SUNSET

Sustainable Social Network Services for Transport

www.sunset-project.eu

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Evaluation methodology and measurement approach

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Summary

This deliverable reports the SUNSET evaluation methodology to be used in assessing the success of the SUNSET system in achieving the SUNSET objectives, which broadly relate to Congestion, Safety, Environment and Well-being. The evaluation methodology has been developed in two stages, the first stage being reported within D6.1 and covering a) key indicators for the evaluation of operational success and b) an analysis approach for the effectiveness of incentives in the SUNSET system. This deliverable derives the final set of indicators (a Cost Benefit Analysis, Safety indicators, Sustainability and Wider Impacts), describes a unified framework and finally provides specific recommendations on measurement in practice within the Living Labs.

In order to specify an overall evaluation framework it was firstly necessary to outline the requirements of the framework, review different methodological approaches to evaluation and assess the state of the art in terms of existing evaluation frameworks- particularly those relating to ICT enhanced transport schemes. A review of the evaluation methods for social-media orientated initiatives generally did not reveal a comprehensive and readily adoptable method for use with SUNSET. Similarly, the state of the art in evaluation of ICT enhanced transport systems revealed a small number of evaluation approaches with relevance, but which did not include social media networks or use of incentives. As a result a new method has been proposed which is informed by the state of the art but focused around the features of the SUNSET system and objectives of the project. The evaluation method has eight main components:

- A Cost-Benefit analysis,
- An indicator based evaluation of Operational success
- An indicator and sentiment based evaluation of social media aspects
- An exposure based Safety evaluation
- An Indicator based Sustainability evaluation
- An indicator based assessment of Liveable Communities
- A qualitative assessment of basic functionality of the system, and
- An assessment of the success of incentives based on both attitudes and revealed choices

The methodological components to each of these are described in some detail in chapters 2-6 of this deliverable and also chapters 2-3 of deliverable D6.1. The approach has been to draw on the state of the art from the literature, review this against the SUNSET evaluation requirements and propose adaptations, interpretations or new indicators as appropriate. Each of the components has been developed individually and with the goal of capturing as fully as possible the potential impacts within particular impact categories. It is expected that the application of the evaluation methodology with real-life data will present results in dissagregate format for each of these components. However, following the example of some established evaluation methods, a description is given of how a weighting and aggregation approach may be used to generate a summary performance statistic for the success of a scheme overall. The advantages and disadvantages of this are described and a broad analysis of double counting reported. This is one of the key issues in generating a composite indicator, with Operational Success and Success of the Incentives components being most affected. A proposal on how to work around this challenge is therefore also described.

Finally, the question of how the indicators within the evaluation components can be measured in practice is addressed, with a detailed tabulation for each of the 130 indicators. This shows the type of data, the units of measurement, the monitoring periodicity, the source of data and finally comments on any local priority or variance in the evaluation approach for each LL. It can be seen from this detailed tabulation that a high degree of concordance is expected between

all three labs, with only a small number of local interpretations. Finally, the overall experimental design for the evaluation process in the living labs is shown, together with comments on the expected interpretation and prioritisation of the design in the living labs. As Enschede is the main living lab, the design will be implemented as fully as possible. Expected prioritisation of the experimental groups is shown for Leeds and Gothenburg, according to the numbers finally recruited and scope of the living lab in each case.

Overall, it has been possible to define an evaluation method that addresses the evaluation criteria and is sufficiently focused to allow practical application. The method has been outlined in such a way that other social media transport projects will be able to adopt the approach or readily adapt it for local use, resulting in added value to the EC and other stakeholders.

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1. Introduction

1.1 Goals

The SUNSET system is intended to achieve impacts against the following objectives (as agreed in the Description of Work):

- **Congestion reduction**: traffic-jams are an increasing problem to tackle. The average travelling times should be reduced. Our objective is 5% less traffic (measured in car kilometres in a specific area) during the rush hours for users of the SUNSET system.
- **Safety**: people must be able to optimize their route, to avoid roads with many cyclists for car drivers, to report local road and weather conditions within community, to detect unusual conditions, or to avoid waiting times on dark and silent railway stations.
- **Environment protection**: for a liveable climate we need reduced CO2 emissions, improved air quality management and reduced noise pollution.
- **Personal wellbeing of citizens**: the system allows individuals to set and monitor personal objectives, like increase individual safety, reduce travel times, reduce costs, improve comfort, and increase health.

The overall objectives of WP6 are therefore as follows:

- To provide a set of key indicators that allow evaluation of the implementation and operational success of the social traffic scheme (success will be measured by a combination of mobility efficiency and sustainability indicators);
- To specify a general framework to evaluate the SUNSET system in against broad EU objectives for improved mobility in the future, including objectives relating to efficiency, sustainability and society;
- To provide specific recommendations to the living lab experiments on the indicators and measurement approach for the analysis of case study data in assessing the achievement of objectives;
- To outline an analysis approach for the effectiveness of the use of incentives in the SUNSET system.

1.2 Main results and innovations

The main results and innovations of D6.2 are given in Table 1.1:

Table 1.1 Contributions of this deliverable to SUNSET innovations

SUNSET innovations	Contribution of this deliverable
Social mobility services that motivate people to travel more sustainably in urban areas	The deliverable contributes by giving a method to understand whether people are motivated to travel more sustainably by the system - either in practice or in attitude.
Intelligent distribution of incentives (rewards) to balance system and personal goals	The deliverable contributes by describing a method to reflect the different degree of achievement between system and personal goals.
Algorithms for calculating personal mobility patterns using info from mobile	N/A

and infrastructure sensors	
Evaluation methodologies and impact analysis based on Living Lab evaluations	This is the primary contribution of the deliverable, which describes the SUNSET evaluation method overall and impact analysis for the Living Labs.

1.3 Approach

This section outlines the main steps taken in deriving the evaluation approach and the general flow to the research development (summarised in

Figure 1.1). The starting point was to define a set of high level evaluation requirements – these included consideration of the objectives against which the impacts of the scheme are to be evaluated, cross-referencing between: 1) the objectives for success of the system (as outlined in the DOW), 2) the work of WP1 in establishing use-cases for the functionality and use of the system, and 3) the findings of D6.1 concerning the definitions of operational success, sub-objectives and definitions of success for particular aspects of the system.

The second stage concerned a critique of existing evaluation approaches commonly used in the evaluation of a variety of transport initiatives. Specific attention was then directed to evaluation methods used within the assessment of Intelligent Transport System (ITS) schemes as these methods were most likely to be directed towards schemes with similar types of technical challenge to the SUNSET system.

The third stage concerned a review of expected impacts from the SUNSET system and a critique of these against the different evaluation approaches possible. This stage led to a refined set of impacts which could be addressed in the overall evaluation and proposed methodologies to evaluate these.

The fourth stage involved the definition of the overall recommended evaluation approach, drawing together the findings from the specific methodologies for particular aspects of the system and their criteria as defined in D6.1 within an overall 'umbrella' framework. This was an integrative process concerning issues of double counting and coherence alongside methodological development concerning composite indicators and summary scores for overall evaluation decision support.

The approach taken to stage four was intended to produce a methodology that (whilst driven by the needs of the SUNSET system), was sufficiently flexible to be adopted and amended by other schemes concerned with the evaluation of social media and pervasive technologies in Transport. This was intended to generate added value to the ICT for Mobility and transport community. However the final stage of the work has concerned transferring the general methodology to the specific needs for the Living Labs (LL) planned for the SUNSET project. At this stage, particular concerns relating to local objectives, the design of the LL around and within local constraints, the availability of different data types in the three different locations and the practical resource limitations were brought to bear at this stage. However this final stage also holds much value for the practitioner in recognising how pragmatic concerns can be incorporated in the evaluation and how the flexibility of the method outlined allows adoption in very different contexts.

The techniques used in the work have been largely desk-based involving problem identification, literature study, design, critical analysis, synthesis, review against best practice and review against practical constraints.

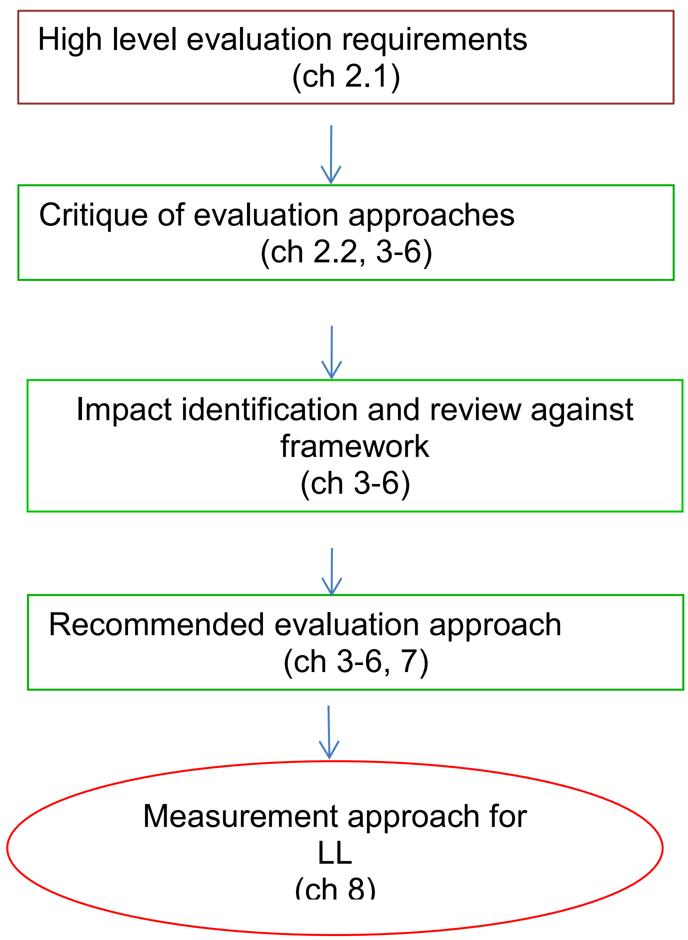

Figure 1.1: Methodological approach for deriving evaluation framework

1.4 Document structure

The overall structure to the document is as shown in **Error! Reference source not found.** below. Following the introduction in chapter 1, the overall framework is defined in chapter 2. Chapters 2-6 then report the development of specific parts of the evaluation methodology, focusing on: a cost benefit analysis, sustainability assessment, safety assessment and evaluation of wider impacts. Chapter 7 is an integrative chapter, drawing the material from the preceding chapters together with that from D6.1 so that the whole scope of the evaluation is clear along with the way it can be used in decision making. Chapter 8 focuses specifically on the needs of the living labs, translating the previous methodologies into practical guidelines which are expected to differ between the three SUNSET LL. Finally, overall conclusions are presented in chapter 9.

Table 1.1 Document structure in relation with objectives

Content	**Ch 1**	**Ch 2**	**Ch 3**	**Ch 4**	**Ch 5**	**Ch 6**	**Ch 7**	**Ch 8**	**Ch 9**
Introduction	√								
Objective 1: Key indicators for evaluation			√	√	√				
Objective 2: General framework against EU transport and other objectives		√				√			
Objective 3: Specific recommendations for LL								√	
Objective 4: analysis approach for incentives							√	√	
Conclusion									√

2. Framework requirements

2.1 High level framework requirements

The first stage in developing the evaluation framework was to outline the requirements for the method. These are needed in order to determine the scope of the framework and the essential functions of the in order to ensure the anticipated impacts could be captured and assessed against scheme objectives. The high level requirements were determined from a combination of 1) the qualitative input of policy level stakeholders who were consulted in the early stages of the project (as part of the WP1 consultation), 2) the expertise concerning evaluation contained within the consortium members and 3) a review against practical considerations of how the system was intended to work and the LL. This process resulted in requirements outlined in Table 2.1 below.

Table 2.1 High level framework requirements

Evaluation Requirement	Essential	Desirable
Comparability against 'traditional' schemes: this is an important features for decision making concerning investment in alternative schemes.	X	
Captures performance against objectives: the evaluation should be able to assess impacts against both system level objectives and individual traveller objectives. Furthermore it should have the ability to reflect the extent to which the scheme meets both of these in different ways. The interaction between individual and system objectives is a fundamental part of the SUNSET concept.	X	
Ability to handle dynamic nature of impacts: the SUNSET system impacts overall will generated by the accumulation of impacts resulting from a number of (potentially small) changes in travel behaviour by individuals. These micro-changes in the system may be different from journey to journey and therefore the level of impact may change in a very dynamic way.	X	
Ability to reflect long term costs and benefits: from the stakeholder/decision makers perspective, the ability to understand longer term goals (e.g carbon reduction, long term 'smarter choices' and more) is desirable.		X
Flexibility for different schemes/contexts: the framework should allow evaluation of different applications and interpretations of the SUNSET system. The urban context (which the system is aimed towards) varies considerably in the nature of transport related problems, the availability of transport options, the types of incentives that may be available or appropriate, and the local transport objectives of the city transport operators and planners.	X	
Ability to monetise some or all of impacts: whilst various types of indicators and evaluation approaches are candidates for the overall framework, it would be advantageous to include		X

monetisation of impacts where feasible. This would allow comparability with many of the existing evaluation frameworks applied in the transport context.		
Disaggregate outputs by stakeholder: a number of stakeholders have already been identified in the business case for the system (see D5.3). These include some stakeholders with different roles to those seen in more traditional transport schemes, for example in providing incentives, in providing governance to data etc. The ability to show disaggregate outputs by stakeholder is important in the framework to identify how any shifts in costs and benefits are distributed – and how these may be different to the pattern of costs and benefits expected from a traditional transport scheme.	X	
Ability to reflect 'intangibles' and broader socio-economic impacts: a system based around pervasive technology, encouraging smarter choices and the use of incentives as 'carrots rather than sticks' has the potential for impacts that may not be usually monitored in a transport scheme. These may include, for example, equity consequences or shifts in perceptions rather than actual behaviour. As a result it is considered essential that a broad range of socio-economic indicators are included as part of the evaluation framework.	X	
Practical with respect to measurability and data demands: the evaluation framework should be developed initially at a methodological level but then is intended for 'real life' use within the living labs. As a result it is necessary that the data requirements implied by the method are feasible in practice, either directly or through use of substitute data and proxies.	X	

The evaluation framework will be designed to capture the impacts of the systems against a set of objectives. These are summarised in section 1.1 and include achievement of high level (system objectives), the travel objectives of the individual and objectives relating to the functionality of the system when in use.

From this set of objectives, the first WP6 (D6.1 Evaluation approach for operational success and effectiveness of incentives) focused on the assessment of two specific objectives relating to 1) Operational Success and 2) the Effectiveness of Incentives. These were articulated as a set of sub-objectives concerning: individual goal achievement, the social networks concept, functionality of the system, usability of the system, behavioural responses to incentive and attitudinal responses to incentives. A summary of the measurement approach to be used for each is given in below. The evaluation of these two objectives also incorporates the method of evaluation for the user scenarios (US) and system scenarios (SS) initially proposed in deliverable D1.1 and finally reported in D1.2. For the rationale concerning which US and SS were finally implemented and the method of implementation, see Deliverable D1.2 'Revised Scenarios and User and System Requirements'. In , a summary of the US and SS cases is also provided for cross-reference to .

Within Table 2.2, the following notation is used:

- IG: The ability to meet travellers' individual goals
- SN: The success of the social network concept
- FN: the functionality of tripzoom
- Usa: the usability of tripzoom

- Beh: Travellers' revealed behaviour (i.e. their mobility profile)
- Att: Travellers' attitudes

Table 2.2 Summary of evaluation approach for operational success and effectiveness of incentives, including evaluation of user and system scenarios

Measurements		**Operational success**				**Incentive Effectiveness**	
		IG	SN	Fun	Usa	Beh	Att
User profile	Social-economic	✓				✓	✓
	Mobility constraint	✓				✓	✓
tripzoom	Mobility profile US3, US4, US5, US7, US16, SS4	✓				✓	
	Friends US2, US3, US6, US22		✓				
Travel diary	Mobility profile					✓	
Questionnaire	Self-categorisation	✓					✓
	Preferences	✓					✓
	Awareness US7, US17, SS1, SS4						✓
	Satisfaction US4, US6, US17, SS4	✓			✓		✓
	Rating of tripzoom US4, US6, US16, US17, US22, SS1, SS4	✓	✓	✓	✓		
Testing	Functionality US1, US2, US3, US4, US12, US13, US14, US15, US16, US17, US21, US22, SS3, SS5, SS6			✓	✓	✓	
	Usability US1, US2, US3, US16, US2, US21, SS2, SS3, SS5, SS6			✓	✓		✓
LL operation	Participants US2		✓			✓	✓
Google Analytics	Portal usage US1, US2, US3		✓				
	App usage US2, US7, US13, US22, SS4		✓				
Radian6	Sentiment US6, US13, US16, US22, SS4		✓				

Table 2.3: summary of User Scenarios (US) and System Scenarios (SS) finally implemented

Scenario ID	User requirements
US1	Mobility App registration &Download
US2	Social Network Reuse
US3	Mobility Pattern Analysis & View
US4	Improved Mobility Pattern Analysis
US5	Trip-based Pattern Analysis & Recommender
US6	Trip Recommender Acceptance & Feedback
US7	Real-Time Trip, Historical Trip, Transport choice, Info.
US12	Group-based aggregated Views of multiple individual Trips
US13	Trip Change Incentives
US14	Ad hoc Location-specific Mobility Offers
US15	Ad hoc group Travel Offers
US16	Public transport recognition:
US17	Experience sampling
US18	Sharing Mobility Status Updates
US19	User-centred monitoring and visualisation of Mobility patterns.
US21	Analysis of Mobility Patterns and Proposals for Mobility Improvement
US22	Users can offer each other travel tips
SS1	Overview of transport movements in the city
SS2	Monitor sub-optimal situations
SS3	Creates incentives
SS4	Monitors effect of incentive use
SS5	Issue new experience sampling
SS6	View aggregated data related to policy objectives

In terms of the WP6 goals for evaluation, the following have therefore been achieved and reported within D6.1:

1) To provide a set of key indicators that allow evaluation of the implementation and operational success of the social traffic scheme (success will be measured by a combination of mobility efficiency and sustainability indicators);
2) To outline an analysis approach for the effectiveness of the use of incentives in the SUNSET system.

The focus of D6.2 is therefore to complete the remaining WP6 goals (which were initiated in D6.1) and incorporate the specific findings from D6.1 with these:

3) To specify a general framework to evaluate the SUNSET system in against broad EU objectives for improved mobility in the future, including objectives relating to efficiency, sustainability and society;
4) To provide specific recommendations to the living lab experiments on the indicators and measurement approach for the analysis of case study data in assessing the achievement of objectives;

In terms of technical challenges to the research, the following issues were identified at the outset and addressed within the course of the workpackage:

- The application of the SUNSET system may be very different from site to site e.g. the nature of local objectives and the exact incentives used – this has been addressed by defining a flexible framework that can be adapted to the local context
- Problems in getting hold of either 'ideal' data or proxies/surrogates – the method has been determined so that as much data as possible is collected automatically through the app and the mobile device
- Some indicators may be difficult to define or to translate into measurable characteristics – the method will use a range of qualitative and quantitative indicators, collected in different ways and analysed with separate techniques as appropriate
- Difficulties in establishing the 'do nothing' case for the indicators – this is more of a challenge with a system based around pervasive technology than with traditional fixed-infrastructure transport schemes. An experimental design (reported within deliverable D6.1) has been produced to generate an individual 'do nothing' case on the basis of mobility patterns prior to use of the SUNSET system
- Ensuring there is data on the responses of individuals to the incentives through either automatic data collection or self-reporting – the design of the incentives market place and city dashboard through which the incentives are offered determined this aspect. A choice was made between requiring individuals to positively accept an incentive or to form an associative presumption based on monitored behavioural response. In order to minimise user workload the latter approach was finally chosen and will be evaluated.
- Establishing the ideal evaluation period i.e. short run versus long run – the experimental design will allow evaluation of short term and longer term responses, within the overall constraints of the project.
- Defining a geographic scope to the impacts over which benefits/performance can be measured – this is a challenge for any scheme using pervasive technology. The scope has been constrained within SUNSET according to the limits of the monitoring and mapping data uploaded for each living lab. This is a pragmatic constraint only and in principle the boundaries could be extended within a real- life (non-experimental) implementation.
- Understanding the nature of secondary impacts (e.g. pollution exposure and health impacts), unintended consequences (e.g. personal security risks rather than benefits) and feedback loops (e.g. rebound, which is a substantive research field in its own right. Some discussion around this is provided in chapter 6
- Assessing the full set of system costs alongside the benefits – the evaluation method has necessary covered a very large range of impacts ranging from Human Machine Interface considerations to the 'business case'. The evaluation approach has been derived in two stages as a result, focusing on specific impact areas in D6.1 and integrating these within the overall framework in D6.2
- Determining what 'success' is for some indicators – for example when an incentive has been successful or not. For any system orientated around behavioural change, there is uncertainty as to how long the behavioural change should endure to be counted as a success. For the SUNSET system the maximum monitoring period is 6 months (although for participants who join after the initial launch of the living labs, it will be less). Working within the theory of trans-theoretical behavioural change (Prochaska and Velicer, 1997), SUNSET has defined success as both attitudinal change and observed changes in behaviour/choice. As a result, definitions of success will involve both longer term (up to six months) and short term revealed changes, the degree of engagement with the system, changes in attitude, achievement of personal and system goals.

These challenges have arisen as a result of the novelty of the project and the difficulty of directly adopting either well established evaluation frameworks or those that have been derived for other types of technology innovations (for example intelligent transport schemes). A review of impacts and other transport-technology evaluation frameworks in the light of the SUNSET requirements is given in section 2.2 below.

2.2 Review of alternative evaluation frameworks and impacts

The aim of this section is to review different evaluation approaches and frameworks that have been established in the transport field and applied in practice. The aim is to ensure the impacts included in the SUNSET application are relevant to the task of reflecting the objectives of the project and the overall approach chosen is appropriate. An introduction to the general principles of different evaluation approaches is given in Table 2.4, whilst an overview of published evaluation methods that have been particularly used for Intelligent Transport Schemes (ITS) is given in Table 2.5 below. For a review of examples of the evaluation of social-media based schemes, see Chapter 2.3 of SUNSET Deliverable D6.1 and the definition of an approach to assess the success of the social media concept.

In Table 2.4, six main approaches are described alongside their advantages and disadvantages with respect to the SUNSET objectives and an indicative reference for further reading. Most of the strengths relate to relevance towards particular impact categories or the extent of the scope of the impacts captured, whilst difficulties in valuation form weaknesses for some methods. As well as the need to capture and reflect the SUNSET objectives, a further requirement on the evaluation method is the desirability of comparison with traditional schemes.

Most of the evaluation methods described in Table 2.5 that follows are appropriate to either fixed infrastructure ITS or the evaluation of in-vehicle ITS systems (such as route/navigation devices). As Intelligent Transport Schemes themselves comprise a 'system of systems' and tend to be highly bespoke, each evaluation method described in Table 2.5 contains a mixture of common and bespoke elements. Each method is briefly described against the components of the SUNSET objectives (see section 1.1). The most notable gaps concern the evaluation of personal security and well-being. This is possibly not surprising as these are impacts that would not necessarily be expected from either fixed infrastructure schemes or in-vehicle schemes, which tend to have objectives and purpose more attuned to system efficiency, safety and the environment. Several of the methods rely on modelling approaches, but with observed/field data being used to calibrate or supplement the modelling. The FESTA (2011) approach incorporates automatic monitoring data with both modelling and qualitative studies – the automatic data being collected from in-vehicle instrumentation and GIS. The CONDUITS project (Kaparias and Bell, 2011) developed a flexible set of indicators according to a categorisation of ITS systems (typically around 3-4 types according to location, fixed base or otherwise and scheme complexity), with the emphasis on data availability, practical application and reflecting policy priorities. The first two studies described (Wang et al, 2003 and Newman-Askins et al, 2003) are at a more strategic level, the first giving an overview of the evaluation method at strategic level and the second reporting on a survey of stakeholders views of how an ITS evaluation approach should be developed. As a result the detail on the evaluation method itself is not given.

Table 2.4 overview of different evaluation paradigms

Approach	Overall Advantage	Disadvantage	SUNSET relevance	Reference
Cost Benefit Analysis, CBA (Based on calculation of monetised cost and benefits of scheme to give a single summary measure)	Impacts are translated into a common monetary scale that allows 'trade-off's' between gains on one impact category and losses on another.	Need to quantify and monetise all impacts Difficulty in reflecting some impacts. Unlikely to reflect dynamic changes. Challenges around discount rate and some values.	Would allow comparison between the SUNSET (non-traditional) scheme and traditional transport schemes. Most investment decisions require a CBA calculation at some stage of decision making.	Mackie and Nellthorp, 2003; Pearce et al, 2006
Multi-criteria Analysis, MCA	Ability to capture impacts that cannot be monetised. Ability to reflect different policy or user objectives and priorities	In order to produce aggregate scores, the method needs weights. Criteria may be determined on different scales that are not comparable.	The SUNSET system is expected to generate a range of impacts that are difficult to monetise, hence the method is highly relevant. It is also appropriate to measure some aspects of functionality, use and engagement that are not suitable for CBA.	DETR, 2000; Hajkowicz, 2007
Lifecycle analysis, LCA	Ability to capture full costs of system if desired from cradle to grave. A range of experts may contribute offering a	Full analysis is data hungry. Only suitable for particular impacts. Temporal	It is essential to define whether attributional or consequential LCA will be applied. Consequential LCA is typically more	Finnveden et al, 2009; Guinee et al, 2011

	multidisciplinary evaluation.	definition of impacts may be crucial for particular products/systems, especially about newly released ones. It may be hard to identify and include a wide range of experts.	conceptually complex and the results obtained are highly sensitive to the initial assumptions. If the implicit assumptions are not well defined, this may lead to a low quality evaluation outcome. Setting the boundaries of LCA may be a challenge within SUNSET, particularly between technical and non-technical ones.	
Environmental Impact Assessment, EIA	EIA considers all sustainability impacts i.e. environmental, economic, social, allowing decision makers to assign values to such impact without the need to predetermine the ultimate environmental outcome. It may include both direct and indirect impacts.	A common criticism of EIA is its restricted spatial and temporal scope of analysis, though this may be addressed at a strategic level with a SEA.	EIA is useful to assess sustainability within SUNSET. However, it is essential to agree on a common set of impacts and measurement units from the outset, as well as about the boundaries of the evaluation in each LL.	Daniel et al, 2004; Wood, 2007
System of Integrated Environmental and	This method links economic with environmental statistics, assessing	It is based on the Social Accounting Matrix principle,	Since this method analyses flows rather than stocks of resources, it may be relevant to	UN, 2003; UN, 2012

Economic Accounting	economic impacts while considering a certain level of environmental standards.	thus linked with the evaluation of an economy as a whole which is not directly relevant to SUNSET.	SUNSET for the marginal analysis within the selected user groups.	
Cost Effectiveness Analysis, CEA	Uses a common monetary value comparing costs and outcomes of measures.	Similarly to CBA, it is essential to quantify and monetise all impacts. Usually linked with health services.	It links directly outcomes and costs for each indicator which is useful for decision makers within SUNSET. However it may be difficult to identify and quantify common impact indicators within all LLs (or even within a single LL).	Bleichrodt and Quiggin, 1999; Eger and Wilsker, 2007

Both the review in Table 2.4 and the studies in Table 2.5 have been used to inform the SUNSET evaluation approach, with broad consistency achieved. However the SUNSET evaluation method clearly requires an approach and measurement methods that are tailored to the additional social media and incentives elements of the system as whole. These are aspects that are unlikely to have been taken into consideration at the time when many of these approaches and frameworks were originally derived. As a result the SUNSET evaluation approach offers a further contribution to the state of the art in transport scheme evaluation.

