea, in this case a shuttle bus with lower frequency and higher occupancy. The second idea, “Mobile-phone ticket”, highlighted the importance of the dematerialization of the ticketing system and that the **positive sustainable effects** of an idea happen only if the idea is widely used by the public transport users. The idea “Real-time information” brought out the **flexibility** of the screening, since it was possible to evaluate an idea without the comparison with other ideas. For the last idea, the screening tool was used to compare “E-Car sharing for public transport”, on the one hand with private car, and on the other hand, with bus. It gave the opportunity to highlight the **practicality** of the screening.

Therefore, the four case studies have been considered as sufficient to test the screening tool, and to assume that it can be run for all various subtopics of urban mobility.

6.5 Recommendations for further development and transferability

Further developments are useful to make the screening more reliable and efficient. For instance, the **scope of utilization** could be extended. The screening has been modelled only for products that have a correlation with public transport. A further development could be to enlarge the scope to every modes of transport in order to provide a more realistic assessment, which reflects the actual multimodal urban mobility. For instance, a stronger integration of cyclists and pedestrians could reveal the actual mobility behaviours in the city. The enhancement of the Ecoinvent database, for instance with additional energy mixes, as well as supplementary demographic and statistical data for other cities than Munich, could make the screening tool usable for any West European cities for a long-term perspective.

Additional environmental indicators, for example land use or noise, could divulge aspects (e.g., savings or impacts) that are otherwise not visible in the screening. Nevertheless, increase the number of indicators must be done with caution in order to avoid the overwhelming of data and information.

Relating to the social indicators, a differentiation in the results between the basic needs and the wants would help for a **weighting of the results**, which is tacitly let for the moment – and for all the indicators – to the screening practitioner.

Regarding the social assessment, the evaluation is made by the screening practitioner with an information support about the most common user behaviours. Nevertheless, this evaluation suffers of a **lack of representativeness** since only one person is making the evaluation. The social screening in this respect could be improved by the application of appropriate **empirical social research methods**, for instance quantitative data acquisition in the form of public surveys.

More generally, sustainability evaluation should get more integration in transport policy and practice. From the vantage point of customers, the screening could be used by policy makers or even independent trusts or NGOs as a feasible method for quick and effective analysis of particular products or services, thus increasing transparency. In fact, it is complicated for the individual consumer to grasp the effects of his/her choice of transportation modes. Finally, a potential transferability of the screening could happen by the integration of the user within the evaluation process. The last step would lead to the **institutionalisation** of the screening

as a flexible instrument for valuation of products and services at the regional level and possibly at a national level available for the stakeholders of sustainable development (businesses, individual consumer and government). A **standardization** of the evaluation process would finally solve the problem of arbitrariness posed by the screening. Concerning the **transferability**, the tool can be easily adapted to other public transport systems in other cities. The database should be completed with primary data about the demographic situation and the actual modal share of the city.

7 Summary

Introduction and objectives

The present study is at the crossing point of two topical issues, namely sustainability evaluation on the one hand, and urban mobility on the other hand. The numerous stakeholders involved and the lack of agreement about the definition of problems make these issues complex to analyze (Chapter 1.2).

For the study, the normative stance relating to sustainable development has been to consider a strong sustainability, where the environment aspect gets more attention since it is the foundation and the boundary of every kind of development in our society. The people are in the foreground with the planet as boundary. Economic aspects are not at the focus.

Relating to urban mobility, it has been identified as the blood system of society. The development of urban mobility has for consequences a high share of motorized individual transport in the city. Consequently, problems occur, for instance, traffic jam, land use, traffic fatalities and injuries, noise, air pollution and petroleum dependence. This development led to irreversible negative mobility impacts and measures have been necessary to slow down this evolution. Among others, pull measures from local authorities and enterprise in charge of public transport encourage the individual consumers to change their mobility behaviour. An example of pull measure is the improvement of the attractiveness of public transport in order to incite people to switch from their private car to public transportation.

The study focused on this very topic, and more precisely on the development of ideas (products and services, innovative or not) that have been designed in order to improve the attractiveness of public transport.

In the hand of the enterprise in charge of public transport, a method – and by extension, a tool – that assesses quickly and simultaneously, on the one hand, the sustainability impacts of ideas and on the other hand, the resulted modal shift, is still missing.

