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ITU-T L.1430 – Guidance on practical application of ITU-T L.1430 to a real-time navigation service

ITU-T L-series Recommendations – Supplement 3

ITU-T

International Telecommunication Union

Supplement 3 to ITU-T L-series Recommendations

ITU-T L.1430 – Guidance on practical application of ITU-T L.1430 to a real-time navigation service

Summary

The real-time navigation service (RNS) is composed of satellite navigation system-based software which provides real-time information of the optimal route to the destination according to traffic conditions throughout the travel as well as the available parking spaces nearby. The transport sector is expected to save on energy consumption by adopting RNS.

Based on the experiences from a Korean study, Supplement 3 to the L-series Recommendations describes how to indirectly estimate energy consumption reduction and greenhouse gas (GHG) abatement potential related to RNS. Future revisions may look into direct estimation methods. This Supplement is bounded to Recommendation ITU-T L.1430, but gives further guidance on boundary setting, GHG accounting and baseline scenario development, and on measurement, verification and monitoring methods from the information and communication technology (ICT) based RNS project perspective.

Whereas Recommendation ITU-T L.1430 focuses on the net environmental impact of ICT services from the entire life cycle perspective, this Supplement describes only the environmental impact of RNS during the use stage compared to one in a baseline scenario.

History

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Keywords

Climate change, greenhouse gas, information and communication technology, real-time navigation service.

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ITU-T L.1430 – Guidance on practical application of ITU-T L.1430 to a real-time navigation service

1 Scope

The purpose of this Supplement is to provide supplementary guidance to [ITU-T L.1430] to help practitioners and organizations assess greenhouse gas (GHG) emission reduction potential enabled by an information and communication technology (ICT) based real-time navigation service (RNS).

This Supplement illustrates general principles, concepts, requirements and methods for quantifying and monitoring GHG emission reductions or removal that result from an increased transportation efficiency due to the technological intervention of an RNS solution, one ICT application in the transport sector. [ITU-T L.1430] provides general guidance for assessing potential energy saving and GHG abatement achieved by ICT based projects. This Supplement intends to provide specific guidance for assessing energy savings and GHG abatement potential of an ICT project involving an RNS. Especially, this methodology focuses on an RNS based on the smart-phone appliance. Based on the experiences from a Korean study, this guidance describes how to indirectly estimate energy consumption reduction and GHG abatement potential related to RNS. Future revisions may look into direct estimation methods.

This Supplement intends to provide a general guidance for:

- planning of a real-time navigation project and defining its baseline and project scenario;
- quantifying GHG emission reduction enabled by the project activities;
- managing data quality;
- monitoring the project performance; and
- validating quantification methods by applying the conservative principle.

The intended audience of this Supplement is policy makers at the national level who might require information to design an effective climate change policy framework to utilize ICT enabled energy efficiency measures in the transport sector as well as practitioners and organizations developing and offering RNS. This Supplement might offer high relevancy to policy makers and technology advisors in intelligent transport system (ITS) domain.

2 References

[ITU-T L.1410] Recommendation ITU-T L.1410 (2012), *Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services*.

[ITU-T L.1430] Recommendation ITU-T L.1430, *Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects*.

[ISO 14044] ISO 14044:2006, *Environmental management – Life cycle assessment – Requirements and guidelines*.

[ISO 14064-2] ISO 14064-2, *Greenhouse gases – Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 baseline scenario [ISO 14064-2]: A hypothetical reference case that best represents the conditions most likely to occur in the absence of a proposed greenhouse gas project.

3.1.2 first order effects [ITU-T L.1410]: The environmental impacts and opportunities created by the physical existence of ICT and the processes involved, e.g., GHG emissions, e-waste, use of hazardous substances and use of scarce, non-renewable resources.

3.1.3 functional unit [ISO 14044]: Quantified performance of a product system for use as a reference unit.

3.1.4 GHG project [ISO 14064-2]: Activity or activities that alter the conditions identified in the baseline scenario which cause greenhouse gas emission reductions or greenhouse gas removal enhancements.

3.1.5 greenhouse gas, GHG [ISO 14064-2]: Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds.

3.1.6 greenhouse gas emission [ISO 14064-2]: Total mass of a GHG released to the atmosphere over a specified period of time.

3.1.7 ICT project [ITU-T L.1430]: A GHG project using mainly ICT goods, networks and services, aiming at GHG emission reductions or GHG removal enhancements; and/or a GHG project using mainly ICT goods, networks, and services, aiming at energy consumption savings and energy efficiency improvement.

3.1.8 life cycle assessment [ISO 14044]: Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

3.1.9 monitoring [ISO 14064-2]: Continuous or periodic assessment of GHG emissions and removals or other GHG-related data.