Table 2.5: Overview of ITS evaluation methods and measurement of impacts

	Summary of context	**Guidance on evaluating congestion**	**Guidance on evaluating safety**	**Guidance on evaluating environment**	**Guidance on personal security**	**Guidance on wellbeing**
(Wang, Tang et al. 2003)	Outline of introduction of ITS schemes in Bejing for the 2008 olympics. Focus on central control system. Fixed base plus GPS.	No defined method	No defined method	No defined method	No defined method	No defined method
(Newman-Askins R., Ferreira L. et al. 2003)	Research towards a method for evaluating ITS projects that will allow comparison of the costs and benefits of such projects with those of conventional road projects. Uses stakeholder workshop to define parameters of method	No defined method	No defined method	No defined method	No defined method	No defined method
(Kaparias . and Bell. 2011)	Aims to define a common evaluation framework for traffic management and ITS in the form of KPIs	Separated into mobility; reliability; operational efficiency; and system condition and performance. Some duplication	1) speed, spacing, number of congestion occurrences 2) traffic volume, number of congestion occurrences,	Available transport emission models be used for quantifying pollution reductions through specific urban traffic management and ITS applications. 2) e.g. ARTEMIS enable a broader	No defined method	No defined method

		on measurement approach for these.	queue lengths 3) number of stops, number of congestion occurrences, queue lengths 4) number of detected critical and non-critical conflicts 5) number of speed limit violations, number of signal violations	forecast of pollutant emissions based on limited available input data, such as vehicle average speed only and traffic general classification (stop-and-go, free flow, etc.), together with detailed data approach. Route data, however, is still required. 3) separate consideration of electric vehicles (power generation etc)		
(FOT-NET 30th sept 2011) and (Karisson I. C. M., Rama P. et al. 2009)	Guidelines for conduct of FOT's. In-vehicle, V2V, V2X systems	Share of time speed <25% of speed limit. STD speed. Delay, negative deviation from intended speed (by GPS), recommends within subject changes due to large variation otherwise.	Subjective safety level reported by user. Change in number of journeys started in adverse conditions (dark, fog, slippery etc)	CO_2 can be derived from fuel consumption. Fuel consumption estimated from CAN-bus where there is access to the data or other special equipment in vehicles.	No defined method	Stress level reported by user. Subjective comfort level reported by user
(Kulmala R., Luoma J. et al.	General framework method for assessing a range	Travel time mean and SD, door to door	Headway (where possible to	CO_2 emissions from modelling, noise studies.	Feeling of safety (interviews,	Noise surveys, number of

2002)	of ITS schemes	travel time, travel time predictability (deviations from expectations), waiting time at stops and interchanges, additional travel time from incidents, deviations from scheduled time for PT	detect), before and after analysis of accidents by severity, conflict analysis, in-vehicle measurements of vision and eye movements. Relationship between accidents, speed and severity of accident from literature		questionnaires)	people affected by emissions
(James N. and Greensmith C. 1999)	The MAESTRO framework follows the life of a Pilot/Demonstration project from the beginning (the problem or the policy that pushes towards the P/D project) to its end (the utilisation and application of project outcomes). Mixed project types – ITS and other pedestrianisation, cycle measures, reduction in private	changes in time spent in travelling changes in the level of traffic congestion	Changes in accident rates for drivers and for other road users measure of injury producing accidents per vehicle km, quantitative, collected, official records	The range of environmental aspects include: • local air pollution; • global warming; • noise/vibration; • pollution of water courses; • geology and soils; • ecology and nature conservation; • landscape/visual intrusion; • severance and amenity. Changes in energy	(pocket picking, fear of attack, etc.)	No method proposed

	road space, public transport priority, parking management and traffic calming			consumption measure of consumption level for all road traffic litre, quantitative, derived, counting Changes in emissions of noxious gases measure of gas emissions from vehicle stock CO, VOC, SO2, NOx Tonne/yr, quantitative, derived, survey		
FESTA	Main purpose is to provide guidance on how to conduct and assess Field Operational Trials for in-vehicle ITS systems. Included guidance on experimental design. Guidance is most focused around in-vehicle use of nomadic devices.	Defined as 'system efficiency' 1) Traffic flow (speed, travel time, punctuality) 2)Traffic volume 3)Accessibility	1)Exposure 2)Risk of accident or injury 3)Incidents and near accidents 4)Accidents	1) CO2 emissions 2) Particles 3) Noise	No defined method	Comfort

3. Cost-benefit approach and interface with business model

This chapter introduces Cost-Benefit Analysis as one of the components of the overall SUNSET evaluation method, discusses the background and challenges to use of this method and concludes with proposals on the impact categories that may be monetised and used within SUNSET. As outlined in chapter 2, there are a wide range of expected impacts from SUNSET that are unlikely to be candidates for monetisation and inclusion within a Cost-Benefit Analysis - these are addressed in chapter 3 -6 that follow. The chapter also provides some example calculations and illustrative costs for the cost categories within the CBA methodology – these are based on representative/example figures only. In practice the most relevant and up-to-date figures for the specific living lab or other implementation of the system should be used.

3.1 Introducing Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) is a widely used appraisal method across a number of sectors as for example infrastructure development (Vickerman, 2007), environmental issues (Turner et al, 2007), housing (Winkler et al, 2002), healthcare (Brent, 2003), e-government (Hwang, 2009) and innovative transport systems (Melkert and van Wee, 2009). It is based around the comparison of costs and benefits of a specific project at a given time period through the assessment of a range of impacts, both positive and negative. The overarching objective is to determine whether an investment decision is justified based on the information available to the decision maker. This objective is also relevant to SUNSET namely for local authorities, public transport operators or third parties to assess whether the SUNSET system would provide additional value. Key features of CBA and its theoretical background are introduced in this section i.e. the Benefit-Cost ratio, welfare maximization, Pareto efficiency, Hicks-Kaldor criterion and Willingness To Pay. A more detailed introduction to those key features may be found in Brent (2006).

At the core of CBA lays the Benefit-Cost Ratio (BCR) which sums up all project benefits and then contrasts those with the sum of all project costs (Mishan and Quah, 2007). In principle, benefits should exceed costs or alternatively, the fraction of project benefits to project costs should be >1. If this condition is satisfied, then it means that the project assessed is eligible to receive funding. Funding decisions for traditional schemes are based on the Net Present Value (NPV) of projects which is a method of converting all costs and benefits to a common value at a given timescale. However, this may not be the case for SUNSET since the project timescale is shorter and it will be adjusted accordingly to fit this project's lifetime (see section 8). Of course there are some cases where projects with BCR <1 have been funded e.g. in the transport sector (Proost et al, 2010) based on decisions by policy makers. This highlights the role of CBA which is a decision aid tool and not a decision making tool.

CBA is built around the welfare maximization approach which assumes that any project or intervention will increase total welfare for society either upon completion or at a later stage. This approach is aligned with the SUNSET objectives of improving well-being and safety while reducing congestion and emissions, since welfare will be improved if these objectives are met. Welfare is measured in utility terms which is an economic term used to quantify impacts or preferences. This theory which has been long discussed by scholars (Barron, 2000; Pearce et al,

2006) is based on the Pareto efficiency principle which states that since all projects redistribute utility for different socio-economic groups (or individual members of society), the 'winners' should compensate 'losers' to ensure that in the end no socio-economic group is in a worst off situation compared to the initial situation. Essentially, this would mean that those benefiting by e.g. using a new public transport facility which reduces travel time or using a new piece of software to facilitate and speed up a certain task, should compensate those who do not use this public transport facility or software although everyone contributes in the development phase e.g. through taxes.

As Mackie and Nellthorp (2001) state, the notion of Willingness To Pay (WTP) is another key factor, since it demonstrates the disutility that 'winners' are willing to undertake in the form of a monetary payment. The underlying assumption here is that although all members of society contributed indirectly to develop this public transport facility or software through e.g. tax payments, only certain segments of society are taking advantage of it due to their home/work location or due to their skills/needs. Hence, in practice it is the Hicks-Kaldor criterion (assuming potential compensation to 'losers' but not practically compensating them) that is applied, since it would not be practically feasible to identify individual 'winners' or 'losers' and go ahead with hardly any project. SUNSET may contribute in this regard in providing a tool to identify actual 'winners' and 'losers', offering a methodological innovation.

The stages usually comprising a CBA include the identification of alternative options (usually including the Business As Usual scenario) and project stakeholders, which in this case would be the users of the SUNSET system, namely, individual users, local authorities, public transport operators, academic institutions and third parties. Then all relevant positive and negative impacts need to be identified and quantified based on a common monetary unit. Ultimately, the Net Present Value (NPV) of these impacts will be calculated, along with the project Internal Rate of Return, to evaluate the welfare contribution of SUNSET (FESTA, 2011: 123).
In sum, the steps to follow according to standard CBA practice are:

- Identify and calculate all project impacts
- Transform all impacts into monetary values
- Calculate the total value of benefits and costs to derive the BCR
- Calculate NPV to assess the impact on stakeholders and overall welfare contribution

3.2 CBA in transport appraisal

3.2.1 Overview and link with SUNSET

It was the French engineer Dupuit who introduced CBA to assess transport projects and railways in particular in the 19th century (Ekelund and Hebert, 1999). Thus, CBA has a long tradition within traditional transport projects during the past two centuries, which has also been borrowed by other disciplines – including Information and Communication Technology (see for example Lagas, 1998; ITRMC, 2002; Dekleva, 2005) which is relevant to SUNSET.. The dominance of CBA has been acknowledged by the European Commission too, since it is a formal requirement to conduct a CBA according to the existing regulatory assessment framework (Florio, 2006; Florio et al, 2008; OECD, 2011). The European Central Bank has introduced the same requirement for projects it co-funds, while the public sector in the US is also using CBA widely (Nickel et al, 2009).

Although there exists a wide range of CBA variations and approaches depending on each project's context, Mackie and Nellthorp (2001), Willis (2005) and Pearce et al (2006) provide a good overview of relevant theory in the context of assessing transport and environmental impacts. The Department for Transport in the UK has a long tradition of using CBA to evaluate project impacts, while other countries such as The Netherlands require a CBA for all major infrastructure projects after the OEEI in 2000 (de Jong and Geerlings, 2003).

As a result, CBA is at the moment the most widely used method for transport appraisal within Europe (Odgaard et al, 2005) and elsewhere which justifies the use of CBA as the backbone of the evaluation approach for SUNSET. Other methods have been considered within SUNSET (section 2 – Table 2.5), but it has been concluded that CBA is able to interact well with the other forms of evaluation employed such as sustainability assessment (section 4), safety exposure (section 5), and the use of impacts indicators (section 6). Moreover, the financial analysis part of CBA is often of higher importance compared to other impacts (e.g. wider impacts – section 6), particularly when evaluating the potential benefits and added value for third parties which form SUNSET innovations. In addition, a CBA is widely used by decision makers to evaluate traditional transport or other infrastructure schemes as already discussed, so it makes sense to use a common approach to aid decision makers in forming meaningful comparisons and prioritise between competing projects within a given budget.

However the extent to which monetisation can and should take place to reflect project impacts remains something of a moot point in the transport scheme evaluation field. This is due to concerns around the ability to monetise certain quantified impacts (such as travel time reliability, noise externalities and other impacts), the discount rate that may be needed and the prices that can be used. In addition there is considerable national variation in the culture of monetisation, although most national approaches monetise at least some impacts. The aim here is to produce an assessment approach that is sufficiently flexible for use with different implementations of the SUNSET system or other similar types of social networking scheme but is widely acceptability. As such the recommendation is to monetise impacts where feasible, according to the implementation context and in line with any accompanying national guidelines.

Following the outline introduced in section 3.1, this section reviews the impacts included in the UK in transport CBA based on the DfT (2012) guidelines (Table 3.1).

Table 3.1: Impacts included in conventional transport CBA (adjusted from DfT, 2012)

	Impact	**Relevance to SUNSET**	**SUNSET objective**
1	Journey time change for business/non-business travelers	+++	Congestion reduction
2	Vehicle operating costs	+++	Well-being, environmental aims
3	Fare costs	+++	Well-being
4	Private sector impact	+	Wider impacts, success of incentives, operational success
5	Accidents	++	Safety
6	Noise impacts	+	Environmental aims
7	Greenhouse gases impacts	+++	Environmental aims
8	Air quality	+++	Environmental aims
9	Accessibility	++	Well-being, congestion reduction

The nine impacts presented in Table 3.1 are all relevant to SUNSET, however some are more significant than others due to their alignment with the SUNSET four key objectives. Consequently, it is relevant to include impacts 1, 2, 3, 7 (and 8) in the evaluation of SUNSET, since those impacts are closely related with the objectives of congestion reduction, safety, environmental and well-being improvement. Measurement units for these impacts are summarised in section 8.

Furthermore, it is worth pointing out at this stage that CBA is evolving and there are various attempts to incorporate more impacts e.g. environmental, noise or others often labeled as wider impacts through hedonic pricing or composite indicators (Hanley et al, 2001; Thanos et al, 2011; Thomopoulos and Grant-Muller, 2012). Such impacts may include journey ambience, reliability, biodiversity, water resources or impacts on sites of historic importance or other heritage value as shown in Table 3.2. Opportunity cost refers to the cost of the decision to fund a project e.g. SUNSET instead of another project, namely the lost opportunity of funding another project which may be neglected in some economic analysis (Wetherly and Otter, 2011). Reliability is linked with the time loss due to transport mode delays or traffic congestion and is intertwined with wider impacts which include a range of other impacts such as productivity or agglomeration effects (Nash and Laird, 2009). It is anticipated that SUNSET will improve reliability and thus diffuse positive wider impacts in the local community. The remaining impacts i.e. biodiversity, water resources, landscape and impacts on historic sites are all associated with the implications of increased traffic and the resulting emissions and noise on sensitive locations. These are potentially negative impacts of SUNSET due to high popularity of the smartphone application and the deriving overcrowding in certain transport arteries, transport modes or locations.

Table 3.2: Impacts excluded from conventional transport CBA (adjusted from DfT, 2012)

Impact	**Relevance to SUNSET**
Journey ambience impacts (e.g. train overcrowding, facilities available at stations and bus stops)	+++
Opportunity cost	+
Reliability	++
Biodiversity	+
Water resources	+
Lanscape/Townscape	+
Impacts on heritage/historic sites	+
Wider impacts	+++

Contrasting the appraisal practice in the transport sector with the practice in the IT sector does not differ a lot in the view that existing practice is partly inadequate and conventional CBA cannot capture all impacts (Neubauer and Stummer, 2007). Therefore, other methods have been tested within the IT sector such as the Technology Roadmapping, the Component Business Model which incorporates the Annualised Rate of Occurrence (ARO) of potential system risks or the Value Measuring Methodology (Dekleva, 2005). The common feature though is that all these approaches aim at complementing CBA in the evaluation of additional impacts which are difficult to monetise. Despite the fact that most of the impacts included in Table 3.2 may be broadly relevant to an ICT for transport project such as SUNSET, journey ambience, reliability and wider impacts are considered to be more relevant, considering also that double counting is an issue when building composite indicators. Therefore, wider impacts are further discussed in section 6 while journey ambience and reliability will be evaluated qualitatively and/or quantitatively within SUNSET. The actual components of the composite indicator are explained in section 8.

3.2.2 Stakeholders and socio-economic groups

As already explained in section 3.1, the relevant stakeholders of each project need to be identified from the outset. This is intertwined with impact distribution which is further discussed in section 6. Stakeholders have one or several of the essential characteristics as outlined by the EC (2012):

1. *one who is affected by or affects a particular problem or issue*
2. *is responsible for problems or issues*
3. *has perspectives or knowledge needed to develop good solutions or strategies*
4. *has the power and resources to block or implement solutions*

(EC, 2012)

In the SUNSET context, stakeholders may include users, local authorities, public transport operators, software developers or local businesses to name a few. According to the DfT (2012) guidelines the following are some generic stakeholders that are commonly included in transport CBA:

- Business travellers
- Non-business travellers
- Pedestrians
- Cyclists
- Others

The rationale of distinguishing between business and non-business travellers is related to the diverse Value Of Time (VOT) of each group of stakeholders (Abrantes and Wardman, 2011; Wardman and Ibanez, 2012). VTPI (2012) defines value of time as "*the cost of time spent on transport, including waiting as well as actual travel. It includes costs to consumers of personal (unpaid) time spent on travel, and costs to businesses of paid employee time spent in travel. The Value of Travel Time Savings refers to the benefits from reduced travel time costs*" and provides a useful summary of values of time for passenger transport in developed countries, with an example of European values:

- *Business: 21€ / person hour*
- *Commuting: 6€ / person hour*
- *Leisure: 4€ / person hour*

(VTPI, 2012)

Of course this may also vary by mode, location or country, but it is common practice to use average nation-wide values. Cyclists and pedestrians are two groups of particular interest to SUNSET, therefore it is sensible to pay particular attention to the implications for these specific groups of travellers. Nevertheless, the groups of stakeholders have been illustrated in more detail in D5.3 for each of the Living Labs. Given the diverse focus of each Living Lab (e.g. employers, families, car drivers on specific routes) and in conjunction with the 7 groups defined in D6.1, it is anticipated that, in accordance with D5.3 and section 8 of this deliverable, each Living Lab will define specifically the specific socio-economic groups prior to the launch of each Living Lab to support the respective evaluation task (D7.3-D7.5).

3.3 Challenges of CBA

As any method, CBA faces a number of challenges tooThis section outlines some key challenges faced when applying CBA in practice.

3.3.1 Valuation/Quantification

Commonly, goods with no explicit price attached to them may be valued through:

- Market prices for alternative goods or through productivity losses/gains
- Consumer choice observations including market goods *(revealed preference methods)*
- User and non-user surveys regarding their preferences *(Willingness To Pay or Willingness To Accept compensation)*

New smartphone applications and innovative systems such as SUNSET fall within this category of goods with no explicit price attached to them yet. Given this context, a general limitation of CBA as introduced in section 3.2 is its inability to address some intangible social, distributional, environmental and strategic concerns (Beuthe 2002; Shang et al. 2004) often referred to as externalities, indirect effects or Wider Economic Benefits (WEBs) (Florio et al, 2008; Thomopoulos and Grant-Muller, 2012). In the UK, DfT usually assesses these impacts qualitatively within the Appraisal Summary Table (AST). This limitation arises from the requirement that all impacts should be monetized, which is either not possible or not feasible due to limited resources in many cases (Johansson-Stenman 1998; SPECTRUM-D6 2004). Those impacts occur either due to market failures or due to market inexistence and are linked with agglomeration externalities, market power arising through product differentiation or geographic isolation and the presence of an indirect labour tax. When markets fail, this could be because they are imperfect or because current prices are not equal to social marginal cost prices (Laird and Mackie, 2009). In the context of SUNSET, this is very relevant since there is a number of markets which either do not exist at a local (i.e. Living Lab) level or are currently failing because of the transition phase from a state controlled market to a free market (e.g. traffic data management).

The prices used within a CBA present a further dimension of variation both between countries and between regions of the same country. A distinction between prices and values should be made explicit here. Prices refer to actual market prices of goods exchanged in existing markets, whereas values correspond to estimates for specific indicators. Observed market prices or wages in less developed regions do not always reflect the social opportunity cost of goods and services, in particular of capital and labour, mainly due to widespread market failure and policy constraints. This distortion, in conjunction with diverse tax systems, have consequences on the financial and social discount rates used within CBA. Consequently, there is a challenge when evaluating a system such as SUNSET due to the variation in wage levels, corporate tax, parking charges or bus fares between e.g. Enschede and Hengelo or Leeds and Bradford.

So overall, it should be obvious that it is a significant challenge to evaluate and quantify consistently all SUNSET related impacts throughout all Living Labs. Therefore, it has been decided to employ CBA as a component of the overall evaluation method of the SUNSET system, which will be complemented by the use of additional impact indicators (sections 4-6) as well as selected proxy indicators which will be used to quantify qualitative indicators (section 8). Nonetheless, CBA forms an indispensable component of evaluation frameworks in other contemporary research (e.g. FESTA, 2011), so it is rational to utilise it within SUNSET too.

3.3.2 Discount rate

"Discounting refers to the process of assigning a lower weight to a unit of benefit or cost in the future than to that unit now" (Pearce et al, 2006). There is an ongoing discussion internationally about the discount rate to be used within CBA (Thomopoulos, 2010). As Pearce et al. (2006) wrote *"few issues in CBA excite more controversy than the use of a discount rate"* – in particular the diverse categories of rates (e.g. financial, social/economic – Bickel et al. 2005) and the diverse rates used, ranging from 3% to 12% (Lopez 2008; Odgaard et al. 2005). Variation also

occurs in other key components of CBA, including values attached to time, human life and emissions (Veron 2010: 23). The distribution of those impacts raises spatial or social equity issues, which are further discussed in section 6.

Each country independently sets the discount rate to be used for schemes in their territory (Table 3.3). Odgaard et al (2005) have found that discount rates in Europe range from 3% to 8%, whereas the World Bank has used a discount rate of 12% for projects it has funded[1].

Table 3.3: Social discount rates in selected EU member states

Country	Discount rate (%)	Method of determination	Year
UK	3.5	Social rate of time preference	2003
Germany	3	Social rate of time preference	end of 1980s
Netherlands	4	Social rate of return on private investment	1994/2003
France	8	Social rate of return on private investment	1985
Portugal	4	Social rate of time preference	2003
Ireland	5	Social rate of return on private investment	1995
Italy	5	Economic literature	2001
Spain	6% real for transport, 4% real for water resource	Depends on the sector	

Source: Florio (2006: p.17)

The divergence in the discount rate may result in a varying NPV of parts of a project in different countries, which is intertwined with the internal rate of return (IRR) or the financial return on investment. This non uniform approach by EU member states (Table 3.3) results in further complications when considering the appraisal of cross border transport infrastructure projects or Living Labs in different locations as in the case of SUNSET. The main Living Lab in Enschede is anticipated to attract tripzoom users from neighbouring communities in Germany, so a uniform approach is needed. This may also be of higher significance in the future if SUNSET is deployed in other cross-border European regions. The main point here though is when conducting the evaluation between the three SUNSET Living Labs, since a common discount rate should be utilised across all LLs.

[1] However, it should be noted that there has been a turn by the World Bank lately towards lower discount rates. For example it is being considered currently to apply a social discount rate of 4-7%, depending on the project's life time (Lopez, 2008).

3.3.3 Time horizon

Another common criticism of CBA is the time horizon used in project assessment, which is again a majorissue for cross border projects or for evaluating projects in different countries (Florio, 2006; Wiegmans, 2008). This is an important factor affecting the NPV of a given project and ultimately the selection of a specific project over another one. The lifetime for different transport infrastructure projects varies in Europe from 20 years to infinity. Again, this is an issue that cannot be neglected when reviewing the challenges of CBA, as it is linked to project funding and the return on investment (Odgaard et al, 2005). Of course the time horizon may be much shorter in ICT projects due to the increased pace of technological developments and hardware/software depreciation as has been confirmed recently (e.g. DoT-Victoria, 2012), but this is something which needs to be decided by the local evaluators. For SUNSET, it would be sensible to assume that the evaluation time horizon is one year or the duration of each Living Lab.

Based on the aforementioned reasons and the identified CBA limitations, other methods (Table 2.5) have been considered within SUNSET to constitute the evaluation framework. Yet, given the current practice in Europe (e.g. EC, 2008) and other developed countries (ITF/OECD, 2011) it is clear that there are attempts to address these CBA challenges. One example to address e.g. distributional impacts is to identify from the outset the socio-economic groups influenced by a given project, which has been incorporated within the SUNSET context through the identification of specific target groups (D5.3, D6.1 and D7.1). More background about the challenges of CBA and suggestions to overcome these may be found in Mackie (2010), Thomopoulos et al. (2009), van Wee and Geurs (2011) or Vickerman (2007). As a result, it has been recommended to employ CBA as a core component of the SUNSET evaluation framework, in conjunction with safety exposure and impact indicators (section 4-7).

3.4 The SUNSET CBA components

This section will collect the previous points and adapt them to the SUNSET needs to generate input for section 7.

3.4.1 Addressing the CBA challenges within SUNSET

Given the challenges described in section 3.3, the practical suggestions within the SUNSET context are:

i. **Valuation/Quantification**: use already existing and tested indicators or design quantified ones for non-monetised impacts
ii. **Discount rate**: use a low discount rate (e.g. 1%) which is sensible for ICT related projects
iii. **Time horizon**: use the duration of the Living Labs or 1 year (which is the duration of the main Living Lab in Enschede)

3.4.2 Interface with the SUNSET Business Model

The evaluation framework discussed in D6.2 aims at evaluating the SUNSET system overall and CBA constitutes one component of this framework. Yet, another essential part of the evaluation of any investment decision is the link with the overarching business model. Dekleva (2005) acknowledged that there have been several firms in the past which did not have a clear picture of the link between their business model and the desired IT investment. The business model per se "*includes the architecture for the product, service and information flows, a description of the benefits for the business actors involved and a description of the source of revenue*" (Weil et al, 2005). The SUNSET business model has been described in detail in D5.3, providing the background and highlighting all dimensions based on the business model canvas. The link with this deliverable is the provision of costs and benefits based on this business model, which of course varies between the main and the reference Living Labs.

This then would provide the opportunity for further enhancement in the future of both the costs and benefits as well as the business model in SUNSET if it is to be implemented in other locations. As stated in D5.3, this would build in the general potential of the SUNSET system to act as a mobility data platform 'marketplace' generating both wider user benefits through content co-production and also generating additional revenues through open development of apps in a range of deployment domains. The evaluation method outlined in this deliverable would then be able to capture such additional impacts and include them in the overall evaluation. However, to fully achieve this, it would again be required to clearly specify all affected groups to evaluate impact distribution. User groups have been defined in D1.1 and D7.1, while other stakeholders have been defined in D5.3.

Five pillars have been used in D5.3 to distinguish the core categories of the business model:

1. Product
2. User interface
3. Infrastructure management
4. Financial aspects
5. Sustainability

These categories are illustrated in Figure 3.1 for the main Living Lab of Enschede where the potential sources of revenue and costs are pointed out. These costs and revenues act as input for the corresponding categories of the CBA as described in section 3.4.3 e.g. SUNSET data storage and management or operation and maintenance costs for the City Dashboard.