The aim of the study was to identify if ideas to improve the attractiveness of public transport are indeed sustainable and if they lead to a modal shift. To answer this question, a tool has been developed. This tool is a screening, which is integrated, e.g., within the enterprise in charge of public transport and provides the sustainability assessment of ideas to improve the attractiveness of public transport and calculates potential modal shift from private car to public transport facilities. The screening (as tool) affords an assistance for decision-making

by identifying potentialities as well as unintended effects of diverse ideas (Chapter 1.3). The screening is essential as 'pre-feasibility' study. It helps for instance to identify the best conditions to develop the idea in a sustainable way or to choose among numerous ideas the one with the best potential.

Development of the tool

The screening tool has been developed based on LCA methodology with goal and scope definition, inventory analyses, impact assessment and interpretation of the results. Nevertheless, the screening tool has been adapted to the present topic area (urban mobility) and it took into account the expectations of the screening practitioner (i.e., the enterprise in charge of public transport) (Chapter 2.1). For that purpose, the system 'urban mobility' has been analyzed thanks to the Sensitivity Analysis from Vester (2002) for complex systems. The variables of the system have been identified as well as the interactions that exist among these variables thanks to a matrix of influences (Chapter 2.4).

Relating to the output of the screening, a selection of sustainability indicators has been made to reflect the both issues under study, namely sustainability and urban mobility (Chapter 2.5). For the environmental aspect, three aggregated indicators have been selected: Greenhouse gas emissions, fossil resource consumption and pollutant emissions. For the social aspect, user needs and wants have been identified and merged. For the economic aspect, the financial value of the idea for the enterprise that implements the idea is put in correlation with the earnings linked with the user acceptance of the idea.

Modules of the screening

The chapter 3 is entirely dedicated to the description of the modules of the screening tool. The tool has been conceptualized with diverse modules (Chapter 3.1). The database has been set up on the basis of the Ecoinvent database (v2.2 2007) and there has been no generation of primary data.

These modules have been modelled in preparation for the case studies that were run in Munich under a spreadsheet application (Microsoft Excel) with general data for Western Europe and specific data for the city of Munich (e.g., regarding demographic data). The specificity of the screening tool is to combine modules with quantitative assessments, modules with qualitative assessments and an extra module for the assessment of the modal shift correlated with people behaviour.

For the environmental impacts' inventory analysis (Chapter 3.3), the screening practitioner has the possibility to select processes and reference flows in order to describe two scenarios: The reference scenario, in which the idea does not exist, and the target scenario, in which the idea is implemented. This process is made with assumptions and cut-off rules that must be reported in order to ensure transparency to the evaluation. Next, if the processes are dependent on the number of people that will use the idea (i.e., target users), these target users are selected in order to quantify the impacts. To refine this quantification, it is possible to make a segmentation thanks to predefined public transport user segments (that differentiate for example public transport regular users from car-captive users) or/and thanks to socio-demographic segments based on age, gender and place of living (Chapter 3.4).

For the social impacts' inventory analysis, the user perception is assessed based on the qualitative evaluation of needs and wants previously selected (Chapter 3.5). For this assessment, additional information about the most common behaviours within the public transport is furnished to the screening practitioner.

The economic impacts' inventory analysis (Chapter 0) is not at the focus of the evaluation. Nevertheless, a qualitative evaluation enables to estimate the value for the enterprise. The earnings linked with the user acceptance are deducted from the previous assessment of the user perception.

Within the screening tool, an automatic module provides the modal split calculation (Chapter 3.7), which reflects the switch of the users (i.e., the individual consumers that use the idea once implemented) from their private car to public transport. This calculation depends on the target users and the user perception. Moreover, the quantification is based on portfolios of actions developed by the enterprise in charge of public transport in Munich (MVV).

Concerning the environmental impacts, the results are normalized and expressed under a descriptive reference: the resident-equivalents, which express the impacts equivalent of the impact of one person for one day. The results are moreover expressed in percent in order to compare the reference scenario with the target scenario. With these both representations, a grading colour is attributed to each indicator (from green for savings, until red for impacts) and it provides an overview of improvement or deterioration of the situation at a glance. Grading colours are also applied for the social and economic spheres considering if the idea supports or restrains the indicator that is evaluated.

Case studies

Case studies have been provided to test the screening tool and to highlight its advantages and the aspects that still can be improved (Chapter 4). These case studies have been run for ideas that could be implemented in the city of Munich.