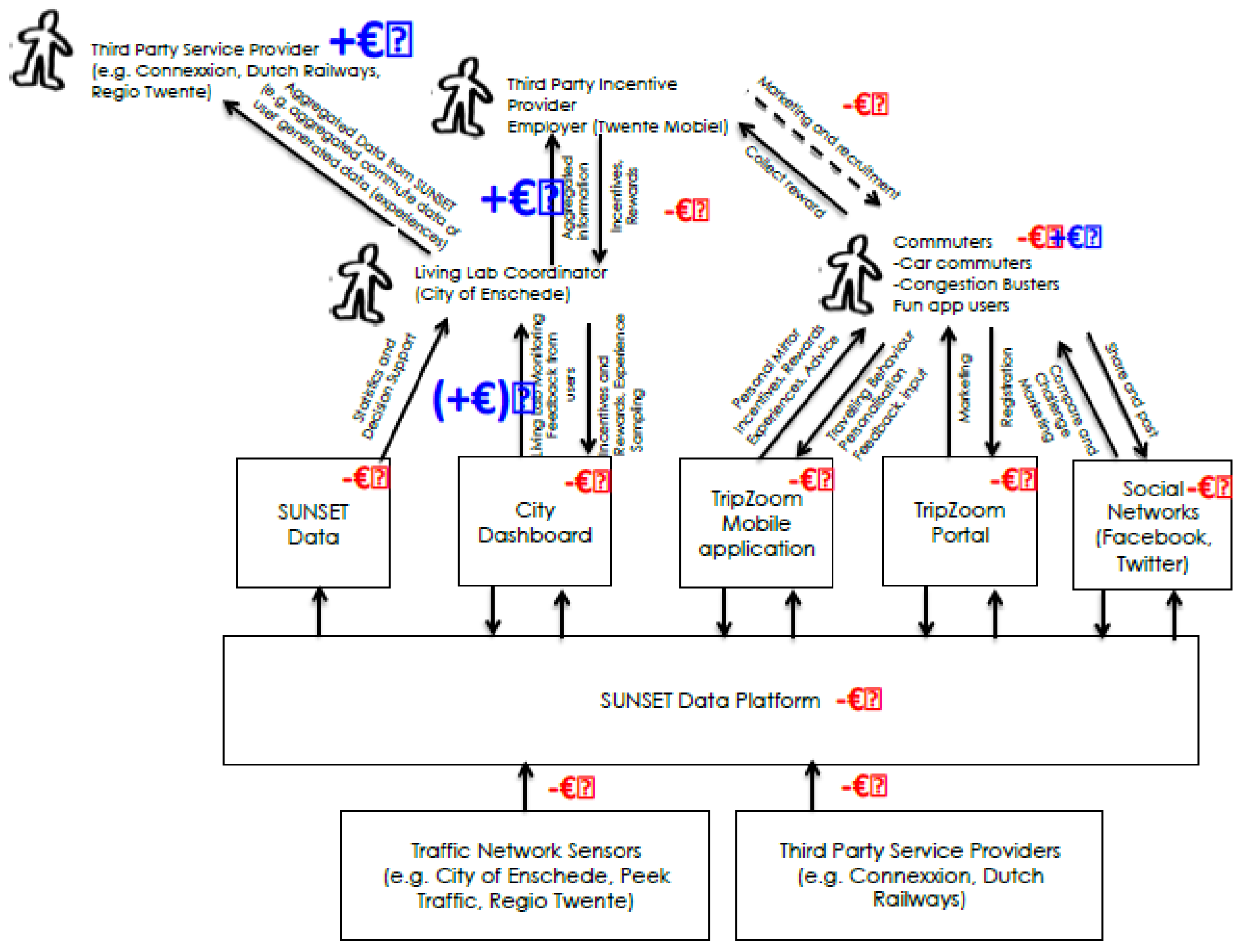

Figure 3.1: The SUNSET business model in Enschede (D5.3)

To summarise the interaction between the SUNSET business model and the evaluation method, the following constitute the essential requirements for each Living Lab which will be highlighted in section 8:

1. Specify the finance pillars in each Living Lab i.e. whether the SUNSET system and required infrastructure will be provided by the public or private sectors (including third party providers)
2. Identify the type and volume of incentive providers to assess any revenue streams (i.e. benefits) for the SUNSET system (D6.1)
3. Specify the targeted user groups in each Living Lab based on D5.3
4. Specify the transfer/operating/user costs and benefits (section 3.4.3)

The following section addresses explicitly point 4, providing detailed insight about the transfer, operating and user costs.

3.4.3 Selecting appropriate CBA components

Building on the previous sections and the background regarding CBA, this section provides recommendations for the specific components to be included in the SUNSET evaluation method. The overall aim is to generate a flexible approach which will be used within SUNSET but will also be flexible to be transferred to the different Living Labs as well as other potential Living Labs in the future.

The link with D5.3 should be obvious here as explained in section 3.4.2 without duplicating previous work. Therefore, the key impacts included in conventional CBA (Table 3.1) i.e. journey time change for business/non-business travelers, fare costs, vehicle operating costs, greenhouse gases and air quality are also addressed in Tables 3.4 – 3.6. It should be clarified here that although all categories are named as costs, they actually encompass benefits too, since a reduction in a given cost category is equal to an equivalent benefit for the respective stakeholder. For example, a reduction in travel cost or travel time is equal to the corresponding benefit for the respective group of users.

Table 3.4 provides a detailed overview of all costs and benefits linked with running the SUNSET system, for the managing authority, public transport authorities, incentive providers and users. For each cost and benefit impacts category, the respective sum and stakeholder are identified to provide better insight to decision makers. These impacts are categorized in Core (C) and Desirable (D) in sections 7 and 8. This is a list of all cost categories, whereas Table 3. 6 focuses on user costs in the main Living Lab of Enschede, acting as input for category 8: User costs in Table 3.4 . All data in Table 3.4 are rough estimates at this stage and would of course vary in each SUNSET LL or in any application in a different location in the future. Therefore, background information and key assumptions have been explained for each impact category. The overarching assumptions made in Table 3.4 are that this CBA has been conducted from the perspective of a given local SUNSET Managing Authority for the full duration of a SUNSET LL with a duration of 6 months and 200 participants.

Table 3.4: Cost and benefit categories for SUNSET
(illustrative benefit sums are indicated in green, whereas illustrative cost sums are indicated in red)

	Impact	Cost calculation = Indicator value	Measurement unit	Assumptions / Comments
1	**Integration costs**	Responsible stakeholder: Local Managing authority		Category sum: **480€**
1	Integration with the local Managing Authority of the SUNSET system (during/after SUNSET)	16 hours x 30€/hour = 480€	person hours	Basic IT employee rate working for 2 days. This cost is optional and refers to the case that the SUNSET managing authority and the PT provider are not a single organisation. In Leeds for example, First is a Public Transport Provider, Metro is the West Yorkshire Integrated Transport Authority co-ordinating public transport in the wider region and of Leeds City Council is a managing local authority. These are all separate entities to the SUNSET system. In Enschede the City Council is part of the SUNSET consortium, so no integration costs with the local SUNSET Managing Authority need be incurred.

2	**Installation costs**	Responsible stakeholder: Local Managing authority		Category sum: **1 240€**
1	for the Managing authority / third parties / end users / PT operators	n/a		It is assumed that the tripzoom portal and City Dashboard will be free web-services which will not require any specific software other than a basic computer running Windows and having access to the internet. If this changes in the future, the relevant cost should be added here.
2	hardware investment	1,000 €	€	It is assumed that all parties will have a basic computer and access to the internet, so optional costs may include an additional/upgraded computer and a backup hard drive for SUNSET to store any useful or confidential data at a local level.
3	installation costs (e.g. time, loss of network access)	8hrs x 30€/hour = 240€	person hours	This includes the time needed to install any additional software and the time needed to adjust the local IT network.
3	**Operating costs**	Responsible stakeholder: Local Managing authority		Category sum: **3 400€**
1	hardware maintenance	80hrs x 25€ = 2000€	person hours	This refers to the equivalent of 10 full working days for hardware maintenance throughout the Living Lab duration and includes e.g. computer, server, network, sensors.
2	software maintenance	1hr/wk x 26wks = 26hrs/LL = 26 x 25€ = 650€	person hours	This includes installing any new software updates and keeping track or recording any software bugs.
3	energy costs	250W x 40hrs used / 1000 x 26 wks x 0.15 cost per kWh = 39€/	€	Additional energy use for the managing authority because of using the SUNSET system for 6 months, based on a single PC running the City Dashboard.
4	system hosting	40€/m x 6m = 240€	€	Webhosting is required for the SUNSET system and mainly the tripzoom portal and registration facility. This may be provided free of charge by the local Managing Authority, it may be hosted in a cloud server or it may be outsourced. It is assumed that webhosting for the portal and registration is not large since it is a basic website. It is also fair to assume that any local Managing Authority would already pay/have such a service in place.
5	data storage/management/ analysis	510€ (for 1TB)	€	Due to the volume of data generated through the SUNSET system, it is essential to include additional storage capacity e.g. 1TB The assumption of 1Tb is considered fair here based on 200 users using tripzoom monthly for 6 months.

4	**Incentive design & management**	Responsible stakeholder: Local Managing authority		Category sum: **10 625€**
1	templates	3hrs/m x 6m = 18hrs x 25€ = 450€	person hours	It is essential to design and use a set of locally adjusted incentive templates.
2	user groups	1.5hrs/m x 6m = 9hrs x 25€ = 225€	person hours	It is essential to design and use a set of locally adjusted user groups.
3	Incentive design and finding vouchers (find and sign agreements)	16hrs/m x 6m = 96hrs x 25€ = 4800€	person hours	This includes identifying, contacting and negotiating with third party providers. Legal support is assumed to be available in-house at no additional cost.
4	data analysis of incentives	1hr/d x 182d = 182hrs x 25€ = 4550€	person hours	This includes the time needed to conduct the analysis which is needed for better incentive design within the system. It is assumed that relevant software is available and 1 hour is sufficient to analyse data generated from 10 incentives with 20 users/per incentive.
5	re-offer incentives (renew/renegotiate contracts)	4hrs/m x 6m = 24hrs x 25€ = 600€	person hours	After having established third party incentive providers, 1hr/wk should be enough to review, renegotiate and renew contracts with successful third party providers.
5	**Marketing costs**	Responsible stakeholder: Local Managing authority		Category sum: **10 200€**
1	launch events (one-off)	3,000 €	€	A major launch event may boost awareness and participation within the SUNSET system.
2	social media advertising	2ads/m at 1€ CPC to generate 200 clicks/ad campaign: 400€/m x 6m = 2400€	€	This may include paid Facebook or Google Ads.
3	online advertising	2ads/m at 1€ CPC to generate 200 clicks/ad campaign: 400€/m x 6m = 2400€	€	This could be either individually or in conjunction with social media advertising.
4	conventional advertising	400€/m x 6m = 2400€	€	This includes e.g. local/regional/national newspapers, magasines, posters, banners, leaflet distribution.
6	**Support costs**	Responsible stakeholder: Local Managing authority		Category sum: **5 950€**
1	FAQs/Complaints/Communication	4hrs/wk x 26wks = 104hrs x 25€ = 2600€	person hours	It is anticipated that FAQs will take less than 1hr/wk, complaints 1-2hrs/wk and general (internal/external) communication about 2hrs/wk.

2	liaison with third parties about incentives support	2hrs/m x #3rd party providers = 6hrs/m x 6m x 25€ = 900€	person hours	It is assumed that it will be essential to contact third party providers every couple of weeks to review incentives issues. It is assumed that there are 3 third party providers.
3	technical support	9hrs/m x 6m x 25€ = 1350€	person hours	This should include 8hrs/m for basic support and 1hr/m for advanced technical support, provided by phone/e-mail/portal/social network.
4	Ethical protocol costs (incl. privacy and protocols for data management/sharing)	16hrs x 50€/hr (start-up) + 2hrs/m x 6m x 25€ = 1100€	person hours	This includes expert input as start-up costs and then monthly reviews. It is assumed that a legal adviser or other expert in ethics will review and provide general input at start up. The local Managing Authority can use own capacity and expertise thereafter.
7	**User costs** *(input from Table 3.6)*	Responsible stakeholder: Local tripzoom users		Category sum: **897 185€ - 12 388€ = 884 797€**
1	battery consumption	2kWh x 200 users x 0.20€ = 80€	€ / day x users	This includes additional battery consumption due to the GPS and Wi-Fi running constantly on the smartphone for 6 months. The kWh cost is estimated at 0.20€/kWh.
2	energy costs	350gr CO_2/kWh x 2kWh x 200usrs = 308€	€ / week x users	This includes charging the smartphone. Average cost of kgCO_2 is estimated at 2.2€/kgCO_2 (http://www.co2prices.eu/).
3	contract/mobile data costs	€5/month x 6m x 200usrs = 6000€	€ / month x users	This includes the additional data use per month due to using tripzoom.
4	device marginal upgrade/purchase/maintenance/insurance costs	10€/m x 6m x 100usrs = 6000€	€	It is assumed that all users have at least a basic mobile phone and a monthly contract of 5€, so the cost of upgrading to a smartphone is the marginal cost. It is assumed that about half of the 200 users will need to upgrade their handset (see also Table 3.6). It is assumed that 90% of Europeans have a mobile phone already, but not all mobiles comply with the minimum tripzoom requirements (e.g. Android 2.2 or latest). Therefore, it can be assumed that some users who wish to use tripzoom will have to upgrade their handset .No insurance cost is included here, although some contract options offer this. This additional cost is a wider impact.
5	installation costs	n/a	€ x month x users	It is assumed that tripzoom will be a free app initially. However, it may be offered at a cost at a later stage.

6	travel time savings	B: 5% x 21€ x 2hrs x 50 usrs = 105€ C: 5% x 6€ x 2hrs x 100 usrs = 60€ L: 5% x 4€ x 2hrs x 50 usrs = 20€	Reduced travel time x € x TT x users	This example calculation is based on the expected 5% reduction in the SUNSET objectives and will in practice depend on the outcome of the Living Lab. If the SUNSET objective of 5% congestion reduction is achieved, users may benefit by 5% reduced travel time (assuming that reduced travel time is a benefit). Assuming that an average user travels for 2 hours/day, the respective benefits are estimated for business, commuting and leisure trips (VTPI, 2012). Due to the diverse nature of the SUNSET LLs, it is not possible to make an accurate assumption about the distribution of users within the 3 travel groups: business, commuters, leisure. This impact category can be considered as a benefit since it means that less time is used for travelling and can be spent on other activities. Of course any actual estimate here is indicative and would depend on the actual LL outcome.
7	trip costs	19500€ x 20% x 25% x 200usrs = 195000€	trip costs x trip cost reductio n	This example calculation is based on an anticipated 20% reduction in costs based on the broad SUNSET objectives and will in practice depend on the outcome of the Living Lab. Assuming that the SUNSET system will offer 20% reduced trip costs for all users through car sharing, group bus fares, more frequent walking/cycling and acknowledging that transport costs form 20-30% (mid-point of 25% used here) of the average income of 19500€ in The Netherlands (OECD, 2012). This impact category can be considered as a benefit since it means that lower costs are incurred for travelling and funds saved can be spent on other purposes. Of course any actual estimate here is indicative and would depend on the actual LL outcome.
8	vehicle operating costs	0.39€/km x 9000km x 200usrs = 702000	cost/km x km	A privately owned car up to 1500cc including all costs for 6 months (RAC, 2012). This impact category can be considered as a benefit since it means that lower vehicle operating costs are incurred by each user and funds saved can be spent on other purposes. Of course any actual estimate here is indicative and would depend on the actual LL outcome.

Table 3.4 describes the costs and benefits of introducing SUNSET, for all stakeholders, including the local managing authority, users and third parties and it demonstrates that based on a conventional CBA the benefits clearly outscore the costs in financial value. Yet, no absolute value is provided here, since the aim of this deliverable is to provide a unified evaluation method, where CBA only forms a single component. In addition, there are certain assumptions which need to be made depending on the local context as explained throughout this table, for example the hourly wage for an IT employee has been assumed to be 30€/hour whereas the hourly wage for a legal employee has been assumed to be at 50€/hour. Additionally, it has been assumed that data hosting space or software used for analysis may be available or not to a given local managing authority. These SUNSET driven assumptions have been explicitly stated in Table 3.4 to be adaptable to any local context. Moreover, Table 3.5 provides a set of

indicative – certainly not exhaustive – further impact categories which may be of relevance if SUNSET is implemented in another context in the future. This alternative context may mean that SUNSET may form part of a wider policy agenda aiming at reducing congestion or CO_2 emissions or increasing safety and well-being. Therefore Table 3.5 should be reviewed under this prism and should be extended based on the relevant wider local policy objectives.

Table 3.5: Examples of additional impacts that may be included in a CBA (e.g. if SUNSET is implemented in another context)

Integration costs			
integration with a PT provider	8 hours x 30€ = 240€	person hours	Basic IT employee rate working for 1 day. PT stands for Public Transport provider e.g First or Arriva in Leeds.
Customisation costs			
any relevant legislative reforms	24 hours x 50€ = 1200€	person hours	Local policy makers, legislators and legal advisors working for 3 days. This may be relevant if issues of data collection, storage and sharing are not specified.
Installation costs			
software investment	1,150 €	€	It is assumed that all parties will already have basic software. However, further software e.g. ArcGIS may be required for analysis and evaluation.
Operating costs			
hardware maintenance	80hrs x 25€ = 2000€	person hours	Various additional hardware may be included here depending on local context e.g. cameras maintenance.

Table 3.6 provides a more detailed breakdown of user costs in the main SUNSET Living Lab in The Netherlands i.e. Enschede. It offers an insight of essential user costs for two types of users: i) a basic user who has only basic smartphone functionality e.g. HTC Wildfire (many other basic smartphones are in widespread use and may have some variation in costs) ii) an advanced user who has advanced smartphone functionality e.g. i-phone 5 (other high specification smartphones are also available and suitable for use in this context). This is a more detailed breakdown of the cost/benefit impact category 7: User costs of Table 3.4.

Table 3.6: Basic and advanced SUNSET user costs in Enschede

	Impact	Estimation	Cost calculation = Indicator	Measurement unit	Assumptions / Comments
Basic					
1	battery consumption	2kWh/6 months	kWh x tariff	Euro's	
2	energy costs	350gr CO_2/kWh x 2kWh = 700			
3	contract/mobile data costs	€5/month x 6m = 30€	MB x tariff	Euro's	

4	device marginal upgrade/purchase/maintenance/insurance costs	€ 130	out of pocket costs	Euro's	It is assumed that all users have a mobile phone, so the cost of upgrading to a smartphone is the marginal cost. NB: HTC Wildfire S compared to Nokia 100. It is reasonable to assume that not everyone will have a smartphone and be able to use tripzoom. Therefore two basic categories of users have been used to illustrate indicative users costs.
Advanced					
1	battery consumption	2kWh/6m	kWh x tariff	Euro's	
2	energy costs	350gr CO_2/kWh x 2kWh = 700			
3	contract/mobile data costs	€11,25/month x 6m = 67.50€	MB x tariff	Euro's	action price
4	device marginal upgrade/purchase/maintenance/insurance costs	€ 290	out of pocket costs	Euro's	It is assumed that all users have a mobile phone, so the cost of upgrading to a smartphone is the marginal cost. NB: HTC Sensation compared to Nokia C2-O2. The assumption is that **one** of these 2 categories will be used (ie either the Basic or the Advanced user) as input for the CBA in Table 3.4.

Naturally, the local context, demands and prices vary between the Living Labs and different locations, yet this is an indicative outline for the generic SUNSET system user.

Table 3.7 demonstrates the revenues resulting from the introduction of the SUNSET system deriving input from D5.3 too. Again, certain assumptions have been made since SUNSET will be provided for free initially but may incur a charge in the future. Mini payments for example may produce a small revenue stream of 600€/year if 1€ is charged by the SUNSET system per transaction and 50 transactions take place each month e.g. to offer individual bike hire or off street car parking place. A considerable revenue stream may arise through the integration of the SUNSET system with other existing digital services or smartphone apps. This could be transport related services e.g. public transport information provision, taxi sharing or other type of apps e.g. apps offering discounts to users. However, Table 3.7 is not conclusive at this stage and will evolve further during the Living Labs evaluation in D7.2-4.

Table 3.7: Illustrative Revenue streams

Data	10€ x 200usrs x	The managing authority

management/storage/sharing revenues	6m = 12000€	may generate revenues by sharing/managing/analysing SUNSET data *(abiding to the Data Management agreement)*. Revenues are estimated at 10€/usr/m.
Mini payments for user collaboration through social media	50 trnscs/m x 1€/trnscs x 6m = 300€	tripzoom users may offer parking space or bicycle hire through on-line payments *(any deriving legal issues need to be addressed and highlighted in advance in each LL)*
Integration with existing digital services revenues e.g. City Council portals, smartphone apps	10 lcns x 2000€/lcns = 20000€	Licensing revenues for the managing authority through collaboration with other smartphone apps.
Third party benefits e.g. increased turnover, higher employment levels	1000€/inctv x 10inctvs x 20% = 2000€	It is assumed that 1000€/incentive is the potential turnover increase and that firms operate at 20% profit.

These costs and revenues will be aligned for each Living Lab in section 8 and this will allow a better overview of the overall BCR of the deployment of the SUNSET system in D7.2-5.

In order to produce a clear summary of the distribution of benefits and costs of using the scheme, it is proposed that an Impact Summary Table is produced, as illustrated by Table 3.8 below. This brings together the more detailed calculations of impacts illustrated by previous tables and allows a clear summary of the distribution of costs and benefits by stakeholder type. The table is based on that given by Grant-Muller et al (2004).

Table 3.8: Impact Summary Table (IST) for SUNSET Benefits and Costs by stakeholder type

Present Value of Impact categirt (cost or Benefit +/-)	**User (i.e Traveller)**	**Local Managing Authority (e.g. Leeds CC)**	**Third Party 1 (e.g. local business)**	**Third Party 2 (e.g PT supplier)**	**(any other impacted stakeholders)**	**Row Total**
Integration						
Installation						
Operating						
Incentives						

Marketing						
Energy costs						
User time benefits						
… etc *						
Column Total:	**User Surplus**	**LGO surplus**	**..etc**			**Net Present Value**

(*a separate row is included for each cost or benefit category appropriate to the scheme)

To summarise, this chapter has introduced CBA and discussed its use within the transport and IT domains. In such, it has identified the strengths of CBA which have led to its wide use internationally, but it has also identified the known weaknesses of this method. Therefore, Table 3.4 has outlined all impacts which may be monetised, leaving all other impacts introduced in sections 4-6 to be evaluated alongside the CBA. Therefore, the subsequent sections (4-6) will discuss these additional impacts to complete the input (of sections 3-6) for section 7 which provides the overview of the SUNSET evaluation framework.

4. Sustainability assessment

4.1 Introduction

This chapter describes how to measure the sustainability performance of the urban everyday travel system. First (section 4.2) the concept of sustainability and sustainable development is described in terms of information monitoring, control, decision making, incentives and management. Next (section 4.3), the measurement of sustainability is introduced, with regards to measurements related to environmental impacts from resource use and emissions from the transport equipment, and with reference to the improved health individuals acquired from transporting themselves by for example walking or biking to work. The latter also of course has system level environmental, economic and social benefits as well. By combining the concepts introduced in the two first sections, section 4.4 presents the transport system approach to sustainability assessment of the SUNSET urban transport system and shows how the smart phone data sampling, the collection of travelers' data, the city dashboard, the incentives system and the travelers together establish a control system. In section 4.5 the previously introduced concepts are combined into a practical way to measure whether the SUNSET system does or does not lead towards sustainable development, within the boundaries of what can be controlled by the system itself. In practice this means that the system can assign values to distances travelled by different transport modes, and may incentivize changes towards transport modes with better sustainability performance, or to incentivize to motivate the maintenance of a behavior that already has a good sustainability performance.

4.2 Sustainability and sustainable development in the SUNSET context

Sustainability is used here as short for Sustainable development, which is a concept drawn in the Brundtland report in 1972 (UN, 1987). "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Within this context sustainable transport means that the urban transport system works well for all those that use it and are otherwise affected by its consequences, and that it also does not harm future generations.

Within the concept of sustainable development lie the three components of:

- *Economic development*, which means that there should be a sound economic system that satisfied economic needs,
- *Equity and social aspects*, which means that there should be a good quality of life for all people, and
- *Earth, nature and environment*, which means that resources should not be depleted, ground, water and soil should not be poisoned and biodiversity should be preserved.

In this chapter the second and the third of these components will be addressed, and they will be addressed as *Social* and *Environmental* respectively.

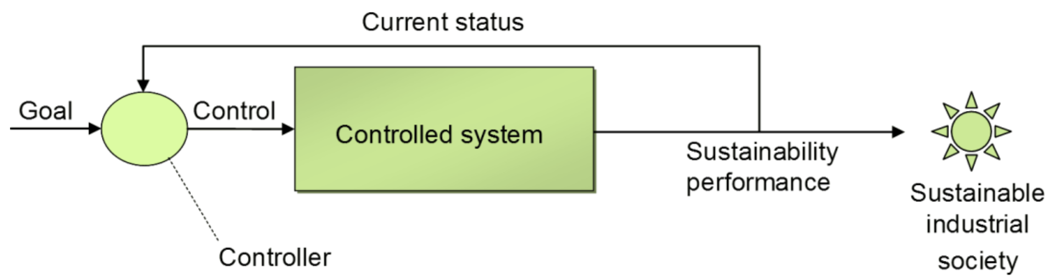

Figure 4.1: Sustainable development described as a cybernetic control model, a feed-back information system. The definition of sustainability as well as the performance of the controlled system is constantly changing. Feedback is constantly updated to inform the controller about how to control. (Carlson, 2006)

Figure 4.1 shows sustainable development as a cybernetic control model (Carlson, 2006). Sustainability is a visionary concept, and should not be misunderstood as an achievable goal. The concept is not static, but changes over time, and depending from which viewpoint one considers it. For example, from the viewpoint of automobiles and buses one may focus on fuel consumption and emissions, and from the perspective of bicycling and walking one may consider social aspects such as physical health, traffic safety and even equal rights to medical care, and for electric vehicles the focus may be shifted to electrical infrastructure, sustainable business models and effective recycling systems. Hence, the definition of sustainability is multifaceted, but depending on technological development, weather, pricing, industrial and urban development and other factors the sustainability performance of the controlled system change as well. Therefore, feedback continuously needs to be updated to inform the controller about how to control the system to achieve the best sustainability performance.

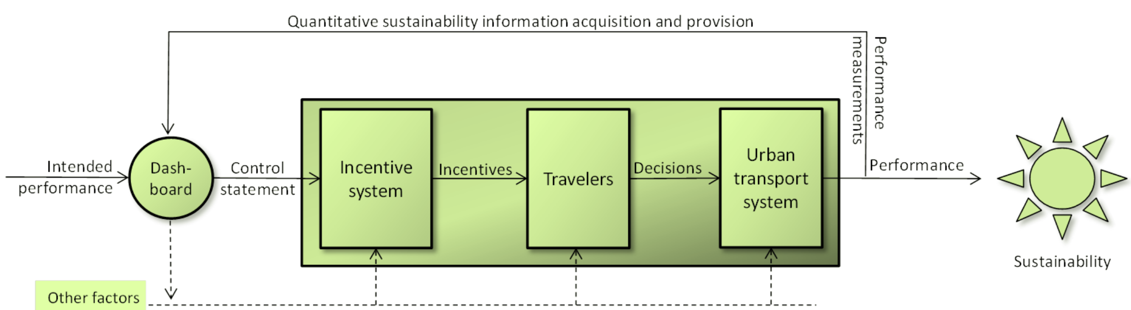

Figure 4.2 Sustainable development in the context of the SUNSET project. Sustainability is the moving target, the performance needs to be measured to provide decision makers with information about how to suggest incentives to improve the performance. But the system is open: Other external factors decide which incentives can be offered, how the travelers chose and how the transport system actually performs.

Figure 4.2 shows the general cybernetic model of sustainable development in the context of the SUNSET project. As for the general sustainability management, the sustainability performance of the urban transport system needs to be continuously measured to provide decision makers with information about how to suggest incentives to the travelers to improve the overall sustainability performance of the system. But there are two major differences. First, the controller is not actually controlling the urban transport system, but is only controlling which incentives to give to the users of the transport system. Having been offered these incentives, it is still up to the travelers to decide whether they will do as suggested or not. In fact, they are very free to choose, and they are open to receive any information or other signals in the form of other factors. Hence, the controlled system is clearly open and there is a somewhat voluntary relationship between the incentive system and the transport system. Hence, the sustainability assessment means to catch the sustainability aspects of both the urban transport system and of the incentive system, i.e. the sustainability effectiveness of the SUNSET incentive system.

There are many connections between the concept of sustainable development and the idea of incentivizing urban travellers to change their behaviour. In fact, the whole problem of sustainable development can be understood from this situation. Anyone may willingly change behaviour into what they feel better meet their needs. But most people do not voluntarily change into what they consider a worse way of traveling, even if they know that that would enable other people, now or in the future to better meet their needs. The idea of incentivizing people to make a better choice, from a sustainability point of view, means to somehow wrap the previously worse way of traveling, from the traveller's point of view, into a package that overall makes it a better choice. The actual way of doing this is not considered in this section, but it is important to mention that the incentives ranges from basically paying travellers to go by bus rather than car, to actually make all the changes to turn the bus ride into a better choice than the car, all aspects included. SUNSET incentives range somewhere between those extremes and incentives could include for example rebate coupons to bikers and bus riders, providing information about environmental performance of different traveling choices etc.

For the systems of incentives to make any difference it is important that the travellers can actually make real choices between alternative different modes of transports. It is also fundamental that the sustainability performance of the different alternatives can be measured in a consistent and meaningful way. If this is the case, it may be possible to measure the sustainability performance of different transportation alternatives, and by incentives suggest to a traveller to change or maintain his or her behaviour. It should be stressed that the SUNSET project does not take part in developing physical infrastructure or vehicles

4.3 Measuring sustainable traveling behavior

There are basically three difficulties with trying to improve the sustainability performance of an urban transport system by suggesting context targeted incentives to individual travelers:

1. To know which traveling mode each individual is using and what their options are or could be.
2. To know which incentive to provide to a traveler to make him or her change towards a 'more sustainable' alternative.
3. To know whether one alternative way of traveling is 'more sustainable' than another alternative.

Difficulty 1 and 2 are in SUNSET dealt with by innovating a new information system and by innovating incentive systems to be communicated through that information system (described in other SUNSET reports). Difficulty 3 is supported with information from the same information system difficulty 1 and 2 and the result of a sustainability measurement might also be communicated by this information system. However, this section will not discuss how the information system is designed, but touch some of the functionality needed to measure the sustainability of travel behaviour. The focus is on measurable sustainability entities for different urban personal transport alternatives. As described in section 4.1, sustainability is not a steady state, and therefore both the information system and the sustainability entities will be discussed in terms of a feed-back information system as the one presented in figure 2.

As stated in section 4.1 here the two components environmental and social aspects of sustainability are dealt with. How to measure these two entities will be presented in the following two sections.

4.3.1 Environmental measurement

Detailed environmental data for different transport modes are readily available in different databases. These databases typically include environmental data related to the transport of for example one person the distance of one km. The environmental data usually concerns fuel and energy use as well as emissions such as carbon dioxide, particles, nitrous oxides and sulphur oxides. Examples of databases with such data are the UK Defra database (Defra, 2013) and the Swedish NTM (Network for Transport Measures) (NTM, 2013) database. By use of these data it is possible to measure the total environmental performance of a transport. If the transport consists of several different transport modes different partial calculations may be added together.

As was explained in section 4.1 sustainable development is about the development of a whole system rather than the behavior of an individual. Therefore it is important to be able to calculate the total environmental performance not only of an individual transport or transport route but also of the entire urban transport system.

When performing detailed calculations about environmental impacts from different transport modes within urban areas, the following ranking between transport modes are achieved:

1. Walk and bike
2. Public transportation
3. Collaborative transportation solutions (car sharing, co-modality, etc.)
4. Car, moped, motorcycle

Of course this simple ranking does not take into account specific aspects such as extremely cold climate and long urban distances that makes biking and walking practically impossible, or the fact that there are electric cars, mopeds and motorcycles with much better performance than public transportation system, or that there are regions and cities where the public transportation is performed with very old buses and with very inefficient systems. But for regular European cities and towns the ranking is pretty correct.

In summary, to achieve a precise value the actual environmental measurement should be calculated for each specific situation, with each specific choice of transport vehicle, transport route etc, as well as with the performance of each alternative transport solution. But this is strongly dependent of the available data, such as data about choice of transport mode and equipment provided by the traveler or detected by the information system. The current SUNSET information system prototype is not yet capable of sufficient auto-detecting to identify such details that are necessary to calculate the actual performance of each vehicle. Hence, environmental performance is suggested later in this chapter to be based on the simple priority list above.

4.3.2 Social measurement

The social aspect of sustainability concerns equity, health and quality of life of people. This means that aspects such as the absence of physical or mental disease or stress caused by traffic congestions, accidents, noise, physical disability, insecurity etc. are of major concern for the sustainability performance of the urban transport system. In principle the SUNSET scope would allow to measure especially congestion, accidents and noise, and it would be pretty straightforward to develop social media solutions to create statistics about security issues and accessibility for disabled travelers. However, this is not yet within feasibility. It is, however straightforward to measure physical health from the exercise people get during their everyday traveling. Some people go by bicycle, and other people walk different distances between car parks and buses and trains and trams. This is measurable, and may be used as estimates for physical health.

Such estimates may be calculated from average calories consumption for specific walk distance and bicycle distances, and precision may increase if the speed is considered in the calculations, as well as if the individuals wish to provide data about their weight, and may be improved even more if they combine the data with for example heart rate monitors.

4.4 The approach to sustainability assessment

Figure 3 show the basic concepts included in the information system of SUNSET. By enabling very detailed data about a sample of urban travelers' behavior (the tripzoom users) the system is intended to support sustainable development of an urban traveling system. Figure 3 should be understood as being basically the same system as described in figure 2, but is intended to be more descriptive, and more aligned with the concepts dealt with in the SUNSET system.

The very detailed data from the tripzoom users is streamed as real time data into one data storage and recalculation unit. At that unit the position data is first interpreted into transport mode data, and is then recalculated into environmental performance. The actual environmental performance data can be directly calculated per individual. To calculate the environmental performance of the total urban transport system it is necessary to extrapolate the behavior of the individuals into the behavior of all travelers in the urban transport system. This extrapolation is mathematically and statistically straightforward, but it is here argued that currently it is probably more easily understood by decision makers and even provides more correct results to rather use the simple ranking presented in 4.2.1. to measure sustainability performance of users and of the system.

Depending on the sustainability performance of the total urban transport system decisions about how to shape the incentives market are taken. The incentives market enables a control function that can at any moment or position stimulate an individual traveler to change to a traveling behavior with better environmental performance (See Figure 4.2). The controllers of the incentives market can at all times both monitor the sustainability performance of the urban transport system, as well as be in direct contact with each individual traveler that uses the tripzoom app. Each individual then makes their own choice whether to accept or ignore the incentives provided by the incentives market (See figure 4.2). If the travelers accept the incentives and behave as the incentive market suggests, the system is intended to move towards a more sustainable development. Thereby the SUNSET system provides important components to actively guide an urban traveling system towards sustainable development, like the system described in figure 4.2.

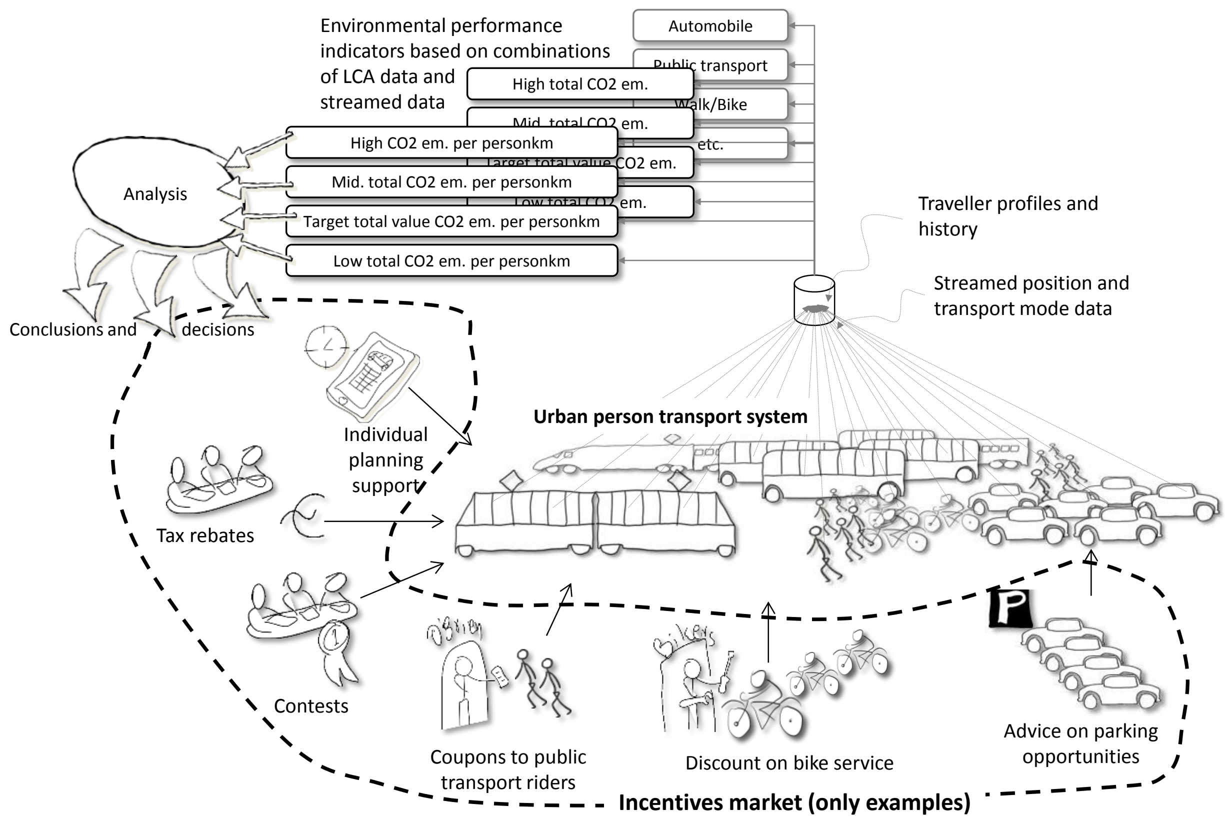

Figure 4.3: The SUNSET information system and its context, from its perspective of sustainable development of an urban transport system through incentives. (Carlson, 2012)

The system described in figure 4.3 can also be used to conclude where there are congestions, to enable estimations of the density of passengers on buses and trains, identify delays, decide where reroutes are necessary, and other relevant urban transport system properties. By such information the SUNSET system can provide individuals with for example context dependent planning support, offering personally designed incentives and providing individual sustainability performance calculations.

In short the objective of figure 4.3 should be understood as that the approach of SUNSET is to deliver a solution for a sustainable transport system that is on the one hand a goal at a high system level, the total urban person transport system shall move towards sustainable development for SUNSET to successful. On the other hand the SUNSET system aims at this high system goal by collecting real time information about detailed movements and behaviour about individual travelers. In addition, the SUNSET system aims to target these individual travelers at precise positions and situations with individually suitable incentives to move the system towards a high level system goal.

Another way to understand the SUNSET system in the view of figure 4.3 is that the SUNSET system is an eco-system. In the eco-system the travelers are continuously willing to provide data about all the details of their traveling. In exchange they are rewarded with incentives that they find valuable. These incentives are designed in such way that they attract the travelers towards a concerted behavior that turns the entire transport system to a sustainable development. Hence, figure 3 and figure 2 are the same.

4.5 Details on calculating sustainability performance of urban traveling

4.5.1 Calculation methodology

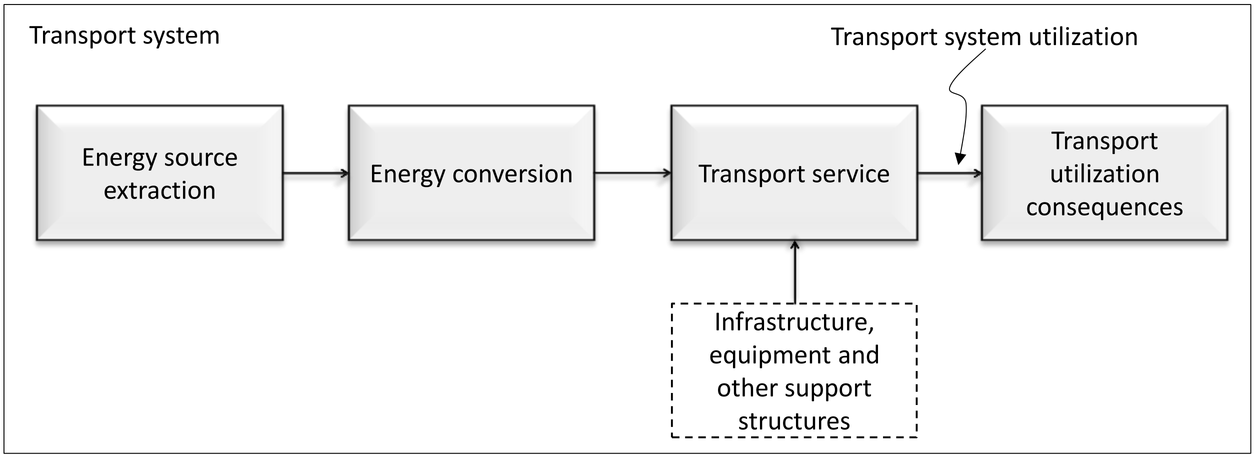

Figure 4.4. The transport system is more than just the actual transport service. Since transport is intrinsically dependent on its energy source an environmental perspective includes the Energy source and extraction, Energy conversion and the Transport service itself. It is acknowledged that a transport also impacts environment through its Infrastructure, equipment and other support structure, as well as through the Transport utilization consequences.

Figure 4.4 shows an overview of the total *Transport system* necessary to provide a *Transport service*, such a total urban transport service system, from the perspective of its significant environmental impacts. Since transports are intrinsically dependent of energy, transports and energy production are inseparable. Depending on whether the vehicle is driven by a combustion engine or fuel cell or whether it is propelled by electricity the *Energy source extraction and the Energy conversion* systems have different environmental significance. In a comprehensive study of the transport system it is relevant to include also the *Infrastructure, equipment and other support structures*. In this project it is also relevant to look at the *Transport utilization consequences*, since they have significant impact on the social aspects of sustainability.

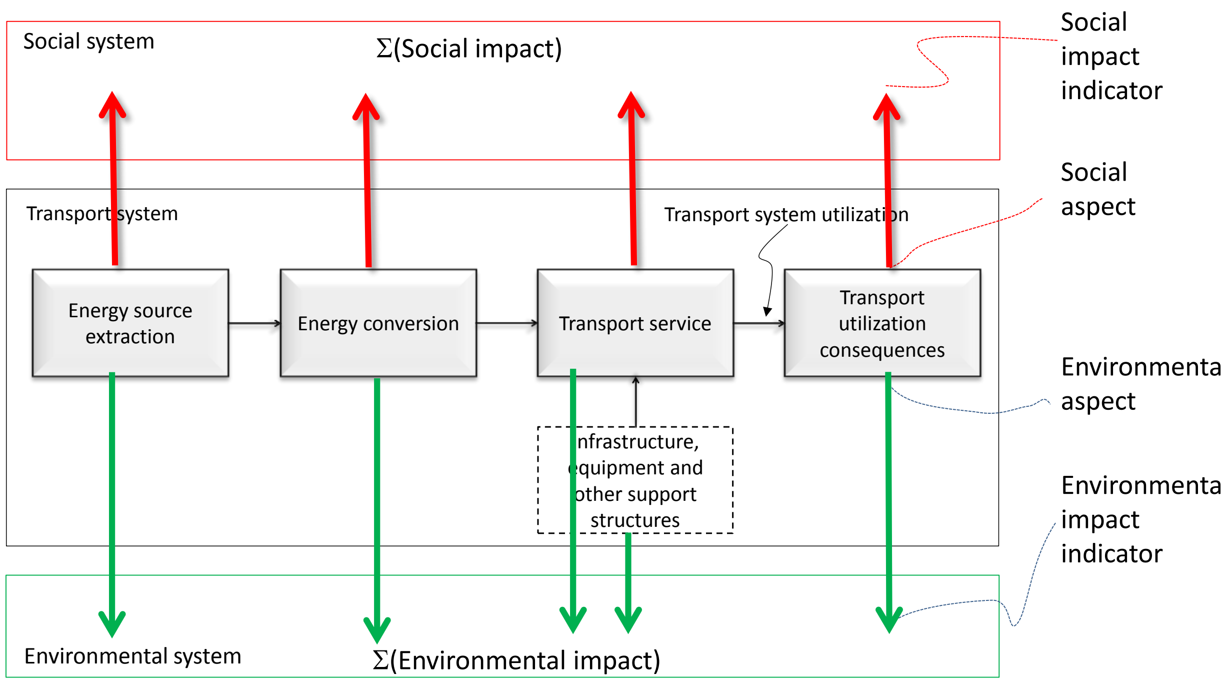

Figure 4.5: The absolute sustainability performance of the Transport system is calculated as the sum of all social social impacts and all environmental impacts.

Figure 4.5 shows a simple conceptual view of how to calculate the absolute sustainability impact of the transport system. The impacts from all environmental and social aspects are summarized to a total impact. A list of normalized absolute impact values may be described as a list of the different impacts, like in the Table 4.1 below.

Table 4.1. An example list of sustainability impacts of a transport service

Impact	**Amount**	**Unit**
Carbon dioxide emission	15	kg/trip
Particles (PM10) emission	15	pg/trip
Congestion stop time/Total travel time	12	%/trip
Calories burned	150	kCal/trip

Another way to present the absolute sustainability value of the total transport system, is to attempt to assign different weights to the different impact values. There are different priority and weighting systems available for environmental impacts. Some of those are based on estimations of social and other external costs. To produce a good weighting system, a combination of scientifically objective severity and a policy oriented prioritization method should be used. In this is example, it is likely that a city government would most highly prioritize the impacts in the following order, here without assigning the different any numerical value:

1. Congestion stop time/Total travel time
2. Particles (PM10) emission
3. Carbon dioxide emission
4. Calories burned

This ranking may be interpreted as that first of all the traffic problems must be solved, and then the city air quality problems, then the global problem of carbon dioxide. And maybe it is up to the citizens themselves to take care of their health, but the city may encourage them. A good urban transport system service system solves all of them, and seeks to optimize them all. This is the objective of SUNSET. It is made by suggesting individuals to change their traveling behavior.

Figure 4.6 describes how to measure the sustainability performance of a change in traveling behavior, i.e. not the absolute behavior, but the impact from a change. This means that it intends to describe how to measure the momentary sustainable development performance of the transport system.

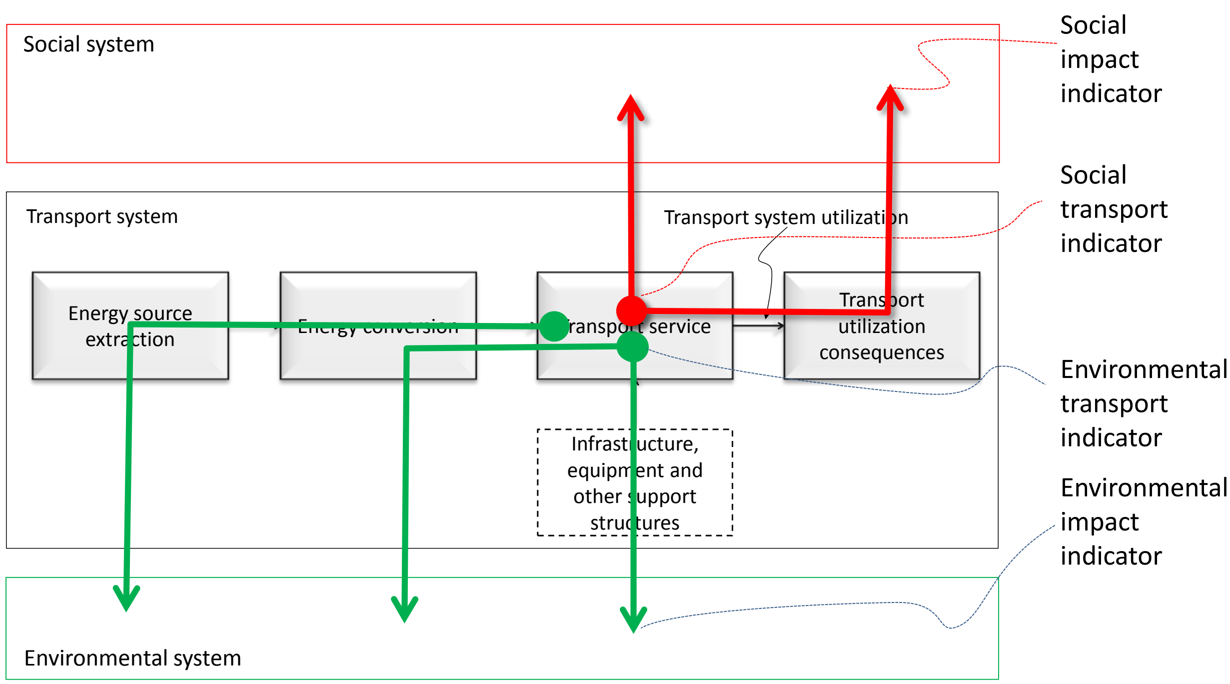

Figure 4.6. Conceptual view of how to measure momentary sustainable development of a transport system by using social and environmental transport indicators.

Figure 4.6 shows how the measurement of specific transport related indicators can be used to measure changes in the specific environmental and social impact indicators chosen. This means that to measure the sustainable development of the transport system it is not necessary to measure the absolute or total environmental and social impact from the transport system, but rather to measure its changes. It is of course necessary also to measure the absolute sustainability performance of the total and to set improvement goals as this level as well, but the SUNSET system is not aiming at changing the transport system itself, but rather to improve the performance of the utilization of the actual system. Hence, only the improvement effectiveness needs to be measured.

4.5.2 Simplified calculations due to transport system inflexibility

4.5.2.1 Simple categories for limited information of choice of transport modes in an inflexible urban transport system

As conceptualized in figure 4.6 there is a direct relationship between the choices that the travellers make and the environmental and social impacts from the total transport system. But the strength of this relationship depends much on which choices those travellers make as well as on the set up of the transport system. To clarify this, using a short time scale, a number of examples will be given.

- **Public transport system**: A public transport system that consists of buses, trains, trams and metros with regular time tables is insensitive to individuals' day to day choices. There is always sufficient capacity marginal to take more passengers aboard. This means that the overall transport system has a stable sustainability impact, pretty independent of whether there are more or less passengers using the system.
- **Motorized personal vehicles**: The total fleet of motorized vehicles in an urban region is pretty much the same, which means that for example an individual car has pretty much the same sustainability impact as any other motorized personal vehicle. Of course, this is not true for electrically propelled motorized vehicles since they are more energy efficient and also do not contribute to the urban air quality problems. But the general traffic behaviour with congestion etc. is pretty much the same. Hence, since the motorized vehicle fleet is pretty homogenous with a very small share of significantly environmentally friendlier vehicles, it may be argued that they are all the same. On the other hand, if sufficiently high quality data is easily available, it is better to distinguish motorized personal vehicles as:
    - **Number of riders**: Since the utilization ratio of a vehicle effectively increases the efficiency by a multiplication of the number of riders, this figure is highly significant to judge the sustainability performance of riding a motorized personal vehicle.
    - **Combustion engine or electric motor**: The shift from combustion engine to electric motor gives a radical shift in sustainability performance for personal vehicles. Hence, if it is possible to distinguish which sort is used, this gives a substantial difference in calculation of sustainability performance of travellers' individual choices.
- **Manpowered transport**: Since the sustainability performance between people transporting themselves by manpower is considerably both different and much higher, it is important to be able to be able to distinguish this type of transport from other alternatives.
- **Avoiding physical transport**: The transport change that both generally leads to the strongest sustainability performance improvement as well as is most difficult to detect, is all sorts of avoided transports. This may include video conferencing instead of travelling, working from home, moving closer to work etc. It is anyway important to include this type of behavioural changes in the overall calculations of transport system sustainable development.

4.5.2.2 Calculations for management of sustainable development of with limited information about choice of transport mode in an inflexible urban transport system

This section considers the overview of the SUNSET system as described in figure 4.3 and the simplification of categories of an urban transport system as described in the previous section.
The SUNSET system of incentives is intended to motivate travellers to make their travelling choices so that the overall system moves towards sustainable development, as this is described in section 4.1. This means that users shall be motivated to go by public transportation or use manpowered transportation means, or avoid traveling altogether. It also means that users shall be motivated not to use motorized personal vehicles. However, if they use motorized personal vehicles they should be motivated to go together. This means that a meaningful assessment of the sustainability performance S of the urban transport system may be conceptually calculated as:

S = (Number of travelers changing from *Motorized personal vehicles*) + (Number of travelers changing to *Public transport system*) + (Number of travelers changing to *Manpowered transportation*) + (Number of travelers changing to *Avoiding transportation*)

However, since this conceptual formula will not really provide a numerical value, a more mathematical and technical realization of this conceptual formula will follow in the next subsection.

4.5.2.2.1 Detailed calculation methodology

Since the sustainable development is measured as a change over time, it is necessary to define the reference or starting point and the end point:

Actual time: t_1
Reference or starting time: t_0
The sustainability performance between starting point and reference point is then written as: $S0_{0 \rightarrow 1}$

This means that there need to be a measurement made to quantify number of travellers at the starting point t_0 using these different transport modes, and one measurement at t_1.

Sustainability performance may actually be measured as some interpretation of these changes in transport modes, but the result of each calculation will then need to be interpreted each time. An alternative way to calculate, which requires more preparations, but which makes it much easier to make quicker use of the result, is to quantify the different priorities that the overall transport system manager gives to different aspects of the travellers' travel behaviour changes. For example, if the public transportation system has a large over capacity then it would be important to strongly prioritize changes towards public transport systems, and if traffic congestion and air quality problems are high, then it would be motivated to highly prioritize changing from motorized personal vehicles etc. The following list gives different variable names to the different priorities that may be given to the differently desired travel behaviour changes. In the next section these calculations will be shown in an example.

Priorities to different travel behavioural changes, based on environmental and social impacts respectively:

- Priority given to environmental impact of Public transport: P_{EP}
- Priority given to social impact of Public transport: P_{SP}
- Priority given to environmental impact of Motorized personal vehicle: P_{EPV}
- Priority given to social impact of Motorized personal vehicle: P_{SPV}
- Priority given to environmental impact of Manpowered transportation: P_{EM}
- Priority given to social impact of Manpowered transportation: P_{SM}
- Priority given to environmental impact of Avoided transportation: P_{EA}
- Priority given to social impact of Avoided transportation: P_{SA}

S_1 = (P_{EP}- P_{SP})*(Number of travelers changing from *Motorized personal vehicles* between t_1 and t_0) + (P_{EPV}- P_{SPV})*(Number of travelers changing to *Public transport system* between t_1 and t_0) + (P_{EM}-P_{SM})*(Number of travelers changing to *Manpowered transportation* between t_1 and t_0) + (P_{EA}-P_{SA})*(Number of travelers changing to *Avoiding transportation* between t_1 and t_0)

Though the formula is long in print, it is simple. It is also intended to be simple to acquire data calculating the formula by the use of the SUNSET system. However, it will be difficult to identify the 'correct' priority values. These are based on a combination of the understanding of the scientifically based urgency for different sustainability issues, as well as on politically formulated policy based on citizens' willingness to pay. Regardless of the complexity of this priority setting they are important, and it is recommended that such values may be 'played with' in the 'City dashboard' of tripzoom.

4.5.3 Examples of indicators and examples of calculation

In this section an example of indicators and calculations is presented. The example is based on the combination of the calculation methodology described in section 4.4.1 and the overall SUNSET approach to sustainability assessment described in section 4.3. Hence, the prioritization weights described in section 4.4.1 is here more transparently referred to as "Priority to avoid environmental impact" and "Priority to avoid social impact" from the same simplified transport categories as presented in section 4.4.2.2.1.

Table 4.2. Policy maker's decision as to how to prioritize avoidance of different sustainability from different transport categories.