Ideas have been gathered from user integration (Chapter 4.1). The user integration was performed in a series of two-day workshops supported by industrial partners. In Munich, the industrial partner was the enterprise in charge of public transport: the Munich Transportation and Tariff Association (in German, Münchner Verkehrs- und Tarifverbund – MVV). During the two workshops that have been organized with the MVV, the participants were asked to developed ideas in the field of 'sustainable mobility' using their daily experience with transportation in Munich. A panel of ideas have been selected to test the screening and specified with the help of expert interviews. In order to apprehend the potential of the screening, infrastructures projects as well as virtual services (e.g. relating to information) have been evaluated. Some of the ideas were innovative, whereas others were traditional. The scenarios were furthermore different since some of the ideas entered directly in competition with existing ideas and others were additionally implemented.

The first idea was a tangential bus line (Chapter 4.2) that connects the suburban train stations all around the suburban area of Munich. The screening identified savings for greenhouse gas emissions and fossil resource consumption, but impacts for pollutant emissions. Particle filters could solve this problem. Simulations with diverse occupancy rates and diverse diffusion ratios showed that a shuttle bus that is driving only few time per day, but with a high occupancy (superior to fourteen persons per bus) would increase the sustainability potential of the idea. Nevertheless, the screening considered only the switch from car to public transport and unintended effects on sustainability could occur if pedestrians and cyclists would change their mobility behaviour and switch to the new idea.

The evaluation of idea 'mobile-phone ticket' (Chapter 4.3) showed almost no environmental savings or impacts since the acceptance of the user has been evaluated to low to lead to a new modal share distribution. Interesting is foremost the dematerialization of the ticketing system (immaterial thanks to the mobile phone since it is supposed that mobile phone are not needed extra for this purpose) which leads to a reduction of the paper production. The analysis of the robustness of the results and the respective simulations have shown that the positive effects are strongly dependent of the utilization of the new mobile-phone ticket in

the future. As a result, the enterprise should develop, on the one hand, a user-friendly product and, on the other hand, efficient marketing actions for a wide diffusion of the idea.

Even if the idea 'real-time information' (Chapter 4.4) did not enter in competition with other products or services, it was possible to evaluate in an descriptive way the savings and impacts of the idea, and the related modal shift. The screening revealed the high potentialities of the idea for the improvement of the attractiveness of public transport thanks to an environmentally neutral idea. Moreover, the idea improves the information, which is a basic need within the set of indicators of the screening.

The ideas E-Car sharing and E-Scooter sharing (Chapter 4.5) have been evaluated and they have shown that they could support sustainable development in the city as amendment to public transport. Nevertheless, the screening has demonstrated that the implementation of these ideas only make sense if the energy used for the vehicles is from renewable sources. Furthermore, relating to the screening itself and especially concerning the social evaluation, the practitioner has to define clearly what the idea replaces, i.e., with which existing idea the new idea is being compared.

Discussion

The first part of the discussion concerned the case studies (Chapter 5.1). The results of the case studies have shown that even if there is agreement that public transport is a friendly alternative to car in the city, the sustainability of the idea to improve the attractiveness of the public transport is not obvious and need to be assessed. Unintended effects occur and lead to a global increase of travel, visible for instance with the augmentation of distances. Therefore, new idea must replace existing products and services.

Relating to the choice of indicators, the case studies showed that aggregation of indicators is sometimes critical since information can get lost. This aggregation is nevertheless necessary to keep simple the comprehension of the results. At last, the case studies have demonstrated how important it is to consider a wide range of social factors, and not only to focus on the environment aspect.

The second part of the discussion dealt with the screening tool itself (Chapter 5.2). As its name indicates, the screening does not provide a detailed sustainability evaluation and it is inevitable that it does not consider every aspects of sustainability. Nevertheless, the tool is flexible enough to be tuned and improved by empirical social research methods, for instance quantitative data acquisition in the form of public surveys.

Another open point for the screening is the lack of subjectivity that occurs during the evaluation since it is run by only one person. However, a high transparency in the process helps to deal with this aspect.

One of the biggest challenge for sustainability evaluation, and therefore for the screening, is to keep powers in balance. Studies confirm the importance to consider the user at the centre, as in the screening.

Back on the definition of the issue 'sustainable development', the evaluation of sustainability is finally referring to the meaning of life and the question of what production and consumption should deliver for humanity. The difficulty to differentiate on an objective way what the necessary from the superfluous shows how hard it is to operationalize sustainability.

In any case, studies have already demonstrated that it is urgent to have something, namely a feasible and pragmatic method in order to make a determined progress taking into account the ticking clock of global challenges.