Transport category causing sustainability impact	Priority to avoid negative environmental impact	Priority to avoid negative social impact
Public transport	1	1
Motorized personal vehicle	10	10
Manpowered transportation	0	-10
Avoided transportation	-1*Alternative	-1*Alternative

Table 4.2 show a simple policy example, where the policy maker has decided that the public transport is the norm, and that it therefore have priority '1' both to avoid environmental impact and social impacts. The policy maker is aware of that even the public transport system has both an environmental and a social negative impact, and therefore assigns the priority value '1' to both these impacts. Note that this is not purely scientifically based, but is based on a subjective reasoning paired with a policy strategy. The Motorized personal vehicle has at least 10 times as much energy demand than public transport, and a reasonable priority factor to avoid environmental impact from this transport category therefore is 10. The factor 10 as priority for negative social impact has no scientific basis, but since motorized personal vehicles both causes traffic congestions, noise, air quality problems as well as health problems due to lack of exercise, a figure 10 may be reasonable to start with. Since Manpowered transportation has almost no environmental impact compared to motorized alternatives, it has the value '0' for priority to avoid its negative environmental impact. At massive scale the social environmental impact from walking and bicycling is strictly positive with regards to congestion, air quality, noise and health

issue. Therefore it will be encouraged, which means that there is a negative value, '-10', to for priority to avoid. (It should be noted, however, that if the air quality, the noise and the traffic safety are bad, these unprotected transportation means may in fact be dangerous to the health.). The most difficult value to measure, but with a high impact, is the Avoided transportation. Though the actual environmental and social negative impacts form any person who stays at home are the, the consequence is rather different depending on which transport category that person usually takes. If the person generally uses a car, the consequence from staying home one day is ten times larger than if the person usually takes the bus. But if the person generally walks or takes a bike, the environmental consequence is the same, while the social impact might even be 10 times worse, due to the lack of exercise that person gets.

This example is not intended to be scientifically rigid or in line with a specific policy, but it is intended to exhibit the important issues with policy setting.

Table 4.3. Calculation of trip examples with priority values from Table 4.2.

Transport category causing sustainability impact	Route 1	Route 2	Route 3	Route 4	Route 4 stays home	P'y environ-mental	P'y social	Route 1		Route 2		Route 3		Route 4		Route 4 stays home	
								Env	Soc	Env	Soc	Env	Soc	Env	Soc	Env	Soc
Public transport	25	0		20		1	1	25	25	0	0	0	0	20	20	-20	-20
Motorized personal vehicle	0	25,9		6		10	10	0	0	259	259	0	0	60	60	-60	-60
Manpowered transportation	1	0,1	26	0		0	-10	0	-10	0	-1	0	-260	0	0	0	0
Avoided transportation					1 day	-1*Alternative	-1*Alternative									0	0
						Sustainability priority		Total	40	Total:	517	Total:	-260	Total:	160	Total:	-160

The calculation examples in Table 4.3 show how the priorities to avoid negative environmental and social impacts from a 26 kilometre route that can be made with different transport categories can be used to quantify how to prioritize incentives towards a changed behaviour. The yellow bottom line shows the total sustainability priority value for each different transport route, i.e. each different set of transport categories.

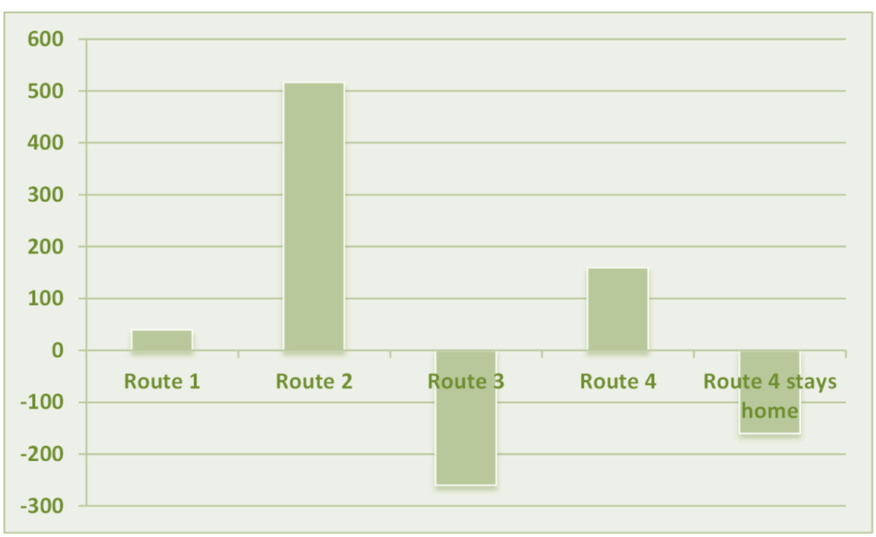

Diagram 4.1. The total sustainability priority result, the bottom line of Table 4.3.

4.6 Summary and conclusion

This chapter first clarifies that sustainability means sustainable development, i.e. which means that the system steadily improves towards its defined sustainability goals. The chapter shows how the SUNSET system can be used for management of sustainable development of an urban everyday travel system. In section 4.3 a general description is given of how to calculate the total sustainability performance of the urban travel system and in section **Error! Reference source not found.**, detail is given of how such calculations of the sustainability performance of a total urban travel system may be performed. Section **Error! Reference source not found.** stresses that it is not possible to use the SUNSET system to improve the sustainability performance beyond the capability of the actual physical limitations of the urban travel system, but that the SUNSET system may be an aid to improve the performance within these limitations.

Figure 2 in section **Error! Reference source not found.** shows that the SUNSET system may only give weak control functionality to the entire urban travel system since there are many other sources of control 'noise' in the system. But the actual degree of the strength or weakness of the control function is due to how successfully the travellers are incentivized to utilize the SUNSET system. Figure 3 in section **Error! Reference source not found.** describes the total SUNSET system, and it shows how the urban travellers are both providing the necessary information about how they behave and respond to incentives.

In section **Error! Reference source not found.** it is shown how the responses of the SUNSET system users can be used to measure the sustainability performance of the urban travel system. This measurement is based on the facts that 1) sustainable development means improvement towards sustainability goals (such as fewer cars, more utilization of public transport systems and more transport by muscle power), 2) policy setting and prioritizations (in a quantitative way) towards the wanted goals, and 3) measurement and incentivisation of behavioural changes or endurance. The chapter concludes by showing how such calculations can be set up by travellers' behavioural and responses data provided by the SUNSET system, and with policy setting of values and weights through the city dashboard.

It should be stressed that the system can work in a strictly technical sense if it is designed in this way, but it is necessary that the travellers consider the incentives as highly attractive so that they actually respond as intended and so that the SUNSET system can have an impact on the system overall. It is also necessary that the SUNSET system data collection and recording process is of high quality, so that the travellers may trust the system. A non –referenced statement by late founder of Apple Computer Steve Jobs, is the 90-90 rule: If the quality is 90% correct then 90% of the users will find it satisfying.

5. Assessment of Safety

There is a distinction between the 'Safety' impact of transport schemes and the 'personal security' impact – this section focuses on the former whilst the personal security is addressed in chapter 6. Safety impacts are defined here in terms of accidents (on the road or other mode). The scope also does not reflect possible safety consequences from use of the devices themselves ie through distraction whilst walking or use whilst driving (which is not how the system has been designed and is not advocated), (Kujala, 2012, Wesley et al 2010, Richtel 2010). Whilst the SUNSET system has not been developed with the singular focus of improving safety, it is anticipated that some safety impacts will be generated. The goal is that there should certainly not be deterioration in safety from using the system and that SUNSET should operate in such a way as to improve safety where possible.

SUNSET has behavioural change and smarter transport choices at the heart of the system. The safety impacts that arise will result from changes in behaviour that involve: mode switch (for all or part of the journey), a decision to stay at home rather than travel, amending the time of travel and diverting to an alternative route. The evaluation challenge is therefore how to assess the safety impacts with diffuse safety impacts, different sources of dynamic data where established evaluation procedures may not be inappropriate.

Five established approaches are used for assessing safety impacts around new schemes in the transport system in general. These can be summarised as: accident modelling, system level monitoring, causal monitoring, Time To Collision (TTC) and exposure studies. Variations on these methods exist, but according to Kaparias and Bell (2011), 'The most commonly-used performance indicators of traffic safety are: accident rate; number of fatalities; number of injured; and economical damage'. Each of the five main methods are therefore seeking to estimate changes in these indicators following the introduction of the scheme. A brief overview of each approach and the relevance to SUNSET follows.

Accident modelling involves the use of a micro or macro simulation model for the site of the new scheme and close surrounding area. The model is calibrated for the current ('before') transport state and effects of the new scheme simulated within the constraints of the features of the model (Wismans et al, 2011). This approach is not well suited to the SUNSET scheme as it does not operate within a fixed-location site and the impacts (positive or negative) are generated across a series of micro-changes in transport choices across a number of modes and locations by the individual. At present a model is not readily available that may be adapted for use for assessing safety impacts in SUNSET, so this approach is not included in the recommended evaluation method here.

System level monitoring (Hauer 1997, Hauer 2002) is almost always used for significant sized transport infrastructure projects (inter-urban highway improvements) and also frequently used for smaller and more localised urban transport initiatives (eg installation of road crossing points, introduction of new bus lane). Changes in safety are usually evaluated by long term monitoring of (fixed location) sites before and after introduction of the scheme. The recommendation is that monitoring for at least a year before introduction of the scheme and at least a year after introduction of the scheme is needed. In practice a longer period of say three years before and three years after may take place for a larger scheme. The total number of accidents, by severity, are recorded and a statistical model used to determine whether any observed change is significant or has arisen by chance. The best approach for the observational "before and after" studies of this type is a combination of a multivariate generalised linear model and the Empirical Bayes (EB) method. However, this approach is also not suited to the SUNSET scheme – the long monitoring periods needed (particularly 'before' use of the system) are not feasible and the standard method of accident recording (through police or recovery records) is unlikely to register any link between the accident and use of the SUNSET system. As a result, this approach is not included in the recommended evaluation method here.

Causal monitoring of safety is used in micro-level studies of individuals' activity and behaviour (Brebbia et al 2005). It is a technique that involves very close logging of each days' activities over a period of time, including accidents that happen of any degree of seriousness. It is normally undertaken with a relatively small number of participants who are asked to keep an activity diary. The change in safety is measured by the change in the observed number of accidents (by severity, including near accidents) after the introduction of a scheme. This is a labour intensive approach with a non-trivial workload and commitment needed by the participants. As the SUNSET living labs are aimed at larger groups (50-200+), where the aim is to minimise participant workload ie with as much 'automatic' data collection as possible, this approach is not included in the recommended evaluation method. However in principle, the approach of micro level reporting would be appropriate for use in a study with a small cohort over an extended period of time.

Time to Collision and the related conflict analysis approach (Ben-Akiva et al, 1999, Laureshyn, et al, 2010) is an approach used to understand safety impacts for fixed location schemes. It involves a period of monitoring and analysis of a particular site where a record is kept of 'near misses' and an estimate of the time gap in seconds before an accident would have happened if averting behaviour had not taken place. Video cameras may be used for recording the activity at the site (or sometimes manual recording is used), but human analysis is needed to judge whether a collision may have been due to happen and to estimate the time to collision. As a result, this method is labour intensive – a period of before and after monitoring is needed. This approach is most frequently used for schemes implemented at fixed sites, particularly urban junctions, but increasingly at interurban sites including points of merge and diverge. For the purposes of SUNSET this approach is not appropriate – the safety and other impacts of the scheme will be in distributed locations and as a result it is practically not possible to establish a priori where these may be and introduce video or other monitoring. As a result, this approach is not included in the recommended evaluation approach for SUNSET.

The final method is one of exposure modelling and this forms the basis of the approach proposed for the SUNSET system. The method will not seek to measure or model changes in accidents for users of SUNSET – given the pervasive technology in use and potentially wide geographic area of study that would be wholly impractical. Instead, the change in exposure to accident risk is measured – for example the increase or decrease in risk when the SUNSET user switches mode for all or part of the journey, or changes the route taken in response to an incentive offered. A summary of the method is outlined below.

5.1 Outline of exposure approach for estimating safety impacts

The general principle of the approach is described in Figure 5.1 below. The method is based on the notion that the individuals journey can be broken down into stages with an accident risk attached to each stage, an approach which is consistent with that of Dijkstra (2011), who looked at accident risk by road classification. From figure 5.1 the accident risk (1) is generated from historical safety records ie static data on accidents of different degrees of severity, by mode, from a centralised source. Through the mobility profile in SUNSET, the number of km travelled by the individual in each stage of the journey will also be known (2). This is dynamic data collected automatically by the system. In response to incentives of different types, the mode may change, the number of km travelled (overall or by particular modes) may change and the route taken may also change, for example to avoid the most congested route. Multiplying (1) with (2) provides an indicator of the exposure to risk for each stage of the journey by accident severity by km travelled. This may then be weighted by either the economic cost of each accident severity, or (for policy development) by locally derived weights – for example around policies for high risk modes or routes (3). The overall safety cost indicator is then given by the aggregation of the individual stages (4).

This calculation therefore results in an individual safety indicator that can either be monetised and interfaced with a traditional CBA approach or can be reflected as a safety indicator using weights that can reflect system objectives and priorities. The approach uses a mixture of system level data that is created routinely and data that can be collected through pervasive devices automatically. Safety can be evaluated on either a 'within-subject' scale (by aggregating all journey scores for a particular individual), or at the level of aggregation of particular socio-economic groups of individuals, or by aggregation of all participants in the scheme. The change in safety impact due to the SUNSET system can then be measured using either the monetised indicator or the policy weighted index and comparing the value before introducing the scheme with that after introduction of the scheme, for example after the introduction to a particular incentive.

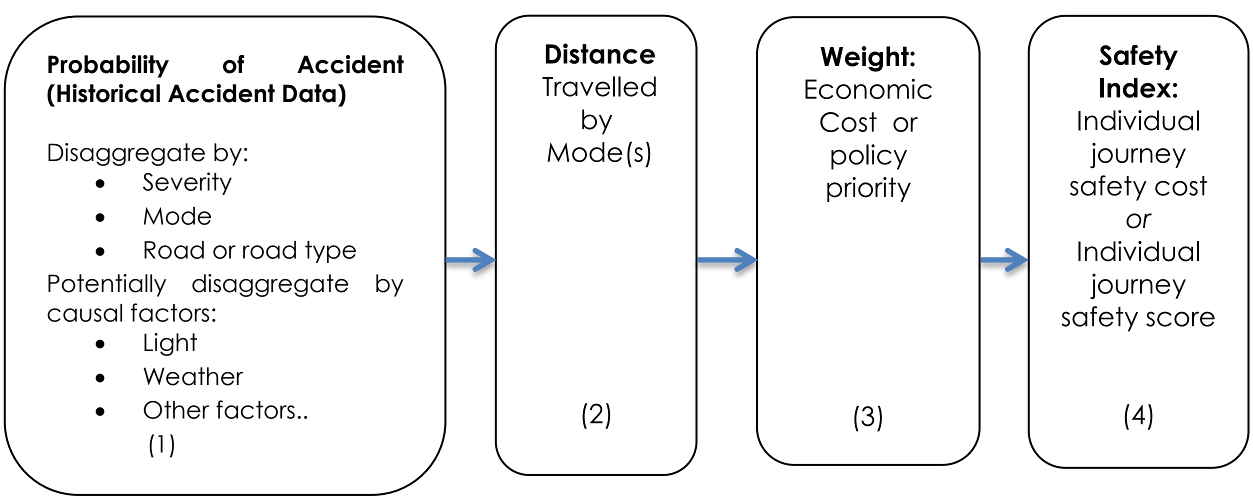

Figure 5.1: Calculation of exposure based safety index or safety cost

More formally, this may be expressed as equation (5.1)

$$\text{Marginal safety cost for trip} = \Sigma\, w_k w_j (\Sigma \text{sev.rate}_{i,j} * w_i) * km_j \qquad \text{...........(5.1)}$$

Severity category i, mode j

W_i = weight for accident severity category, with default value = economic cost for accident severity $_i$

W_j = mode weighting for mode j, with default weight for all modes = unity

W_k = link or spatial segment weight, with default weight for all links = unity

For an *ex-ante* appraisal of system level safety impacts of a scheme: the safety index (estimated for the base year transport pattern aggregated over trips) is compared with the estimated safety index following scheme implementation. The target behavioural change is used with either base year accident rates (or a trend estimate of accident rates) by severity. The nature of the scheme and expected lifetime of impacts determines which is appropriate. In this case the economic cost of accidents as a weight would allow interface of the index with a wider CBA if appropriate

This approach to evaluating safety impacts is flexible in terms of the level of data available to calculate exposure. Where very detailed local historical accident data is available from police or official records, a good estimate of the exposure can be derived for a range of road types in and around the study area. Where this isn't available, the method may still be used to give more broad brush estimates of safety impacts using either representative national accident rates for particular road types and modes, or even (in extremis) EU rates from published statistics. However the more accurate the external historical accident data used to calculate exposure, the better the estimate of safety impacts from the scheme.

A summary of how this approach may be applied flexibly according to the evaluation goal and data available is given in Table 5.1. Alongside variation in the input accident risk, the weights used for the final stage of aggregation may also be varied. For example, if a local authority had a policy priority around reducing motorcycle accidents, then in application case 4 an analytic hierarchical weighting process (AHP) may be used to generate policy weights rather than using the economic cost.

Table 5.1: Application cases for exposure method to assess safety

Application case	Accident Risk data	Weights	Context driven Index calculation
1	National (aggregate)	Weight based on economic cost	Aggregation over a number of travellers. Supports comparison between the base case/ Business as Usual and scheme implementation in economic appraisal
2	Regional (county)	Weight based on economic cost	Aggregation over a number of travellers. Supports comparison between the base case/ Business as Usual and scheme implementation in economic appraisal
3	Local (link level)	Weight **based** on economic cost	Aggregation for an individual traveller, supports evaluation of changing personal cost and goal achievement with behaviour change
4	Local (link level)	Weight based on AHP	Aggregation over a number of travellers, supports evaluation of local policy priorities

In the case of the SUNSET living labs, both a specific corridor/route will be targeted with incentives and a broader geographic area may be impacted by use of the system. As a result, the calculation of the safety impacts will need both specific historical accident rates for the corridor and accident rates for particular road types that may be used as representative for a broader urban area.

5.2 Example data and calculation

A more detailed discussion of how the safety index will be calculated in the SUNSET living labs is given in chapter 8, however for the purposes of illustrating the method, an example calculation and example data is given here.

Table 5.2 provides example accident data for Great Britain based on nationally collated statistics. The data represents average casualty rates per passenger/billion/km, corrected for multi-occupancy vehicles. The data in Table 5.2 are cumulative, so that category Killed or Seriously Injured (KSI), includes the data for Killed and the category All includes Killed and KSI. As can be seen from Table 5.2, there is considerable variation in the casualty rates between different modes and as result, the types of mode change encouraged by the SUNSET system – and the number of Km travelled by each mode - may change the expected safety impact substantially. It is also worth noting that without personal mobility monitoring such as that produced with SUNSET, this type of analysis would not be possible without very detailed travel diary recording by individuals of the exact km travelled and routes travelled by particular modes. Due to participant workload involved, in practice this type of very detailed journey data has been rarely produced in scheme assessment. Indeed at the time of deliverable production it has not been possible to find published examples of previous studies with data that would support this approach.

Table 5.2: UK Passenger Casualty rates by Mode: 2001-2010 (TSGB, 2011)

Bus or Coach	
Killed	**0.3**
KSI	**9**
All	**162**
Car	
Killed	**2.3**
KSI	**22**
All	**275**
van	
Killed	**0.7**
KSI	**7**
All	**71**
Motorcycles	
Killed	**100**
KSI	**1,174**
All	**4,345**
Pedal Cycles	
Killed	**28**
KSI	**556**
All	**3,732**
Pedestrian	
Killed	**35**
KSI	**394**
All	**1,773**

Table 5.3: example severity rates and safety costs for bus and coach

Severity rate (for bus or coach)	Expected safety cost/Kmbn (scale to Km travelled by mode)	Safety cost as relative weight
0.3	1650000	0.87
8.7	235100	0.12
153	18600	0.01

In Table 5.3, for the bus or coach mode alone, these have been translated into severity rates (without accumulation) and an example of the economic cost for each category of severity. In practice in the LL the calculation should be made for each mode used in order to subsequently calculate changes in exposure. In the second column of Table 5.3, an example of the economic costs for each severity type is given. These data apply to the UK only and are based on the EU funded IMPACT study (CE Delft, 2008, Maibach et al.). However the study generated a set of national costs for externalities for most EU countries (values given in €2002). The study also generated representative EU costs with more generic applicability where data may not be available and this level of calculation is acceptable. Where more recent or more accurate data may be available, this should be used instead. The data given here are in expected costs per Kmbn and so in practice should be converted into the cost for the km travelled by the system user by the mode (eg 10km, 20 km etc). Where the safety impacts are forming part of a CBA calculation, these can be used to give an estimated safety cost before and after scheme.

implementation by aggregating the total Km travelled by the mode. Where the safety impacts are assessed as part of an MCA, the costs can be taken as relative weights as shown in column 3 of Table 5.3 and used to generate an index value.

Table 5.4: example severity rates bus/coach and pedestrian

Severity category	Severity rate (for bus or coach)	Severity rate (Pedestrian)
Killed	0.3	35
KSI	8.7	359
All	153	1379

Table 5.4 gives corresponding values between bus and walking (pedestrian) modes. As an illustrative example only, and assuming the same accident costs for each of the two modes (which in practice may not be the case, as vehicle recovery costs may be lower for a pedestrian accident for example), a change in journey from a 22km bus only mode to one which comprised 20 km by bus and 2 km walking would generate the following change in safety cost:

(i) 22 km bus journey safety cost =
(22/1,000,000,000)*((0.3*1650000)+(8.7*235100)+(153*18600))

= 0.1185€

(ii) 20 km bus journey safety cost + 2 km walk cost

((20/1,000,000,000)*((0.3*1650000)+(8.7*235100)+(153*18600))+
((2/1,000,000,000)*((35*1650000)+(359*235100)+(1379*18600))

= 0.107723€+2.316506€ = **2.424229€**

It can be seen that the change in mode is reflected in a higher expected safety cost. However it should be noted that as part of a whole cost benefit analysis, the cost of pedestrian accidents is likely to be lower and other savings eg in travel time, health benefits from walking, should also be considered.

Further examples of safety data are given in Appendix A. A1 illustrates the format and type of data that will be available for use with the Enschede living lab, which is entirely consistent with use of the approach outlined here. A2 gives some further examples of the economic cost of accidents from different countries and for specific modes. This type of data may be useful in estimating relative costs between mode types where no accurate data exists.

To summarise, the estimation of safety impacts will take an exposure type approach following a review of different methodologies used elsewhere. This recommendation is based on considerations around the expected lifetime of the technology, the lack of a fixed site/fixed infrastructure evaluation context, the geographic scope of potential impacts and the likely period of time for before and after monitoring. A new, simple and flexible method has been proposed which takes advantage of detailed micro-level data on mode choice, route and distance. Previous accident history data are needed to calculate risk factors. An illustration has been provided of how calculations can be made to generate either a monetised impact or a

MCA index. A potential source of error with the approach will arise from accuracies related to the individual mobility profile; however it will be impractical to try to eradicate this entirely.

5.3 Summary and Conclusion

The aim of this section has been to describe a method for assessing the safety impact of the SUNSET system (as opposed to personal security, which is dealt with in section 6). A review of existing methods has indicated that none is suitable for direct adoption with the SUNSET system as there is little possibility of long term monitoring, the impacts are expected to occur at micro scale and the possible geographic scale of the impacts could be widespread. The method described is based on the notion that the individuals journey can be broken down into stages with an accident risk attached to each stage. The accident risk should be calculated using historical data for the local context ie it will be different for each of the Living Labs and is based on exogenous data. In practice either local, national or European data may inform this accident risk although the more localised the risk calculation, the more relevant the calculations will be. Changes in accident exposure will occur as the individual changes their mode, their route, the number of Km travelled by each mode on each route and finally the decision to travel or not. These changes by the individual are encouraged by the SUNSET app and the issuing of relevant incentives. An illustration of the calculation method has been given, including examples of how this can then be translated into an overall economic safety cost for the journey (using European or national accident costs) or a safety index (using relative policy priorities as a weight). The overall evaluation in SUNSET is then based on the total safety cost (or index value) in the ‘before’ mobility profile, compared with that following use of the system and the introduction of particular incentives.

6. Wider impacts

This section addresses the challenges of CBA (section 3.3) in order to complete the review of the individual components of the SUNSET evaluation framework. In this regard, it first introduces the notion of wider impacts, including equity, which encompasses a key EU policy objective, it then discusses Multi-Criteria Analysis (MCA) as a main alternative and it concludes with the essential components to complement CBA in the SUNSET context.

6.1 The notion of wider impacts in transport appraisal

Wider impacts have been first introduced in section 3. Generally speaking, all impacts not assessed in conventional evaluation frameworks may be viewed as wider impacts. It becomes apparent therefore that due to the innovative and multidisciplinary nature of the SUNSET system they should constitute a component of the overall evaluation framework, with varying importance reflected in respective weights of course.

The inclusion of the wider impacts of transport infrastructure in transport appraisal gained additional interest when the Strategic Environmental Assessment (SEA) was first introduced through the milestone European Directive 2001/42/EC, with enforcement by EU-27 from 2004. It promotes the inclusion of environmental impacts in transport appraisal (Jiliberto Herrera 2009) and was recently implemented in assessing expressways in China, but with ambiguous outcomes (Zhou and Sheate 2011). SEA can also promote broader sustainability related objectives i.e. wider impacts as discussed in section 4. Sustainability lies at the core of SEA and equity lies at the core of sustainability (see section 6.1.1).

Alongside these developments, a small group of countries have led the way and updated their transport appraisal frameworks to include wider impacts. These are countries with a generally well developed transport infrastructure and a welldefined assessment framework. As potential candidates for new methodologies addressing wider impacts which may include projects similar to SUNSET, an overview of these frameworks follows.

Developed countries such as England, Scotland, Germany and Japan have developed their own inclusive assessment frameworks. NATA Refresh (New Approach To Appraisal) includes guidelines on wider impacts and impact distribution, stressing the value of those issues, although the primary focus is particularly on social exclusion e.g. disadvantaged groups (DfT 2011a; DfT 2011b). Increased interest in England is reflected in the Treasury's Green Book (HMT, 2011 – Annex 5), which acknowledges current limitations e.g. in the assessment of non-monetary impacts where average values are used across all income groups according to relative prosperity (HMT 2011: 92). No uniform weight derivation approach is proposed though, with only a social welfare function linking personal utility with income as an example. The need for adjusted weights for specific projects is explicitly mentioned and this is of relevance to SUNSET (section 6.1.1). Impact distribution among a range of socio-economic groups will be assessed within all SUNSET LLs to evaluate equity implications and overcome the relevant CBA challenge identified in section 3. The ongoing sustainability debate in the UK also covers notions of distributional impacts and accessibility of transport systems (Marsden 2007) and the debate has been invigorated by the 2007 NATA Refresh (Mackie 2010). Japanese practice uses the Benefit Impact Table (BIT) which provides discrete user-categories as well as indirect effects (Nakamura 2000). As a result it provides the data and information needed to assess the wider impacts (Morisugi 2000). In Germany, the recently updated Federal Transport Infrastructure Plan (FTIP), departs from a traditional CBA with a separate appraisal section covering spatial impact assessment. This is considered to be inclusive of wider impacts although in a more restricted sense (FTMBH 2003; Rothengatter 2000).

In contrast, practice in the Netherlands has evolved alongside EU policy and is still largely based on CBA, including SCBA. The Guidelines Framework for Project Assessment (OEEI - Overview of Economic Effects of Infrastructure) launched prior to 2000 followed lengthy discussion on the spatial and wider impacts of transport (De Jong and Geerlings 2003; EC 2009b). In France, whilst certain wider impacts were part of the former MCA appraisal method, they are not explicitly included in the current, more specific approach (Quinet 2010).

These developments illustrate the international interest and practical difficulties in incorporating wider impacts in the appraisal of transport infrastructure projects. The outcome of this brief overview based on Thomopoulos and Grant-Muller (2012) is mixed, with both similarities and differences highlighted between developed countries (Hayashi and Morisugi 2000). Veron (2010) provides a useful overview of the assessment of wider impacts in a broader selection of countries, distinguishing between quantitative approaches (monetisation) and those assessed qualitatively. The latter recommendation of a flexible evaluation framework accommodating both quantitatively and qualitatively assessed impacts is adopted within SUNSET as explained further in section 7.

6.1.1 Treating equity

In spite of the explicit appearance of equity issues a few decades ago (Beatley, 1988; Hay and Trinder, 1991) as issues to be addressed within transport appraisal, there has only been limited progress observed on this matter to date and no consensus exists yet. This section does not attempt to resolve this matter, yet it sets the scene for the treatment of equity within the SUNSET context, which may be also transferred elsewhere in the future.

As it has been already mentioned, it is extremely difficult to provide a unanimous definition of equity. Young (1994:41) stated: "*equity is a complex, nuanced, multifaceted idea that can be described as a balancing of competing considerations*". Therefore, no attempt to define this notion may be above criticism, as it is dependent on the diverse views of people which define the allocation formula for a given issue. The three most dominant approaches, although still open to criticism, are the ones by Aristotle (proportionality principle), Bentham (greatest good principle i.e. welfare) and Rawls (difference principle). Of course the problem of indivisibility of certain benefits or costs by projects leads to the problem of putting such theories into practice, especially regarding infrastructure projects (Young, 1994). There is a particular difficulty in applying such theories in transport projects due to the fact that those projects aim to address a wide range of objectives (for example congestion reduction, environmental impacts, wider economic benefits e.g. increased employment opportunities), which often follow contradicting equity principles. So, a lack of consistency in applying equity theories into practice may be identified as one of the core problems for transport projects. When one compares the three fundamental equity theories in the context of transport infrastructure projects, it is questionable how appropriate Aristotle's and Bentham's approaches are for such issues (Thomopoulos, 2010). Other critics exist too, with e.g. Martens (2012) advocating the use of Walzer's theory (1983).

Through this short review of theoretical background about equity it is obvious that this already is a challenging task. When bringing ICT in the discussion too, this issue becomes even more complex. Thus, additional issues such as smartphone ownership and familiarity, the cost of mobile data services, 3G/4G and wi-fi network availability, GPS coverage and the existence of updated maps, all link to specific equity implications which need to be evaluated through the SUNSET LLs.

Whilst equity has previously been viewed as one of the set of wider impacts and their distribution (Arora and Tiwari, 2007; Deakin, 2001; DfT, 2005; Lucas et al. 2001; Lucas and Markovich, 2011; Weisbrod et al. 2009; Worsley, 2011), the basis of the approach within SUNSET implies that equity is not another wider impact per se, but rather it refers to the distribution of a number of other project impacts (Figure 6. 1). The latter is associated with usability (D6.1), incentives distribution (D6.1) and other environmental (section 4) and socio-economic (section 6) impacts. Although there is some variation in the terminology used globally, a number of different equity types (e.g. social, environmental, spatial, horizontal, vertical) feature in existing policy documents at European levels (EC 2002; EC 2006; Proost and van Dender 2010), for example the Europe 2020 strategy (EC 2010) or the EU 5th Cohesion report (EC 2011a), which explicitly refers to economic, social and territorial cohesion. It is worth noting that equity is often intertwined with broader socio-economic or environmental objectives under the sustainability concept (EC 2009a; Taebi and Kadak 2010), which should make obvious the link with the issues discussed in section 4. Many of the objectives reflected in these high policy documents (i.e. improving transport infrastructure whilst delivering broader socio-economic and environmental benefits to meet relevant policy aims (MOVE, 2010)) have formed the rationale for funding the development of a range of transport infrastructure projects within the EU. It is therefore at least appropriate – if not a requirement – to capture equity effects in the assessment of project impacts. Consequently, equity has to be evaluated within SUNSET and this will be conducted under the wider impacts label.

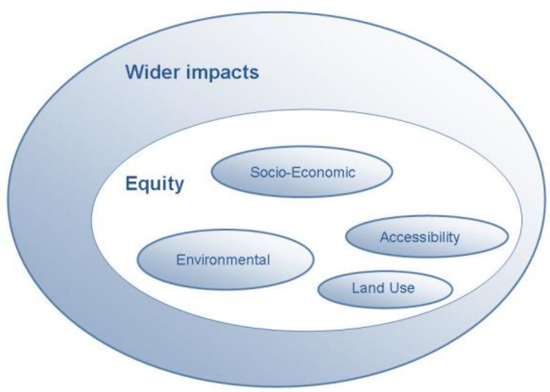

Figure 6. 1: Interrelation between wider impacts of transport projects and equity (Thomopoulos and Grant-Muller, 2012)

In this respect, equity is a policy objective which is assessed according to the observed or (a-priori) forecast distribution of transport project impacts, including other types of wider impacts. Despite the lack of agreement among academics regarding the terminology used for wider impacts, Annema et al (2007) highlight the significance of this issue for standardised assessment methods, including CBA. Various approaches exist to address equity issues (e.g. Broecker et al, 2010; Camagni, 2009; Preston and Raje, 2007; Thomopoulos and Grant-Muller, 2012). The equity types and principles included in an application of the method can be varied according to the specific context, so this is addressed in sections 7 and 8 for SUNSET. Ramjerdi (2005) has categorized the equity measures in:

- statistical
- welfare
- axiomatic

Therefore the suggestion within SUNSET is to utilise established statistical equity measures such as the Gini or the Theil indices to measure equity impacts based on a range of indicators listed in Tables 7.1 and 8.1.

Gini coefficient

The Gini coefficient forms an example of a disproportionality measure of inequality, which has been initially employed to estimate income inequality between countries or groups. Currently it holds as the most widely inequality measure, used also in economics and health disciplines as wells as in transport research. Its strong advantage is that it takes values between 0 and 1, with 0 indicating a perfectly equal distribution among the selected segments. Its link with the Lorenz curve provides additional visualisation of its changes. It has certain limitations e.g. weak transfer property, and it also reflects total inequality, which is not particularly useful when assessing impact distribution within social or spatial groups too (Shaw et al, 2007).

Theil index

Another example of a disproportionality measure of inequality is the Theil index (Theil, 1967) which belongs to the group of general entropy measures. It can be simply written:

$$\mathbf{T} = \sum_{j=1}^{J} p_j r_j \ln r_j \qquad (1)$$

where *j* the number of groups, *p* is the population proportion of this group *j* and r_j is the ratio of the variable assessed. The most attractive feature of the Theil index is its decomposability, which allows to estimate and compare both the between groups inequality as well as the within groups inequality. It may also be used for rankable and unrankable groups (Shaw et al, 2007). This index has not been used as widely as the Gini index, so there are not so many documented studies about its accuracy, particularly in the ICT sector. It has been applied in various disciplines, but again economics have been most influential (Galbraith, 2007).

Along with the two aforementioned indices, the Atkinson index is another inequality measure that has been used recently. Broecker et al (2003) have reviewed this index in the light of ESPON requirements at a European wide level.

It is recommended that the Gini index is the most suitable to be used within SUNSET if a quantified output is desired for equity impacts in the LLs, due to its simplicity and wide use by policy makers, as well as due to its 0-1 range and link with the Lorenz curve which would allow to visualise and communicate findings better. Of course this would entail additional resources in each LL for data preparation, analysis and interpretation.

6.2 Evaluating alongside CBA

A multitude of other methods can replace CBA in theory. However, there are only a handful which have been tested in practice and produced encouraging output e.g. Multi-Criteria Analysis (MCA), Cost-Effectiveness Analysis (Table 2.5) or the Capability Approach (CA). MCA and CA are briefly reviewed here to justify the selection of MCA to evaluate the wider impacts of SUNSET.

6.2.1 Multi-Criteria Analysis (MCA)

A great number of multi-criteria methods (e.g. MACBETH, EQUITY, Promethee, ELECTRE, AHP) has evolved and been applied in diverse contexts (Bana e Costa, 1990; Macharis et al, 2004; Hajkowicz and Collins, 2007;). The number of MCA methods is still growing due to differences in the:

- *type of decision*
- *time available*
- *data available*
- *analytical skills available*
- *administrative culture and requirements of each organisation/stakeholders group*

Source: DETR (2000)

It appears that due to the multifaceted evaluation context of SUNSET, the decisions that need to be taken about designing and issuing incentives in each LL, the time and resources available for system management and analysis, and the range of stakeholders involved, MCA can serve well the evaluation of wider impacts in the core and reference LLs.

After confirming that MCA methods are appropriate to accommodate the evaluation of wider impacts , it is important to identify which particular MCA method would best fit the purpose of SUNSET given the existing resources and constraints. According to DETR (2000), there are a range of criteria to be used on the selection of an appropriate MCA method depending on each actual task. This comprises a challenging task on its own. In summary, the criteria which should be used to make an informed choice are:

- *internal consistency and logical soundness*
- *transparency*
- *ease of use*
- *data requirements*
- *time and effort required for the analysis*
- *software availability*

Source: DETR (2000)

At this stage, it is recommended to construct a MCA based composite indicator (OECD-JRC, 2008) to evaluate wider impacts, since this method has been applied in a transport context before (Thomopoulos and Grant-Muller, 2012) and provides sufficient flexibility for each LL depending on the actual LL context (section 8).

6.2.1.1 MCA weighting methods

One of the most common criticisms of MCA methods is the use of weights, due to the often arbitrary nature of weights applied (Thomopoulos, 2010). The following weighting methods are reviewed to aid in deciding which would fit better the SUNSET context:

- *Ranking by ordinal specification of criteria importance. Here the decision makers rank the criteria in order of importance.*
- *Rating, involving unconstrained point allocation. Here the decision makers attach point scores to indicate criteria importance.*
- *Fixed point scoring involving constrained point allocation, either in absolute numbers or in proportions. This usually includes allocating 100 points.*
- *Graphical scales where importance is indicated by marking a continuous scale from low to high. Measures are still being developed in this method.*

- *Paired comparisons based on AHP (Saaty, 1987) which involves expressing the importance of each criterion relative to every other criterion on a nine point scale.*

Source: Hajkowicz (2000: p.514, 2007: p.180)

It is possible to utilise a different weighting method or a different set of weights for wider impacts in each Living Lab. This will be decided by each LLC within WP7 and reported within D7.5. Nonetheless, it would be very useful to sustain some consistency aiding in comparability (WP7) and use the same weighting method across all SUNSET Living Labs if possible.

6.2.2 Capability approach

The Capability Approach (CA) based on Sen's theory (Beyazit 2011) is another proposal to include social justice and equity in transport appraisal and could act as an alternative to MCA. However, this approach has only been tested for small projects at a local level in developing countries, as it requires participation by a large number of community members and stakeholders. The latter feature could be relevant and also facilitated through SUNSET due to the direct communication between system users and the managing authority. However, since CA is very context specific, it does not propose any firm rules, nor it has a concrete approach to aggregate weights from different stakeholders or conduct a sensitivity analysis. As a result, it is not considered appropriate for the SUNSET context which is currently linked with developed countries.

6.3 Complementing CBA

The suggestion within SUNSET is to evaluate wider impacts using a broader framework bringing together CBA with other approaches such as MCA as has been suggested in the past (EUNET, 1998; Leleur, 2007; Tudela et al, 2005). Of course, such a framework should try to avoid double counting of impacts either positive or negative. Thus, this section presents a comprehensive list of all the wider impacts potentially linked with SUNSET and concludes with some practical recommendations which are reviewed – along with the issue of doublecounting - in sections 7 and 8.

6.3.1 Wider impacts SUNSET Table

Table 6.1 outlines all wider impacts which cannot be monetised (section 3) and have not been reviewed in sections 4 and 5. It is evident here that there exists some duplication with the sustainability indicators of section 4 (e.g. about health impacts), but this is further addressed in section 8. The aim here is to identify all impacts not mentioned so far, related to the four main SUNSET objectives.

Table 6.1: Wider impacts evaluated through the SUNSET evaluation framework

	Wider impact	Essential / Desired for tripzoom (E/D)	Indicator
1	**Well-being**		Dutch LCI, UK Happiness Index

1	social inclusivity	E	common trips with neighbours/colleagues/friends, FB/Twitter comments count/emotion
2	education	D	basic/higher
3	cycle/walking routes	E	not/ available
4	PT stops/PT service frequency	D	number of PT stops available not/exceeds predefined threshold / PT service frequency similar to city average
5	waste management	D	below average/average compared to city average
6	employment opportunities	D	additional opportunities not/available
7	social interaction	E	number of tripzoom messages above/below average
8	local economy impact (e.g. by encouraging not to make a trip)	D	in/significant
9	set up & maintaining burden/benefit	E	time needed to register, complete user profile, participate in discussions/blog/social networking
10	research participation burden	D	time needed to participate in research, e.g. fill in experience sampling questions, questionnaire, etc.
2	**Health impacts**	E	BMI, trips to medical centres, QALYs, Health Impact Assessment (e.g. Gorman et al, 2003)
3	**Transport network reliability**	D	reliability as defined in D6.2
4	**Accessibility**	D	potential market indicator
5	**Personal security/safety**	D	area crime rate, tripzoom safety rating (XPS)
1	burden from imperfect functionality (e.g. data is not accurate)	D	time needed to manually fix the data (e.g. mode choice), and other qualitative indicators (e.g. mistrust, disappointment)
2	user privacy burden	E	the number of sensitive information given to the system in the profile (e.g. name, email, date of birth/age); the number of sensitive data recorded by the system (e.g. home location, work location, departure time); the number of information shared with friends (e.g. current location data); the number of friends recieving personal information
3	trust burden - cyber criminals	D	unquantifiable (perhaps can be derived from the risk figure of internet hacking)

6	**Equity** *(tripzoom)*		distribution within the identified socio-economic groups (including e.g. age, gender, (income), home/work location, car ownership), smartphone ownership (with data connection) VS number of travellers (perhaps also based on trip purpose)

The major contribution of Table 6.1 is towards the well-being objective of SUNSET. Although it is difficult to define well-being, a variety of relevant indicators exist, as for example the Living Conditions Index in The Netherlands (Boelhouwer and Stoop, 1999; Boelhouwer, 2002), the newly introduced Happiness Index and National Wellbeing Index in the UK (ONS, 2012) or the ESS Well-being index at a European level (Huppert et al, 2008). Common aspects of these indicators are included as sub-indicators of the overall SUNSET evaluation framework, namely about social inclusivity and participation, availability of green spaces, sports and recreational facilities, public transport facilities, shopping centres, medical facilities, employment opportunities and active involvement in local area issues. These indicators are based on contemporary research at a European level (Santangelo, 2011) but it is acknowledged that not all indicators may be of direct relevance or applicable to the SUNSET LLs. This is both because there is low relevance with the main SUNSET objectives, but also due to resource limitations in the main and reference LLs. In addition, well-being indicators 9 and 10 are associated with the user burden of participating in a LL with a research purpose, thus are linked specifically with the SUNSET context and may be of interest for simnilar research design in the future depending on the LL outcomes (D7.5). All these impacts discussed here can be evaluated through proxy scalar indicators if deemed relevant and of course depend on each LL context (section 8).

Other wider impacts initially identified in section 3 such as accessibility and transport network reliability are also included in Table 6.1. Furthermore, any positive health impacts due to increased exercise reflected for example in changes in an individual's BMI (Body Mass Index) can also be evaluated e.g. through proxy indicators if sufficient data exist.

Moreover, there is another set of issues which falls within wider impacts and is gaining importance within the ICT sector. It is linked with privacy issues and may have diverse outcomes. The most important aspect is user private data storage and management which may aid in creating or losing trust in the SUNSET system. An interlinked issue is this of cybercrime and potential threats to users, third parties, local authorities and system managers. Since this is an evolving field, no relevant indicator exists yet and proxies will be used to evaluate this aspect. Lastly, there is an issue due to SUNSET data inaccuracy (e.g. due to the fact that GPS data are not 100% accurate) which may result in inconvenient and undesirable situations for users.

Finally, equity issues will be evaluated through proxy indicators either quantitatively or qualitatively. Quantitative evaluation may rely on the Gini index for example, which will require a range of different spatial or social groups to generate meaningful comparisons or to a more basic statistical variation indicator. Therefore, this will depend on each LL context and the existence of different location data to contrast travel behaviour and/or modes used. Regarding social groups, age is a characteristic which may be employed as a minimum scenario if no other socio-economic data (e.g. household size) are available. Alternatively, equity issues may be evaluated through in-depth interviews or focus groups at each LL to gain detailed insight at a more individual level.

It is also significant not to neglect equity issues deriving from smartphone ownership or mobile data restrictions since this would mean that SUNSET would only focus on a specific niche of users with particular biases towards specific age groups or those with higher educational level. The latter will be avoided through the designed recruitment method in each LL (D7.1). Such impacts are interrelated with operational success indicators too (D6.1).

Consequently, examples of equity sub-indicators to be used in the LLs may be the following:

- use of tripzoom by younger/older users
- use of the tripzoom portal by younger/older users
- use of tripzoom by users at specific locations

6.4 Evaluation of impacts within SUNSET

Concluding this section on wider impacts, it is of high relevance to clarify which impacts are deemed essential to be evaluated and which are deemed desirable to be evaluated within the context of the specific LL. Table 6.1 acts as the input for sections 7 and 8, providing input to the overall framework and also indicators to be measured in practice in the LL.

7. Framework as a whole: Interfaces between evaluation components

The purpose of this chapter is to draw together the whole SUNSET social media evaluation framework, demonstrating the different elements of the evaluation and how they may, in principle, be aggregated to form a composite indicator for the project as a whole. The main elements are shown in Table 7.1 below, together with the data type. It can be seen that the overall framework has seven components that fulfil the high level evaluation requirements defined in chapter 2, in brief, to reflect the objectives of the project, to allow an interface with the evaluation of other kinds of projects and to recognise the scale and scope of the scheme. The reader is referred to chapter 2-6 of this deliverable and deliverable D6.1 for more specific detail on each impact category and indicator. A short critique of the components and evaluation approach overall follows.

The first element is a cost-benefit analysis (CBA) - reported firstly here in the table by convention and not to imply it is the primary evaluation component. The inclusion of a cost-benefit component positions the overall framework alongside the orthodox approaches to transport scheme evaluation, largely favoured by national, transnational and European evaluation frameworks (Thomopoulos and Grant-Muller, 2012). It is noteworthy that the 'nearest neighbour' evaluation method FESTA (in terms of the evaluation problem) similarly recommends both a CBA and a mixture of other types of components and indicators. The advantage to the CBA element (as defined within the SUNSET framework) is the inclusion of a financial analysis, following the EUNET (1998) approach. In that method – and for most other large transport infrastructure projects – the third party stakeholder component reflects large scale financial inputs arising from, for example, Public Private Partnership schemes. For SUNSET and similar schemes, third party involvement may well be at the level of several commercial organisations, including small, large and community based organisations who are associated with the scheme for either a longer or shorter term. The presentation of results must therefore identify each stakeholder type and the expected net costs or benefits. This is a similar presentational approach to the former UK NATA evaluation guidelines (DfT, 2011a) which recommended an appraisal summary table (AST) showing each impact category, each stakeholder impacted and a qualitative report on impacts where appropriate. The disadvantage of the CBA element is that indicators may be even more difficult to correctly value than is the case with other schemes due to the novelty of the evaluation context.

However the SUNSET evaluation approach also includes components that are not present in most orthodox evaluation methods. Notably the evaluation of 'the success of the social media concept' and the 'success of incentives' components. Neither component currently exist in the standard recommended national or transnational transport scheme evaluation methods, neither do they exist in (published) evaluation approaches for ITS schemes. For the evaluation of the success of the social media concept, the collection and analysis of a new type of data comprising posted comments and information is recommended – so called 'sentiment analysis'.

The components 'operational success' and functionality are also not generally included in national or international evaluation methods, but variations of these may be seen in the evaluation methods derived for use in EU funded projects such as the Field-Operational Trials (e.g FESTA, FOT-NET and CONDUITS). Each of these evaluation methods proposes indicators of operational success with interpretations of this aimed towards the main type of ITS scheme they address in the evaluation problem. This necessarily implies some restrictions in the extent to which the method is transferable (for example from fixed-based ITS to pervasive and mobile ITS). Whilst the most recent of these methods, CONDUITS, (Kaparias and Bell. 2011) gives illustrative examples of indicators for a range of schemes, these do not extend to the social media centred scheme. The remaining components of Sustainability and Liveable communities in the SUNSET evaluation method may be recognisable as being present in many social-welfare based evaluation approaches, although the precise indicators developed here may vary.

Table 7.1: summary evaluation components and data types

SUNSET evaluation components	€	Q	Scalar
• Cost-benefit analysis	✓		
• Operational success		✓	✓
• Success of social media concept		✓	
• Sustainability indicators		✓	
• Liveable communities		✓	✓
• Basic functionality			✓
• Success of incentives		✓	✓

These seven components are all measured on either a Quantitative scale (Q), Scalar (S) or are monetised (€). It can be seen from Table 7.1 that several components have a single data type but Operational Success, Liveable communities and the success of incentives are mixed data types. In chapter 8 more detail on the measurement method will be given together with indications of the variations between living labs.

Following calculation of the impact indicators (summarised in Table 7.2 below) a presentation of the project performance is required. The default assumption is that the net changes in each of the indicators is shown for each evaluation component, according to each impacted stakeholder type (where appropriate) and separately for the different data types ie indicators based on scalar data being reported separately to Indicators based on Quantitative data. This approach would give a detailed reflection of where exactly increases and decreases in indicators have taken place following introduction of the scheme.

Whilst reporting each indicator at the most detailed level of disaggregation has the advantage of demonstrating where precisely any changes in impacts have occurred, it also holds a disadvantage in gaining a 'birds-eye' view of performance. It is therefore proposed that alongside the disaggregate reporting of impacts, an overall composite indicator can be generated, using weighted aggregate scores for all the impacts. The proposal to report both disaggregate and aggregate evaluation results is not new and dates back to methods such as EUNET (1998). Whilst offering the advantage of either an overall summary statistic, or interim summary statistics, there are also some disadvantages and difficulties with this general approach. These may be summarised as: issues with double counting, indicators have being collected on different scales, fundamental orientation of the indicators (ie is high positive or negative), derivation of weights for the aggregation process and the need for some fundamental (and possibly unrealistic) assumptions on a linear additive utility function. Despite these challenges, the process is in principle achievable and outlined in summary form here.

The most substantive of these challenges is that of double counting, particularly as in the case of the SUNSET method, the indicators have been developed largely independently and with the goal of how best to capture impact changes, rather than how best to fit within a unified framework. In Table 7.3, an analysis is provided of where double counting arises with the indicators defined in the SUNSET approach. The table has been orientated with the evaluation components in the horizontal scale and all previously identified individual indicators in the rows. A double tick mark highlights where the indicators acts in a primary role to reflect the evaluation component, whilst a single tick highlights a secondary role. From Table 7.3, it can be seen that only in the case of Operational Success and evaluating incentives is there a significant double counting where indicators serve in a primary role in both cases. For other cases the double counting comprises an indicator acting in a primary role for one evaluation component and a secondary role for another. Double counting is not generally desirable but can be difficult to fully eradicate from any evaluation method. If the evaluation interest concerns performance at disaggregate level then the double counting is explicit to the decision maker, who can then make local decisions on how to interpret this. For performance at aggregate level, there is some necessity to reduce this to a minimum to avoid distortionary effects in the summary value. For the SUNSET indicators, the following process is proposed where there is a wish to aggregate:

- For the Operational Success, this is measured using the set of scalar (qualitative) indicators only, with those indicators marked Q being used for the assessment of incentives instead. The consequence of this is that the success of incentives will be measured using revealed preferences on choices rather than stated intentions.
- For all other evaluation components with potential double counting, the indicator is used as a contributor where it acts in a primary capacity only.

Subsequent treatment of each impact is as follows, although more sophisticated techniques may be available. The aim here is to establish a reasonably robust and transparent default, taking into consideration the likely availability and reliability of data.

- Following the recommendation of Beuthe et al, 1998, the overall metric proposed for each impact is used to generate a single score in the range 0 to 100. A score close to zero will represent a substantial negative effect, a score close to 50 will represent a neutral effect and a score close to 100 will represent a substantial positive benefit for the impact. Some calculation will be involved in translating and orientating the overall scores for some impacts onto the standard metric.

- A weighting process is then undertaken in for the 7 impact components (at a more sophisticated level, weights could also be derived within the category). Chapter 3 describes some alternative approaches to weighting. Ahlroth et al, 2011 give a detailed review of weighting and valuation methods (mid-point and end-point) that are needed with a variety of evaluation approaches which can be applied with environmental data, including CBA. However for the purposes of this methodology, a relatively simple approach based on pairwise comparisons (Saaty, 1980) is recommended. This method is well-established and has a good level of practicality, efficiency and user – acceptance in many cases. One of the most frequently used pairwise comparison methods is the Analytic Hierarchy Process, AHP and this method forms a basic recommendation here. Whilst it is possible to undertake the process using a spreadsheet, this may be rather clumsy and lack the ease of use that a specially designed software tool may offer.

- Finally aggregation using the assumption of a simple additive, linear utility to produce the overall score for the project.

It should be noted that this process of producing a summary score is not a 'compulsory' step in the SUNSET method, but rather a user driven option to support decision making.

To briefly conclude, a description has been given of the whole (integrated) SUNSET framework, drawing together the components that have been derived and described in both D6.1 and chapters 2-6 of this deliverable. The relative positioning of this approach amongst the established evaluation frameworks is described, highlighting some commonalities and areas of novelty. An outline process to aggregate and weight the criteria to form a composite indicator has also been described, with suggestions on how the treat the particular challenge of double counting. In section 8, a more detailed and practical look at the measurement of the indicators is given, reporting the work of the final WP subtasks.

Table 7.2: summary of SUNSET evaluation framework.