Conclusion

To conclude (Chapter 6.1 to 6.4), the sustainability screening gives a first insight about positive and negative effects of ideas (products, services or infrastructure projects described in a low level of detail) in the field of public transport about sustainability and about a potential modal shift. It provides therefore a helpful new possibility within the decision-making process for enterprises and urban planning stakeholders in order, for instance, to identify between diverse ideas or diverse variants of an idea, the one with the best sustainability potential. In other words, the screening provides a "pre-feasibility" study with the early identification of unintended side effects of products and services.

As recommendation (Chapter 6.5), the screening could be amended regarding the social evaluation with empirical social research methods. Institutionalization and standardization of the tool would lead to a transparent way for enterprises to evaluate their actions respecting general interest and specific concern of individual consumer. To transfer the tool to other public transport systems in other cities, the database should be completed with primary data about the demographic situation and the actual modal share of the city.

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Annexes

A List of abbreviations

COE	Crude oil equivalents
CO_2-e	Carbon dioxide equivalents
GHG	Greenhouse gas
LCA	Life Cycle Assessment
MIT	Motorized Individual Transport
MVV	Munich Transport Network Association, in German, Münchner Verkehrsverbund
Pkm	Person-kilometre(s)
PM10-e	Particle Matter (<=10 µm) equivalents
PT	Public Transport
SME	Small and Medium-sized Enterprise

B Glossary

Term	Definition	Reference
Diffusion	Used in the field of innovation development, the diffusion of an idea is the spreading of this idea through a market.	Beck et al. 2009; Belz & Pattie 2009
Emission	Emission is a delivery of material and energy from a source to the environment.	Weber-Blaschke 2009
Idea	In the thesis, an idea represents a product or a service. It can be innovative or rather traditional.	Chapter 1.2.5
Individual consumer	A consumer is someone who can make the decision whether or not to purchase a product or a service (e.g. mobility service). Individual refers to one person rather than to a large group.	Chapter 1.2.2
Modal shift	A modal shift (i.e., new distribution of modal split) is induced when people change their mobility behaviour. In the screening, the focus is on modal shift from private car to public transport facilities.	Chapter 3.7.1
Modal split (synonym to modal share)	It is a ratio that represents the choice of mode of transportation per trip for a population. It is divided into Motorized Individual Transport, Public transport, walking and cycling.	MVV 2007b
Resource	In the thesis, the narrower sense of resource is used. It merges the natural capital, raw material and energy source. Renewable and non-renewable resources are differentiated.	Weber-Blaschke 2009
Scenario	Projection of a situation in the future based on certain assumptions and factors. Scenarios are used in estimating the probable effects of one or more variables. In the thesis, the reference scenario is distinguished from the target scenario	Chapter 3.2 and Ness et al. 2007

Term	Definition	Reference
	(situation in the present without the idea and situation in the nearby future with the idea).	
Screening	From 'to screen', in the sense of 'to check', the screening is evaluating a large number of items in a short term. In the thesis, 'the screening', i.e. the model that has been developed, is synonym for 'sustainability screening'.	Chapter 2
Sustainability	In the thesis, sustainability is associated to the definition of Sustainable Development from the Brundtland report "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The stance within the thesis is to support a strong sustainability, in which the environmental aspect is central.	Chapter 1.2.3 and WCED 1987
Sustainable product	It refers to a product that have been designed and manufactured in compliance with sustainability principles.	Chapter 1.2.5
System	A system is a set of interrelated objects (elements, parts). It fulfils a certain function and it has a characteristic constellation of elements. It has system boundaries that separate the system from the rest of the world, as well as state and behaviour variables.	Chapter 2.4 and Bossel 1994
Travel Time Budget	It represents the quantity of money and time that people invest to travel.	Crozet 2009
Urban mobility	Urban mobility merges the issues of transport and traffic in the city. In the thesis, only transport of person is considered.	Chapter 1.2.4
User	The user represents the individual consumer who travels with public transport and therefore utilizes the idea.	Chapter 1.2.2

C Index of figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

D Index of tables

Chapter 1

Chapter 2

Chapter 3

Chapter 4

E Screening tool (Beta Version)

The screening tool has been developed under the spreadsheet application Microsoft Excel 2007. The version presented in this thesis is a beta version that constitutes the scientific background (i.e., data for the case study and calculations) that can be used for a future development of the tool. In preparation of a potential commercialization, the screening tool needs to be developed in cooperation with software engineers in order to make the interface more user-friendly.