Cost benefit analysis	Operational Success	Success of social media concept	Sustainability indicators	Live-able communities	Basic Functionality	Success of Incentives
Integration costs: Integration with the local Managing Authority of the SUNSET system (during/after SUNSET) (€) **Installation costs :** for the Managing authority/third parties/the end user/PT operators hardware investment installation costs (e.g. time, loss of network access) (€) **Operating costs** hardware maintenance software maintenance energy costs system hosting data storage/ management/analysis (€) **Incentive design & management** Templates user groups vouchers –agreements data analysis of incentives re-offer incentives (renew/ renegotiate contracts) (€) **Marketing costs** launch events (one-off) social media costs	No. trips/ trip purpose (Q) No. trips/ distance (Q) Total KM travelled (Q) Total travel time/ trip purpose and distance (Q) Objective indicators on social networks (e.g. No. friends) (Q) Subj. indicator of travel time/trip purpose and distance (S) Subj. indicator of scheduling effort/trip	No. unique visitors to web portal (Q) No. people that register for tripzoom (Q) No. people that agree to participate in a living lab (Q) No. or % of participants recruited using a LL/city-FB site (Q) No. or % of participants recruited using a FB-add (Q) No. or % of participants recruited via a friend on an external	Heart rate (Q) Calories burnt (Q) Bike speed (Q) Walking speed (Q) Cycling distance (Q) Walking distance (Q) Congestion stop time/Total travel time (Q) Particles (PM10) emission (Q) Carbon dioxide	**Well-being:** Well being (S) social inclusivity education cycle/walk routes PT stops PT service freq. waste management employment social interaction (Q) **Wider impacts** Health impacts Transport network reliability Accessibility Equity (Q) Personal security/safety (S) Safety (exposure index) (Q)	Battery use of phone (S) Interference with other uses of phone (S) Robustness (S) Security (S) Privacy (S)	Behavioural change - trip level (Q) Behavioural change - mode and context (Q) Awareness of (impact of) the personal mobility pattern; (S) Awareness of existence and/or performance of alternatives (modes, etc.) (S) Awareness of societal impact of traffic (externalities) (S)

online advertising conventional advertising **Support costs** FAQs/Complaints/Communication liaison with third parties about incentives technical support ethical protocol costs (incl. privacy and protocols for data management/sharing) (€) **User costs/benefits** battery consumption energy costs contract/mobile data costs device marginal Installation cost upgrade/purchase/maintenance/insurance costs value of travel time savings trip cost vehicle operating costs (€) **Safety** Expected safety (exposure) cost (€) **Revenue streams** Data management/storage/sharing revenues Mini payments for user collaboration through social media Integration with existing digital services revenues e.g. City Council portals, smartphone apps Third party benefits e.g. increased turnover (€)	purpose and distance (S) Subj. indicator on distance (S) Subj. indicator on costs (S) Subj. indicator of social networks (e.g. support, feedback) (S) Dislike of travel (S) Attitudes on pro-environment policy (S) Attitude on commute (S) Attitudes on travel freedom (S) Attitudes on pro-high density (S)	social network (Q) No. or % of participants recruited via a friend invite by email (Q) No. or % of participants engaged in the tripzoom social network (Q) No. or % of participants as 'friends' in the tripzoom social network (Q) No. mutual friends within the local tripzoom social network (Q) No. messages posted on external social media	emission (Q)			Self-category, (preferences, satisfaction, social attitude). (S)

	Attitudes on travel stress (S) Personality (S) Lifestyle (S) Excess travel (S) Desired mobility (S) Output (added value of) (S)	relating to tripzoom (Q) The % of positive messages on social media that relate to tripzoom (Q)				

Table 7.3: Double counting in SUNSET indicators

Impact indicator	Data type	Cost benefit analysis	Operational Success	Success of social media concept	Sustainability indicators	Liveable communities	Basic Functionality	Success of Incentives
Number of trips by trip purposes (work related or leisure)	Q		✓✓					✓✓
Number of trips by distance (short vs. long)	Q		✓✓					✓✓
Total kilometres travelled	Q		✓✓					✓✓
Total travel time by trip purpose and distance	Q		✓✓					✓✓
Objective indicators on social networks (e.g. number of friends)	Q		✓✓					
Subjective indicator of travel time by trip purpose and distance	scale		✓✓					
Subjective indicator of scheduling effort by trip purpose and distance	scale		✓✓					
Subjective indicators on distance	scale		✓✓					
Subjective indicators on costs	scale		✓✓					
Subjective indicators of social networks (e.g. motivational support, feedback, and satisfaction)	scale		✓✓	✓				
Attributes related to disliking travel	scale		✓✓					✓
Attitudes on pro-environmental policy	scale		✓✓					✓
Attitudes on commute benefit	scale		✓✓					✓
Attitudes on travel freedom	scale		✓✓					✓
Attitudes on pro-high density	scale		✓✓					✓

Attitudes on travel stress	scale		✓✓					✓
Personality	scale		✓✓					✓
Lifestyle	scale		✓✓					✓
Excess travel	scale		✓✓					✓
Desired mobility (with regard to travel goals by trip purpose and distance)	scale		✓✓					
Output (the added value of tripzoom app in relation to each of the desired mobility)	scale		✓✓					
The number of unique visitors to the web portal	Q			✓✓				
The number of people that register for tripzoom	Q			✓✓				
The number of people that agree to participate in a living lab	Q			✓✓				
The number or percentage of participants that are recruited using a LL/city-FB site	Q			✓✓				
The number or percentage of participants that are recruited using a FB-add	Q			✓✓				
The number or percentage of participants that are recruited via a friend on an external social network	Q			✓✓				
The number or percentage of participants that are recruited via a friend invite by email	Q			✓✓				
The number or percentage of participants engaged in the tripzoom social network	Q			✓✓				
The number or percentage of participants linked in as ‘friends’ in the tripzoom social network either actively or passively	Q			✓✓				
The number of mutual friends within the local tripzoom social network	Q			✓✓				
The number of messages posted on external social media that relate to tripzoom	Q			✓✓				
The percentage of positive messages on social media that relate to tripzoom				✓✓				
Battery usage of the mobile phone	scale	✓					✓✓	
Interference with other uses of the mobile phone	scale						✓✓	
Robustness –ability to work or at least not crash with network problems, ability to recover unobtrusively, ability to signal to a user that there is a problem to contact the developer	scale						✓✓	
Security – ability to maintain confidentiality and integrity of data	scale						✓✓	

Privacy – have sufficient procedures in the operation to support privacy	scale						✓✓	
Behavioural change - trip level	Q		✓					✓✓
Behavioural change - mode and context	Q							✓✓
Awareness of (the impact of) the personal mobility pattern;	scale							✓✓
Awareness of the existence and/or performance of alternatives (modes, routes, etc.);	scale							✓✓
Awareness of the societal impact of traffic (externalities);	scale							✓✓
Self-categorisation, preferences, satisfaction, social attitude.	scale							✓✓
Integration costs (D6.2)		✓✓						
Integration with the local Managing Authority of the SUNSET system (during/after SUNSET)	€	✓✓						
Installation costs (D6.2)		✓✓						
for the Managing authority/ third parties/ the end user/ PT operators	€	✓✓						
hardware investment	€	✓✓						
installation costs (e.g. time, loss of network access)	€	✓✓						
Operating costs (D6.2)		✓✓						
hardware maintenance	€	✓✓						
software maintenance	€	✓✓						
energy costs	€	✓✓						
system hosting	€	✓✓						
data storage/management/analysis	€	✓✓						
Incentive design & management (D6.2)		✓✓						
templates	€	✓✓						
user groups	€	✓✓						
vouchers (find and sign agreements)	€	✓✓						
data analysis of incentives	€	✓✓						
re-offer incentives (renew/renegotiate contracts)	€	✓✓						
Marketing costs (D6.2)		✓✓						

launch events (one-off)	€	✓✓						
social media costs	€	✓✓						
online advertising	€	✓✓						
conventional advertising	€	✓✓						
Support costs (D6.2)		✓✓						
FAQs/Complaints/Communication	€	✓✓						
liaison with third parties about incentives support	€	✓✓						
technical support	€	✓✓						
Ethical protocol costs (incl.privacy and protocols for data management/sharing)	€	✓✓						
User costs (D6.2)		✓✓						
battery consumption	€	✓✓					✓	
energy costs	€	✓✓						
contract/mobile data costs	€	✓✓						
device marginal upgrade/purchase/maintenance/insurance costs	€	✓✓						
Installation costs	€	✓✓						
value of travel time savings	€	✓✓						
trip costs/benefits	€	✓✓	✓					
vehicle operating costs/benefits	€	✓✓						
Safety (D6.2)		✓✓						
Expected safety (exposure) cost **OR**	€	✓✓						
Expected safety (exposure) index	Q	✓✓						
Revenue streams (D6.2)		✓✓						
Data management/storage/sharing revenues	€	✓✓						
Mini payments for user collaboration through social media	€	✓✓						
Integration with existing digital services revenues e.g. City Council portals, smartphone apps	€	✓✓						
Third party benefits e.g. increased turnover, higher employment levels	€	✓✓						

Heart rate	Q				✓✓			
Calories burnt	Q				✓✓			
Bike speed	Q				✓✓			
Walking speed	Q				✓✓			
Cycling distance	Q		✓		✓✓			✓
Walking distance	Q		✓		✓✓			✓
Congestion stop time/Total travel time	Q		✓		✓✓			✓
Particles (PM10) emission	Q				✓✓			
Carbon dioxide emission	Q				✓✓			
Well-being (D6.2)						✓✓		
Well being	scale					✓✓		
social inclusivity	Q					✓✓		
education	Q					✓✓		
cycle/walking routes	Q					✓✓		
PT stops/PT service frequency	Q					✓✓		
waste management	Q					✓✓		
employment opportunities	Q					✓✓		
social interaction	Q					✓✓		
Wider impacts (D6.2)						✓✓		
Health impacts	Q					✓✓		
Transport network reliability	Q					✓✓		
Accesibility	Q					✓✓		
Personal security/safety	scale					✓✓		
Equity	Q					✓✓		

Note:
✓✓ indicates that the indicators acts in a primary role to reflect the evaluation component and ✓ indicates that the indicator acts in a secondary role.

8. Measurement approach for Living Labs

8.1 Measurement of impacts and indicators

The final aspect of the evaluation methodology is to consider how the framework and individual indicators can be interpreted within a practical environment. This is the work of Task 6.3 and is reported here for the specific cases of the three SUNSET living labs in Enschede, Gothenburg and Leeds. The evaluation methodology has potential applicability beyond the SUNSET project - for other social media based schemes in transport. As a result this chapter provides a useful illustration for the wider community. The three cases considered are very different in location, scale and focus, so the purpose here is to also illustrate the flexibility of the evaluation method. The output of this chapter will form an input for tasks within SUNSET WP7 and specifically tasks D7.2-D7.4, with more detail on the practicalities of evaluation reported in the WP deliverables.

Table 8.1 below summarises the role of the evaluation components in reflecting the achievement of the SUNSET objectives. From this it can be seen that contributions are made by evaluation components across the objectives. Only one component ie Basic Functionality does not have a direct correspondence with the project objectives. This is because it is targeted towards evaluation of the technical system itself, which must be functioning in order to generated any impacts.

Table 8.1: correspondence between SUNSET objectives and evaluation framework components

SUNSET objective	Evaluation components
• **Congestion reduction**: traffic-jams are an increasing problem to tackle. The average travelling times should be reduced. Our objective is 5% less traffic (measured in car kilometers in a specific area) during the rush hours for users of the SUNSET system.	Operational Success, CBA, Success of Incentives, Sustainability
• **Safety**: people must be able to optimize their route, to avoid roads with many cyclists for car drivers, to report local road and weather conditions within community, to detect unusual conditions, or to avoid waiting times on dark and silent railway stations.	CBA, Well-being, Success of social media concept
• **Environment protection**: for a liveable climate we need reduced CO2 emissions, improved air quality management and reduced noise pollution.	Sustainability, success of incentives
• **Personal wellbeing of citizens**: the system allows individuals to set and monitor personal objectives, like increase individual safety, reduce travel times, reduce costs, improve comfort, and increase health.	Well-being, success of incentives, sustainability, CBA

Definition of Base Case for Evaluation

In order to assess whether the SUNSET objectives have been achieved, it will be necessary to observe changes in the Indicators when compared with either a) the 'Base Case' or b) the 'Business as Usual Case (BAU)'. Where a new scheme is evaluated after a short time period following introduction and behaviour is known to be routine for that duration, then generally the Base Case is chosen. This is because the likelihood of underlying change in e.g trip patterns or a movement into a different part of the behaviour cycle is relatively unlikely. If the scheme is evaluated after an extended time period following introduction then generally the BAU case is chosen. This is because after a longer time has elapsed there is more of a likelihood of behaviour settling into longer term patterns and cycles. This can make direct point comparisons with the Base Case (e.g of the type of trips or the number of trips) less appropriate. The exact length of time which applies to move from the Base Case to the BAU case cannot be firmly determined without knowledge of the data. As a very rough indication a period greater than a month may warrant calculation of BAU.

For the SUNSET LL, evaluation takes place on a 'within-subject' basis and then the set of individual changes are extrapolated to estimated impacts at City scale. The Base case will be derived from the initial mobility pattern for each individual prior to introducing the incentive. The BAU case would also be calculated on an individual subject basis and formed by estimating the level of repeat behaviour at the future time point. In practice this may not deviate substantially from the Base Case.

In Table 8.2 a more detailed measurement approach is described for each evaluation component, with the following column headings, definitions and notation being used:

- **Data Type**: this is used to broadly indicate whether the indicator will be calculated as Euros (€), Quantitative (Q, which may be any type of quantitative data other than scalar eg continuous, discrete) or Scalar (S)

- **Units of measurement**: the units that the data will be recorded and reported in. This is separate to the units of aggregation that the results will be presented within. For example the data may have the units of Km and be presented and evaluated in Km/peak period/interpeak.

- **Data availability**: this signals the main source of data for the indicator ie whether it is recorded as part of the operation of the SUNSET system or whether external data is required, for example historical accident data.

- **Core/Desirable**: the terms core indicator and secondary indicator are used with different interpretations in evaluation methodologies. For example Core indicators may be defined as those that are: able to be monetised, likely to be applicable to a range of schemes, simple, more directly related to the objectives, reflect immediate impacts in the primary study area or immediate stakeholders, likely to be most measurable, likely to be available in restricted resource evaluation, likely to be consistent and reliable in reflecting the objectives. See the EU funded Inforegio project for more discussion http://ec.europa.eu/regional_policy/sources/docgener/evaluation/evalsed/guide/evaluation_capacity/index_en.htm in this case the allocation of indicators as either Core or Desirable has been undertaken on the following basis: all categories should have some Core indicators, the ability of the indicator to most directly reflect the technical attributes of the objective it is allocated to, the ability to collect the data automatically rather than with resource intensive effort, the ability to reflect immediate and tangible impacts within the scope of the particular objective.

- **Monitoring period for evaluation**: a summary of when and how often the indicator is calculated within the experimental design
- **Recorded data in SUNSET**: the characteristics of the data where it is collected automatically by the system
- **Comments:** this records the individual variations, relevance issues and data collection within each of the living labs.

Some general comments apply to the table. For wider discussion on the exact definitions and measurement of the indicators, the relevant chapter in either Deliverable D6.1 or D6.2 is shown. Space restrictions allow only a summary title for the indicator in the table. Not all the indicators proposed in the SUNSET method may be collected within the SUNSET living labs – the rationale behind their inclusion is that (in similar vein to FESTA, CONDUITS and other evaluation approaches), the method has been developed on a theoretical level with the expectation that it may be adapted and used by other projects and evaluation contexts outside SUNSET. This is one of the sources of added value generated by the project.

Table 8.2: Impacts, indicators and measurement in practice

Tick if relevant to this LL	Correspondence with business model	Impact indicator	Data type	Units of measurement	Data availability	Core / Desirable	Monitoring period for evaluation	Additional local adjustments and/or links with specific incentive
		Operational Success (Chapter 2, D6.1)						
✓		Number of trips by trip purposes (work related or leisure)	Q	count	SUNSET	D	Constantly	Could be analysed by time of day for the Leeds LL to assess journey to work.
✓		Number of trips by distance (short vs. long)	Q	count	SUNSET	D	Constantly	
✓		Total kilometres travelled	Q	meters	SUNSET	D	Constantly	Focusing on car kilometres within peak-periods
✓		Total travel time by trip purpose and distance	Q	seconds	SUNSET	D	Constantly	
✓		Objective indicators on social networks (e.g. number of friends)	Q	count	SUNSET	D	Periodically	
✓		Subjective indicator of travel time by trip purpose and distance	scale	5 points scale; none/a lot	SUNSET	D	Periodically, at least once at outset	
✓		Subjective indicator of scheduling effort by trip purpose and distance	scale	5 points scale; none/a lot	SUNSET	D	Periodically, at least once at outset	Not particularly interesting for Enschede LL, but of interest to other LL
✓		Subjective indicators on distance	scale	5 points scale; none/a lot	SUNSET	D	Periodically, at least once at	

							outset	
✓		Subjective indicators on costs	scale	5 points scale; none/a lot	SUNSET	D	Periodically, at least once at outset	
✓		Subjective indicators of social networks (e.g. motivational support, feedback, and satisfaction)	scale	5 points scale; none/a lot	SUNSET	D	Periodically	
✓		Attributes related to disliking travel	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Once at outset	
✓		Attitudes on pro-environmental policy	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Once at outset	
✓		Attitudes on commute benefit	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Once at outset	
✓		Attitudes on travel freedom	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Once at outset	

		Attitudes on pro-high density	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Once at outset	
✓		Attitudes on travel stress	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Once at outset	
✓		Personality	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Once at outset	
✓		Lifestyle	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Once at outset	Socio-Demographic profile may make a difference to uptake and usefulness.
✓		Excess travel	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Once at outset	
✓		Desired mobility (with regard to travel goals by trip purpose and distance)	scale	5 points scale; much less/much more	SUNSET	C	Periodically	
✓		Output (the added value of tripzoom app in relation to	scale	5 points scale;	SUNSET	C	Periodically	

		each of the desired mobility)		none/a lot				
		Success of the social media concept (Chapter 2.3 D6.1)						
✓		The number of unique visitors to the web portal	Q	count	SUNSET	C	Constantly/ Periodically	
✓		The number of people that register for tripzoom	Q	count	SUNSET	C	Constantly/ Periodically	
✓		The number of people that agree to participate in a living lab	Q	count	SUNSET	C	Constantly/ Periodically	Initial goal is 240 participants for Enschede LL
✓		The number or percentage of participants that are recruited using a LL/city-FB site	Q	count/per centage	SUNSET	C	Constantly/ Periodically	Also a Twente Mobiel mailing/recruitment will be done in Enschede
✓		The number or percentage of participants that are recruited using a FB-add	Q	count/per centage	SUNSET	C	Constantly/ Periodically	
✓		The number or percentage of participants that are recruited via a friend on an external social network	Q	count/per centage	SUNSET	C	Constantly/ Periodically	
✓		The number or percentage of participants that are recruited via a friend invite by email	Q	count/per centage	SUNSET	D	Constantly/ Periodically	
✓		The number or percentage of participants engaged in the tripzoom social network	Q	count/per centage	SUNSET	C	Constantly/ Periodically	
✓		The number or percentage of participants linked in as 'friends' in the tripzoom social network either actively or passively	Q	count/per centage	SUNSET	C	Constantly/ Periodically	
✓		The number of mutual friends within the local tripzoom social network	Q	count	SUNSET	D	Constantly/ Periodically	In Leeds and Gothenburg this should relate to workplace networks

								In Enschede also focusing on groups of colleagues that together use tripzoom
✓		The number of messages posted on external social media that relate to tripzoom	Q	count	SUNSET	C	Constantly/ Periodically	
✓		The percentage of positive messages on social media that relate to tripzoom		percentag e from count	SUNSET	D	Constantly/ Periodically	In Leeds this could relate to issues of trust.
		Basic Functionality (chapter 2.4, D6.1)						
✓		Battery usage of the mobile phone	scale	5 points scale; agree/disa gree for a number of statements	SUNSET	D	Periodically	For Enschede and Gothenburg, as a proof of concept, focus on the effects of battery use for using tripzoom (e.g. does the battery consumption make you stop using the app)
✓		Interference with other uses of the mobile phone	scale	5 points scale; agree/disa gree for a number of statements	SUNSET	C	Periodically	Enschede: May wish to assess how this affects the willingness to use the system/app In Gothenburg also using the app over time
✓		Robustness –ability to work or at least not crash with network problems, ability to recover unobtrusively, ability to signal to a user that there is a problem to contact the developer	scale	5 points scale; agree/disa gree for a number of statements	SUNSET	C	Periodically	Enschede: May wish to explore whether the system is robust and how does this affect the willingness to use the system/app. In Gothenburg also using the app over time
✓		Security – ability to maintain confidentiality and integrity of data	scale	5 points scale; agree/disa gree for a	SUNSET	C	Periodically	Enschede: may wish to explore how this affects the willingness to use the system/app. In Gothenburg

				number of statements				also using the app over time
✓		Privacy – have sufficient procedures in the operation to support privacy	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Periodically	Enschede: May wish to explore whether the system is robust and how does this affect the willingness to use the system/app. In Gothenburg also using the app over time
		Success of Incentives (Chapter 3, D6.1)						
✓		Behavioural change - trip level	Q	[Depending on the behavioural change to target; i.e. number of trips, distance travelled, travel time, costs, emissions]	SUNSET	C	Constantly	Göteborg: How does this affect the willingness to use the system/app over time
✓		Behavioural change - mode and context	Q	[Depending on the behavioural change to target; i.e. mode, pupose, location, timing, trajectory]	SUNSET	C	Constantly	

✓		Awareness of (the impact of) the personal mobility pattern;	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Periodically	
✓		Awareness of the existence and/or performance of alternatives (modes, routes, etc.);	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Periodically	
✓		Awareness of the societal impact of traffic (externalities);	scale	5 points scale; agree/disagree for a number of statements	SUNSET	C	Periodically	
✓		Self-categorisation, preferences, satisfaction, social attitude.	scale	5 points scale; agree/disagree for a number of statements	SUNSET	D	Periodically	
		Integration costs (Chapter 3, D6.2)				C		
	Intg1	Integration with the local Managing Authority of the SUNSET system (during/after SUNSET)	€	person hours	secondary source	C	Once	Leeds does not integrate with transport managing Authority In Enschede and Göteborg no specific integration
		Installation costs (Chapter 3, D6.2)				C		
	Inst1	for the Managing authority/ third parties/ the end user/ PT operators	€	person hours	SUNSET	C	Once/periodically	Intention is not to help with the installation process in Enschede
✓	Inst2	hardware investment	€	Euro	SUNSET	C	Once/periodically	SUNSET server is working for all LL's

	Inst3	installation costs (e.g. time, loss of network access)	€	person hours	SUNSET	C	Periodically	
		Operating costs (Chapter 3, D6.2)				C		
	O1	hardware maintenance	€	person hours	SUNSET	C	Periodically	Leeds LL minor responsibility assoc. with the City Dashboard
	O2	software maintenance	€	person hours	SUNSET	C	Periodically	Leeds LL not responsible for this aspect
✓	O3	energy costs	€	Euro	secondary source	C	Once	
✓	O4	system hosting	€	Euro	SUNSET	C	Before	Leeds LL minor responsibility assoc. with the City Dashboard
	O5	data storage/management/analysis	€	Euro	SUNSET	C	Periodically	Leeds LL not responsible for this aspect
		Incentive design & management (Chapter 3, D6.2)				C		
✓	Inct1	templates	€	person hours	SUNSET	C	Before	No specific templates in Enschede
✓	Inct2	user groups	€	person hours	SUNSET	C	Periodically	All 7 groups in Enschede 4 groups planned in Göteborg
✓	Inct3	vouchers (find and sign agreements)	€	person hours	SUNSET	D	Periodically	Not planned in Enschede or in Göteborg
✓	Inct4	data analysis of incentives	€	person hours	SUNSET	C	Periodically	
✓	Inct5	re-offer incentives (renew/renegotiate contracts)	€	person hours	SUNSET	D	Periodically	
		Marketing costs (Chapter 3, D6.2)				C		
✓	M1	launch events (one-off)	€	Euro	SUNSET	D	Once	In Leeds expect to align to existing campaigns for ‘green travel’. In relation with Twente Mobiel

								associated companies In Göteborg the launch is a standalone SUNSET event
✓	M2	social media costs	€	Euro	SUNSET	C	Periodically	
✓	M3	online advertising	€	Euro	SUNSET	C	Periodically	
✓	M4	conventional advertising	€	Euro	SUNSET	C	Periodically	
		Support costs (Chapter 3, D6.2)				C		
✓	SC1	FAQs/Complaints/Communication	€	person hours	SUNSET	C	Periodically	Translating the system to Dutch and Swedish
✓	SC2	liaison with third parties about incentives support	€	person hours	SUNSET	D	Periodically	This is both a cost and a benefit
✓	SC3	technical support	€	person hours	SUNSET	C	Periodically	Will probably be needed in all LL
✓	SC4	Ethical protocol costs (incl.privacy and protocols for data management/sharing)	€	person hours	SUNSET	C	Periodically	This is both a cost and a benefit CBP-registration for use in Enschede (= free of cost) In Sweden it is not clear yet what if any it will cost; an estimation can be made
		User costs (Chapter 3, D6.2)				C		
✓	Us1	battery consumption	€	Euro/day	SUNSET/secondary source	D/C	Constantly	Of great importance for Göteborg
✓	Us2	energy costs	€	Euro/week	SUNSET/secondary source	D/C	Periodically	
✓	Us3	contract/mobile data costs	€	Euro/month	SUNSET/secondary source	D/C	Before/After	
✓	Us4	device marginal upgrade/purchase/maintenance/insurance costs	€	Euro	SUNSET/secondary source	C	Before/After	
	Us5	Installation costs	€	Euro	SUNSET/secondary	C	Periodically	

					source			
✓	Us6	value of travel time savings	€	Euro	SUNSET/secondary source	C	Periodically	
✓	Us7	trip cost	€	Euro	SUNSET/secondary source	C	Constantly	
✓	Us8	vehicle operating costs	€	Euro	SUNSET/secondary source	C	Once at outset	
		Safety (Chapter 5, D6.2)						
✓		Expected safety (exposure) cost **OR**	€	Euro	SUNSET/ secondary source	C	Periodically	
✓		Expected safety (exposure) index	Q	Index unit	SUNSET/ secondary source	D	Periodically	
		Revenue streams (Chapter 3, D6.2)						
		Data management/storage/sharing revenues	€	Euro	SUNSET	D	Periodically	
✓		Mini payments for user collaboration through social media	€	Euro	SUNSET	D	Periodically	Not in Enschede or in Göteborg
✓		Integration with existing digital services revenues e.g. City Council portals, smartphone apps	€	Euro	SUNSET	D	Once/periodically	In Enschede linking it with i-Zone and Twente Mobiel mobility management web-site. Have been excluded in Göteborg as the app is not connected to the congestions charging fees implemented in GOT from 1/1/ 2013
✓		Third party benefits e.g. increased turnover, higher	€	Euro	secondary source	D	Once	

		employment levels						
		Sustainability indicators (Chapter 4, D6.2)						
✓		Calories burnt	Q	kCal/trip	SUNSET	D	Constantly/ Periodically	
✓		Bike speed	Q	Meter/second	SUNSET	C	Constantly	
✓		Walking speed	Q	Meter/second	SUNSET	C	Constantly	
✓		Cycling distance	Q	Meter	SUNSET	C	Constantly	
✓		Walking distance	Q	Meter	SUNSET	C	Constantly	
✓		Congestion stop time/Total travel time	Q	Second	SUNSET	C	Constantly	In Leeds this would be useful if this was by trip purpose. Focus on peak-periods in Enschede
✓		Particles (PM_{10}) emission	Q	pg/trip	SUNSET	C	Constantly/ Periodically	
✓		Carbon dioxide (CO_2) emission	Q	kg/trip	SUNSET	C	Constantly/ Periodically	
		Well-being (Chapter 6, D6.2)				C		
		Well being	scale	5 points scale; agree/disagree for a number of statements	SUNSET		Periodically	
✓	WB1	social inclusivity	Q	5 points scale; agree/disagree for a number of statements & by contrasting with the	SUNSET	C	Periodically	

				number of travel buddies during LL				
	WB2	education	Q	education level & 5 points scale; agree/disagree for a number of statements about familiarity with ICT use	secondary source/ SUNSET	D	Before/After	
	WB3	cycle/walking routes	Q	kilometer of walking/cycling route per km2 of city area	secondary source	C	Before/After	
	WB4/ WB5	PT stops/PT service frequency	Q	number of PT stops per km2 of city area / number of PT stops per km2 and number of PT services per hour	secondary source	D	Once	
	WB6	waste management	Q	5 points scale; agree/disagree for a	secondary source	D	Before/After	

				number of statements about change in waste managem ent within local area				
	WB7	employment opportunities	Q	new employme nt posts facilitated through the SUNSET system	secondary source	D	Before/After	
✓	WB8	social interaction	Q	number of messages exchange with other users through tripzoom portal	SUNSET	D	Before/After	In Leeds measurement of work-place based interaction would be useful
		Wider impacts (Chapter 6, D6.2)						
✓		Health impacts	Q	Index unit	SUNSET/se condary source	C	Before/After	

✓		Transport network reliability	Q	Time (Standard deviation for arrival time - from individual travelers' and network perspectives) and number of alternatives available e.g. a number of road paths connecting A to B - from network point of view)	SUNSET/secondary source	C	Periodically	
✓		Accessibility	Q	Percentage reduction of traffic congestion	secondary source	C	Before/After	
✓		Personal security/safety	scale	5 points scale; agree/disagree for a number of statements	SUNSET/secondary source	C	Periodically	
✓		Equity	Q	index unit	SUNSET/secondary source	C	Before/After	

8.2 Experimental design adaptations by Living Labs

In Deliverable D6.1, the experimental design was outlined which will be used to collect data, measure the indicators and form a schema for the issuing of incentives. Here the design is shown for each of the labs (Tables 8.3a to 8.3c) with an indication of any local adaptation according to the specific lab. Within each table, QR1 refers to a single qualitative survey (using indicators from Table 8.2), QMR refers to repeat/multiple surveys and XP refers to experience sampling surveys. The main living lab is Enschede and this is expected to aim for the full experimental design. The adaptations for Leeds and Gothenburg follow in Table 8.3b and 8.3c respectively, with a short description of the local issues. The experimental designs may be subject to further refinement in the immediate planning period before the LL begin.

As main living lab Enschede LL will recruit users for all the experimental groups (1-7) as is shown in Table 8.3a. In this way it is possible to compare all types of groups with each other within the same living lab. We expect Group 7 to join and participate with the tripzoom application as they would within 'real-world' while the other groups will experience incentive types in isolation or in combination or in sequence to be able to assess the impact of those incentives. Participants, which are people working in Enschede, will be recruited in collaboration with Twente Mobiel. This is a network of employers in Twente that have committed to reduce the number of peak hour car kilometres of their employees. Besides that also recruitment will be done online and using social network. It is planned that each normal experimental group (1-6) will have at least 40 participants at the start of the living lab. The recruitment will aim for as many users as possible, in order to prevent any problems with 'drop outs'. Possibly, this goes up to 500 users. In cooperation with the technical workpackages, the system capacities will be monitored. If capacity will become an issue, new recruits will be informed that they are unable to join the system in order to guarantee a functioning system for the existing users.

Table 8.3a Experimental design and schedule of qualitative data collection (Enschede LL)

<table>
<tr><th rowspan="2">Group</th><th colspan="7">Time period</th></tr>
<tr><th>1</th><th colspan="2">2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td rowspan="3">1</td><td>*Travel diary (manually) to establish non-app travel patterns and mode</td><td colspan="2">Mobility feedback and performance against community</td><td colspan="2">Challenges</td><td colspan="2">Social media</td></tr>
<tr><td rowspan="2">QR1</td><td>QRM(i)</td><td>QRM(ii)</td><td></td><td>QRM(iii)</td><td></td><td>QRM(iv)</td></tr>
<tr><td colspan="2">XP</td><td colspan="2">XP</td><td colspan="2">XP</td></tr>
<tr><td rowspan="3">2</td><td>*Travel diary (manually) to establish non-app travel patterns and mode</td><td colspan="2">Mobility feedback and performance against community</td><td colspan="2">Social media</td><td colspan="2">Challenges</td></tr>
<tr><td rowspan="2">QR1</td><td>QRM(i)</td><td>QRM(ii)</td><td></td><td>QRM(iii)</td><td></td><td>QRM(iv)</td></tr>
<tr><td colspan="2">XP</td><td colspan="2">XP</td><td colspan="2">XP</td></tr>
<tr><td rowspan="2">3</td><td>*Travel diary (manually) to establish non-app travel patterns and mode</td><td colspan="6">Mobility feedback and performance against community only</td></tr>
<tr><td>QR1</td><td>QRM(i)</td><td>QRM(ii)</td><td></td><td>QRM(iii)</td><td></td><td>QRM(iv)</td></tr>
</table>

			XP		XP		XP	
4	Mobility feedback and performance		Challenges					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
5	Mobility feedback and performance		Social media based incentives					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
6	Mobility feedback and performance		Challenges and social media					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
7	All mob feedback, challenges and incentives							
	QR1 and QRM(i) on joining at time t; QRM(ii), QRM (iii), QRM(iv) successively at time (per month or week) depending on lab design.							

The Leeds reference LL will prioritise recruitment to the shaded groups (1, 4, 5, 6, 7) in Table 8.3b. These are the groups that are most likely to be able to contribute understanding in the areas of innovation in SUNSET particularly the use of incentives as challenges and in social networking services. Leeds Reference LL does not rule out recruitment to the other groups if there are sufficient numbers of volunteers. We expect Group 7 to join and participate with the tripzoom application as they would within 'real-world' while the other groups will experience incentive types in isolation or in combination or in sequence to be able to assess the impact of those incentives. It is expected that within the social media based and challenges type incentives the LL will generate stimulus to stimulate characteristics of those incentives. Participants will be recruited using online, social network and more traditional media using both passive and active advertising and collaborating with the existing network of employers in the West Yorkshire Travel Plan Network. This is a network of 100 employers in the West Yorkshire area managed by the Public Transport Authority: Metro who has offered their support. It is planned that each group will have 30 or more participants and as a contingency the LL will over-recruit to address any 'drop-outs'. In total it is estimated that there is a need for 200 participants.

Table 8.3b Experimental design and schedule of qualitative data collection (Leeds reference LL)

Group	**Time period**						
	1	2		3	4	5	6
1	*Travel diary (manually) to establish non-app travel patterns and mode	Mobility feedback and performance against community		Challenges		Social media	
	QR1	QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)
		XP		XP		XP	
2	*Travel diary (manually) to establish non-app travel patterns and mode	Mobility feedback and performance against community		Social media		Challenges	
	QR1	QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)

			XP		XP		XP	
3	*Travel diary (manually) to establish non-app travel patterns and mode		Mobility feedback and performance against community only					
	QR1		QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)
			XP		XP		XP	
4	Mobility feedback and performance		Challenges					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
5	Mobility feedback and performance		Social media based incentives					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
6	Mobility feedback and performance		Challenges and social media					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
7	All mob feedback, challenges and incentives							
	QR1 and QRM(i) on joining at time t; QRM(ii), QRM (iii), QRM(iv) successively at time (per month or week) depending on lab design.							

The Gothenburg reference LL will prioritise recruitment to the shaded groups (1, 4, 6, 7) in Table 8c. These are the groups, similar to the Leeds reference living lab, that are most likely to be able to contribute understanding in the areas of innovation in SUNSET particularly the use of incentives as challenges. Gothenburg Reference LL does not rule out recruitment to the other groups if there are sufficient numbers of volunteers. It is expected that Group 7 will join and participate with the tripzoom application as they would within 'real-world' while the other groups will experience incentive types in isolation or in combination or in sequence to be able to assess the impact of those incentives

Participants, commuters from the outer municipalities to inner Gothenburg, will be recruited with the help of flyers and advertisements on electronic boards in collaboration with the existing network of employers at Lindholmen Science Park. This is an area that occupies 60000 employees in different companies It is planned that each group will have 25 participants and as a contingency the LL will over-recruit to address any 'drop-outs'. In total approx. 100 participants are expected.

Table 8.3c Experimental design and schedule of qualitative data collection (Gothenburg reference LL)

Group	**Time period**							
	1		2		3	4	5	6
1	*Travel diary (manually) to establish non-app travel patterns and mode		Mobility feedback and performance against community		Challenges		Social media	
	QR1		QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)

			XP		XP		XP	
2	*Travel diary (manually) to establish non-app travel patterns and mode		Mobility feedback and performance against community		Social media		Challenges	
	QR1		QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)
			XP		XP		XP	
3	*Travel diary (manually) to establish non-app travel patterns and mode		Mobility feedback and performance against community only					
	QR1		QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)
			XP		XP		XP	
4	Mobility feedback and performance		Challenges					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
5	Mobility feedback and performance		Social media based incentives					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
6	Mobility feedback and performance		Challenges and social media					
	QR1 QRM(i)	QRM(ii)		QRM(iii)		QRM(iv)		QRM(v)
	XP		XP		XP		XP	
7	All mob feedback, challenges and incentives							
	QR1 and QRM(i) on joining at time t; QRM(ii), QRM (iii), QRM(iv) successively at time (per month or week) depending on lab design.							

8.3 Conclusion

The aim of this chapter was to provide the more detailed measurement approach that will be taken in the living labs, following the SUNSET evaluation method that has been defined. The evaluation framework as a whole has been outlined within two deliverables, D6.1 and early chapters of D6.2 and unified in chapter 7. Starting with a summary of how the evaluation components contribute towards assessing the different SUNSET objectives, Table 8.2 has given the detailed measurement information such as units, data type and whether particular indicators are nominated as compulsory or discretionary. The comments in the final column of Table 8.2 demonstrate local issues and interpretations. From these it can be seen that a considerable degree of concordance is expected between the LL. Finally, in Tables 8.3 a-8.3c the expected experimental design that will be used in practice is shown for each LL. These show in particular the recruitment and allocation priorities to each LL. Naturally some further adjustments may be need before the LL kick-off, which will be reported in the WP7 deliverables.

9. Conclusions

The overall objectives of WP6 were as follows:

- To provide a set of key indicators that allow evaluation of the implementation and operational success of the social traffic scheme (success will be measured by a combination of mobility efficiency and sustainability indicators);
- To specify a general framework to evaluate the SUNSET system in against broad EU objectives for improved mobility in the future, including objectives relating to efficiency, sustainability and society;
- To provide specific recommendations to the living lab experiments on the indicators and measurement approach for the analysis of case study data in assessing the achievement of objectives;
- To outline an analysis approach for the effectiveness of the use of incentives in the SUNSET system.

Deliverable D6.1 reported the first stage of the development in the work, addressing the development of the evaluation method for operational success and evaluating incentives. The main focus of D6.2 has therefore been to complete the development of the wider impact groups, demonstrate their use in a unified framework (drawing together the work of D6.1 with the remaining indicators) and to detail their measurement in practice. In terms of technical challenges to the research, the following issues were identified at the outset and addressed within the course of the workpackage:

- The application of the SUNSET system may be very different from site to site
- Problems in getting hold of either 'ideal' data or proxies/
- Some indicators may be difficult to define or to translate into measurable characteristics–
- Difficulties in establishing the 'do nothing' case for the indicators
- Ensuring there is data on the responses of individuals to the incentives through either automatic data collection or self-reporting
- Establishing the ideal evaluation period i.e. short run versus long run
- Defining a geographic scope to the impacts over which benefits/performance can be measured
- Understanding the nature of secondary impacts
- Assessing the full set of system costs alongside the benefits
- Determining what 'success' is for some indicators

These challenges have arisen as a result of the novelty of the project and the difficulty of directly adopting either well established evaluation frameworks or those that have been derived for other types of technology innovations. As a result, some of the impacts that are described in this deliverable may be subject to further refinement in the light of experience within the LL, for example as issues such as data quality and reliability in practice become clearer.

A review of existing evaluation approaches and the merits or disadvantages of particular evaluation methodologies have been used to inform the SUNSET evaluation approach. The SUNSET evaluation method clearly requires an approach and measurement methods that are tailored to the additional social media and incentives elements of the system as whole, which were largely unavailable at the time when many of these approaches and frameworks were originally derived. As a result the SUNSET evaluation approach offers a further contribution to the state of the art in transport scheme evaluation.

A Cost-Benefit analysis has been included as one of the evaluation components in order to interface with the business model (WP5) and to form a bridge with the evaluation approach used for many current transport initiatives. To summarise the interaction between the SUNSET business model and the evaluation method, the following constitute the essential requirements for each Living Lab:

- Specify the finance pillars in each Living Lab i.e. whether the SUNSET system and required infrastructure will be provided by the public or private sectors (including third party providers)
- Identify the type and volume of incentive providers to assess any revenue streams (i.e. benefits) for the SUNSET system
- Specify the targeted user groups in each Living Lab
- Specify the transfer/operating/user costs and benefits

Alongside the financial analysis, other monetised impacts include a range of those often seen in CBA frameworks (eg operating costs, maintenance costs) although these have definitions that are adapted to the SUNSET scheme here. Other costs that would not usually be seen in a CBA include user support costs. In addition to adapting the definitions, some example values and costs have been given although for use of the CBA outside SUNSET or in different countries or contexts, these should be adapted to the local case.

In common with many evaluation frameworks, a Sustainability component has also been described. Sustainability is here used as short for Sustainable development, which is a concept drawn in the Brundtland report in 1972 (UN, 1987). Within the concept of sustainable development lie the three components of:

- Economic development, which means that there should be a sound economic system that satisfied economic needs,
- Equity and social aspects, which means that there should be a good quality of life for all people, and
- Earth, nature and environment, which means that resources should not be depleted, ground, water and soil should not be poisoned and biodiversity should be preserved.

In the SUNSET evaluation method for sustainability, the second and the third of these components are the focus and addressed as Social and Environmental respectively. The sustainability method is illustrated figuratively, showing how the measurement of specific transport related indicators can be used to measure changes in the specific environmental and social impact indicators chosen. This means that to measure the sustainable development of the transport system it is not necessary to measure the absolute or total environmental and social impact from the transport system, but rather to measure its changes. It is of course necessary also to measure the absolute sustainability performance of the total and to set improvement goals as this level as well, but the SUNSET system is not aiming at changing the transport system itself - rather to improve the performance of the utilization of the actual system. Hence, only the improvement effectiveness needs to be measured.

There is a distinction in the SUNSET evaluation approach between the 'Safety' impact of transport schemes and the 'personal security' impact, these being evaluated separately and personal security lying within the component concerning liveable communities. Safety impacts are defined here in terms of accidents (on the road or other mode). This scope does not reflect possible safety consequences from use of the devices themselves ie through distraction whilst walking or use whilst driving as this isn't the intended mode of operation of the SUNSET system. To summarise, the estimation of safety impacts will take an exposure type approach following a review of different methodologies used elsewhere. This recommendation is based on considerations around the expected lifetime of the technology, the lack of a fixed site/fixed

infrastructure evaluation context, the geographic scope of potential impacts and the likely period of time for before and after monitoring. A new, simple and flexible method has been proposed which takes advantage of detailed micro-level data on mode choice, route and distance. Previous accident history data are needed to calculate risk factors. An illustration has been provided of how calculations can be made to generate either a monetised impact or a MCA index. A potential source of error with the approach will arise from accuracies related to the individual mobility profile; however it will be impractical to try to eradicate this entirely.
One of the challenges of CBA is to be able to capture and monetise a set of wider impacts which may be more subjective in nature and less easy to measure. A further component of the evaluation method therefore includes a subset of 'wider impacts' that are generally focused towards the 'liveable communities' objective. These include some key impacts for the system such as equity and social inclusivity. In general these impacts are measured by either proxies or scalar indicators and in some cases should be included in the evaluation only if the nature of the scheme suggests this is appropriate.

Having described the fuller set of components and indicators for the SUNSET evaluation methodology, a description follows of the whole (integrated) SUNSET framework, drawing together the components that have been derived and described in both D6.1 and chapters 2-6 of this deliverable. The relative positioning of the SUNSET approach amongst the established evaluation frameworks is described, highlighting some commonalities and areas of novelty. An outline process to aggregate and weight the criteria to form a composite indicator has also been described, with suggestions on how the treat the particular challenge of double counting. This is followed by a comprehensive and more detailed measurement approach that will be taken in the living labs, following the SUNSET evaluation method that has been defined. The detailed measurement information described includes the units, data type and whether particular indicators are nominated as compulsory or discretionary. A set of qualitative comments are also included to demonstrate the interface between the method as a whole and local issues or interpretations. From these it can be seen that a considerable degree of concordance is expected between the LL. Finally, the expected experimental design that will be used in practice is shown for each LL. These show in particular the recruitment and allocation priorities to each LL. Naturally some further adjustments may be need before the LL kick-off, which will be reported in the WP7 deliverables.

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Appendix A. Examples of safety data

A1: Enschede Safety data

Accidents by road characteristic (Enschede)

Reported:All accidents in the years 2001 to 2011

description	Total accidents	Accidents with casualties	Severe accidents (=hospital + fatal)	Fatal accidents	Hospital accidents	Other accidents with casualties	Accidents with only material damage
Crossing	11882	1623	455	24	431	1168	10259
Secondary road inside urban area	2882	340	103	5	98	237	2542
Secondary road outside urban area	720	92	43	4	39	49	628
Primary road inside urban area	3414	449	137	14	123	312	2965
Primary road outside urban area	590	97	35	6	29	62	493
Inapplicable	390	40	22	3	19	18	350
Highway	82	6	2	0	2	4	76
Unknown	566	110	56	10	46	54	456
Total	**20526**	**2757**	**853**	**66**	**787**	**1904**	**17769**

Drivers – Pedestrians / mode

Reported: All accidents in the years 2001 to 2011

description	Drivers total	Victims	Severe victims (= hospital/fatal)
Car	28475	1208	361
Van	3208	101	28
Truck	1382	17	4
Motor	347	115	52
Other	750	11	3
Train	2	0	0
Moped	2066	655	167
Bicycle	2571	1007	263
Pedestrian	239	172	67
Object	0	0	0
Animal (led)	0	0	0
Animal (unled)	3	1	0
Total	**39043**	**3287**	**945**

A2: Examples of Economic cost of accidents

Official Norwegian costs per injured or killed in road accidents, NOK 2004 prices

	Slight injury	Serious injury	Severe injury	Fatality
Medical	*21,667*	*211,596*	*246,870*	*9,822*
Lost output	*20,000*	*1,489,156*	*3,151,535*	*7,533,661*
Property	*50,000*	*81,844*	*72,223*	*94,948*
Administrative	*40,000*	*79,847*	*91,920*	*68,756*
Traffic delays	*1,667*	*5,989*	*5,253*	*8,185*
Quality of life	*186,667*	*1,796,569*	*3,692,548*	*15,584,627*
Total	*320,000*	*3,665,000*	*7,260,348*	*23,300,000*

Note: the estimations are based on estimated true numbers of road accidents involving all types of road accidents. Source: Elvik (2004), based on Elvik (1993) and Statens vegvesen (1995).

Bicycle accidents in Norway – Source: Veisten, 2007

Extrapolation of police-reported number of cyclists or cyclist passengers injured or killed in Norway, 1996–2004

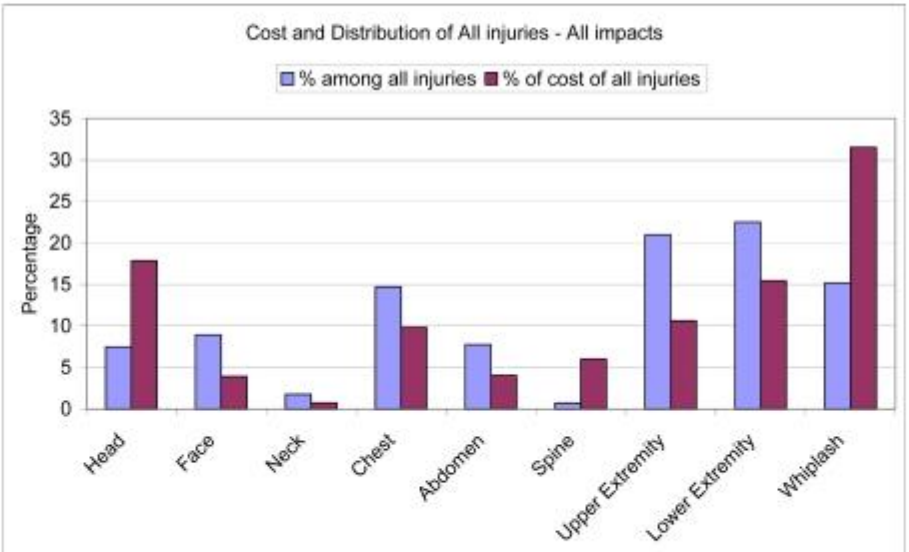
Year	Minor injury (AIS = 1)	Moderate injury (AIS = 2)	Serious injury (AIS = 3)	Severe injury (AIS = 4)	Critical injury (AIS = 5)	Fatality (AIS = 6)	Total
1996	*5284*	*2045*	*299*	22	1	6	*7658*
1997	*4968*	*1923*	*363*	13	2	9	*7276*
1998	*4621*	*1788*	*311*	18	5	20	*6763*
1999	*4274*	*1654*	*247*	14	3	12	*6204*
2000	*4274*	*1654*	*225*	8	3	10	*6175*
2001	*3826*	*1481*	*161*	6	1	5	*5480*
2002	*4364*	*1689*	*189*	6	2	10	*6259*
2003	*3910*	*1513*	*213*	10	3	11	*5660*
2004	*3957*	*1532*	*152*	6	2	8	*5657*

– Source: Veisten, 2007

Economic costs (Million NOK, 2004) of bicycle injuries/fatalities in Norway, 1996–2004

	Minor	Moderate	Serious	Severe	Critical	Fatality	Total
1996	*227*	*1768*	*960*	*144*	*11*	*149*	*3260*
1997	*214*	*1662*	*1166*	*81*	*18*	*235*	*3375*
1998	*199*	*1546*	*999*	*117*	*40*	*533*	*3434*
1999	*184*	*1430*	*794*	*90*	*24*	*320*	*2841*
2000	*184*	*1430*	*725*	*54*	*21*	*277*	*2691*
2001	*164*	*1280*	*519*	*36*	*10*	*128*	*2137*
2002	*188*	*1460*	*607*	*36*	*19*	*256*	*2566*
2003	*168*	*1308*	*686*	*63*	*22*	*299*	*2546*
2004	*170*	*1324*	*489*	*36*	*16*	*213*	*2249*

– Source: Veisten, 2007



– Source: AAM, 2006

Overall, 7573 cases were identified as being school travel-related, representing 1.6% of total, and 11.4% school travel period injuries. Walking (30.7%), cycling (30.3%), and motor vehicles (27.7%) provided the majority of injuries. Risk of injury per million trips was highest for cycling (46.1), walking (10.3), and motor vehicle travel (6.1). Schofield et al (2008)

Overall prevalence of actual mode, ACC claims, and exposure risk by school-related travel mode for July 2003 to June 2005 in New Zealand youth

Mode	Travel prevalence % (±95% confidence interval)	Injury frequency		Number of trips for 1 injury (±95% confidence interval)	Injuries per million trips (±95% confidence interval)	Injuries per million hours (upper–lower limit of estimates)	Average cost per claim (New Zealand $) (25th/75th percentiles)
		n	%				
Walk	26 (±0.47)	2324	31	97,007 (±456)	10.3 (±0.05)	29.0 (20.4–36.5)	502 (34/410)
Private motor vehicle	40 (±0.53)	2095	28	164,330 (±871)	6.1 (±0.03)	13.3 (9.0–16.1)	539 (33/511)
Bus	23 (±0.45)	521	7	386,670 (±1740)	2.6 (±0.01)	4.0 (2.8–5.6)	393 (33/305)
Train	1 (±0.11)	5	0.1	1,822,810 (±2005)	0.6 (±<0.00)	0.6 (0.3–0.9)	147 (33/216)
Cycling	6 (±0.26)	2293	30	21,711 (±56)	46.1 (±0.12)	194.3 (140.6–235.4)	467 (48/312)
Other	3 (±0.18)	335	4	88,805 (±160)	11.3 (±0.02)	32.1 (21.9–42.0)	389 (33/410)
Total	100	7573	10	113,537	8.8		

– Source: Schofield et al (2008)

Table 6. Selected social costs due to cars in Sydney (2005)

Social costs category	Total road $ million	Due to cars $ million	Cost/ vehicle-km	Cost/ passenger-km
Congestion	$12072	$9320	$0.28	$0.20
Accidents	$3864	$2983	$0.09	$0.06
Greenhouse gas emissions	$148	$114	$0.00	$0.00
Air pollution	$1223	$944	$0.03	$0.02
RTA subsidies	$741	$572	$0.02	$0.01
Total	**$18048**	**$13933**	**$0.43**	**$0.29**

Source: Centre for International Economics (CIE) (2005). Note that this table uses CIE estimates of the share of social costs which are due to cars (as opposed to other road vehicles). Per passenger-km estimates in last column are by the author.

– Source: Glazebrook, 2009

Singapore

Using the casualty rates in Table-6, the total cost for each category of accident severity is as follows: S$878,000 per fatal accidents, S$171,000 per serious injury accident, S$17,000 per slight injury accident and S$3,000 per damage-only accident. ADB (Chin et al, 2003) obtained a cost of $1.481 million per fatal accident, $269,500 per serious injury accident, $15,900 per slight injury accident and $3,400 per damage-only accident. The most significant difference in this study is in the estimates of fatal accidents, which is nearly 50% lower than the previous. The most significant cost components that contributed to this large difference is the human cost and the lost output. (Chin et al, 2006)

Appendix B. SUNSET Review Form

Document Info	
Title	Evaluation methodology and measurement approach
Deliverable number	D6.2
Reviewer	Marcel Bijlsma
Partner	Novay
Date	<date reviewed>20 jan 2013

How Do You Rate This Deliverable?

Check the appropriate boxes below:

- Insufficient: not acceptable
- Reasonable: major improvements required
- Good: minor improvements required
- Excellent: hardly any improvements required

To check a box, right click, go to Properties, and enable Checked or Not Checked.

Readability				
Spelling, grammar	☐ insufficient	☐ reasonable	☐ good	☒ excellent
Style	☐ insufficient	☐ reasonable	☒ good	☐ excellent
Structure	☐ insufficient	☐ reasonable	☐ good	☒ excellent
Conciseness	☐ insufficient	☐ reasonable	☒ good	☐ excellent
General readability	☐ insufficient	☐ reasonable	☒ good	☐ excellent

- *Spelling and grammar:* Is the document free of language defects, such as typos, missing words, and warped sentences?
- *Style:* Is the deliverable easy to read and understand? Is the text specific and does it avoid unnecessary generalities that might lead to unintended interpretations? Is the document consistent with other information in the document and in related documents.
- *Structure:* Is the text well organised (in terms of sections) and written in a logical manner?
- *Efficiency:* Is the text written in a concise way? Does it avoid repetitions and wordy sentences? Is the length of the document reasonable for the content discussed?

Content				
Scientific originality	☐ insufficient	☐ reasonable	☒ good	☐ excellent
Scope	☐ insufficient	☐ reasonable	☐ good	☒ excellent
Clearness of message	☐ insufficient	☐ reasonable	☒ good	☐ excellent
Scientific value	☐ insufficient	☐ reasonable	☐ good	☒ excellent
Industrial relevance	☐ insufficient	☐ reasonable	☒ good	☐ excellent
Overall quality	☐ insufficient	☐ reasonable	☐ good	☒ excellent

- *Scientific originality*: Is the work sufficiently new from a scientific perspective? Does the document clearly indicate how the work differs from prior work?

• *Scope:* Does the content of the deliverable fall within the scope of SUNSET? Is the scope of the document itself sufficiently clear? Does it refer to other (scientific) documents for topics that are outside the scope of the document? • *Clearness of message:* Is it clear what the document is about? Is it clear about the problem it addresses and the chosen solution to solve that problem? • *Scientific value:* Does the document analyze the impact of the problem it addresses? Does it analyze the pros, cons, and limitations of the chosen solution? Does it describe the advantages gained by solving the problem? • *Industrial relevance*: Does the work described in the document have an impact on industries relevant to SUNSET?

Final Checks		
Does the deliverable follow the SUNSET deliverable template?	☒ yes	☐ no
Have all fields of the template been filled out?	☒ yes	☐ no
Have all comments and visible edits been removed?	☒ yes	☐ no

Reviewer Recommendation		
Send deliverable to EC?	☒ yes	☐ no
• *Reviewer Recommendation*: In your opinion, can we send the document to the EC after editors have processed your comments?		