3.1.10 other effects [ITU-T L.1410]: These may include the impacts and opportunities created by the aggregated effects on social and infra-structural changes by using ICT. These additional impacts are difficult to track and can be either rebound or enabling effects.

3.1.11 project activity [ITU-T L.1410]: Any activity performed in a project which directly changes GHG emissions, removals or storage, and/or energy consumptions, energy consumption reductions, energy generation or energy storage enhancements.

NOTE – The project activity may include modifications or alterations to existing production, process, consumption, service, or management system, as well as the introduction of new systems. Activities related to management of the project are not considered as project activities in this Recommendation.

3.1.12 second order effects [ITU-T L.1410]: The impacts and opportunities created by the use and application of ICT. This includes environmental load reduction effects which can be either actual or potential, for example travel substitution, transportation efficiency enhancement, working environmental changes, use of environmental control systems, use of e-business, e-government etc.

3.2 Terms defined in this Supplement

This Supplement defines the following terms:

3.2.1 baseline emissions: An estimation of GHG emissions, removals or storage associated with a baseline scenario.

3.2.2 direct GHG emissions: Emissions or removals from GHG sources or sinks that are owned or controlled by the project developer.

3.2.3 direct impact: The impact which occurs directly due to GHG emissions.

3.2.4 distance-priority route: A route which introduces the shortest distance from a departure point to a destination point regardless of expected time and velocity.

3.2.5 GHG project of RNS: A GHG project which expects GHG emission reductions or GHG removal by implementing real-time navigation (RTN) itself.

3.2.6 position determination entity (PDE): A network entity which manages the position or geographic location determination of the mobile station.

3.2.7 real-time navigation service: A navigation service which provides time-priority routes (see Note) to drivers from departure points to destination points, enabling drivers to travel at higher speed and in less time.

NOTE – Real-time navigation systems provide routes based on a time-priority algorithm.

3.2.8 real-time traffic information: Information about current traffic conditions conveyed to motorist in real-time.

3.2.9 satellite navigation system: A system of satellites that provide autonomous geo-spatial positioning with global coverage.

3.2.10 time-priority route: A recommended route by real-time navigation, which is expected to minimize the expected travel time from a departure point to a destination point. Therefore, this is a detour route with a relatively longer distance.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

CTICC Central Traffic Information and Communication Centre

GHG Greenhouse Gas

GNS Goods, Networks and Services

ICT Information Communication and Technology

IPCC Intergovernmental Panel on Climate Change

ISO International Standardization Organization

ITS Intelligent Transport System

ITU International Telecommunication Union

LBS Location-based Service

LCA Life Cycle Assessment

LNG Liquefied Natural Gas

PDA Personal Digital Assistant

PDE Position Determination Entity

RNS Real-time Navigation System

RTN Real-time Navigation

SVFE Standard Velocity and Fuel Efficiency

VICS Vehicle Information and Communication System

WBCSD World Business Council for Sustainable Development

5 Conventions

None.

6 Overview of RNS

The real-time navigation service (RNS) provided by a satellite navigation system and location-based service (LBS) based navigation system, is a basic component of an intelligent transport system (ITS). This service interacts directly with drivers based on processed real-time traffic information generated by the ITS infrastructure. An RNS is comprised of a satellite navigation system, a mobile network, and a service platform consisting of a map database, a position determination entity (PDE) server and a navigation server.

The satellite navigation system is a core element of an RNS. It combines the use of signals from satellites with interactive on-board maps, which are provided from the map database for recognizing the current geographic location and plotting routes of travel based on a number of variables to the destination. PDE is used to facilitate determination of the position or geographical location of a wireless terminal. In addition to searching for shortest routes, it also offers real-time traffic information, such as congestion or abrupt blockage due to construction, which automatically enables drivers to reflect such information in their route selection. If a driver misses any turns, RNS quickly corrects the error and provides new routes with updated traffic information.

An RNS provider collects real-time traffic information from the vehicle information communication system (i.e., national ITS infrastructure); however, it might operate its own traffic monitoring fleet which transmits real-time traffic flow information into the service provider's service platform. The service platform consisting of a PDE, navigation server and map database collects the position and vehicle movement data, such as speed and direction, from the navigation device at the user's domain via the mobile network. As illustrated in Figure 6-1, the RNS navigation server integrates traffic data provided by the vehicle information and communication system (VICS) and the vehicle movement data into its route calculation algorithm and suggests to drivers, either time-priority routes or other alternative routes that can avoid congested traffic conditions. The route information is transmitted via mobile network to the service user.

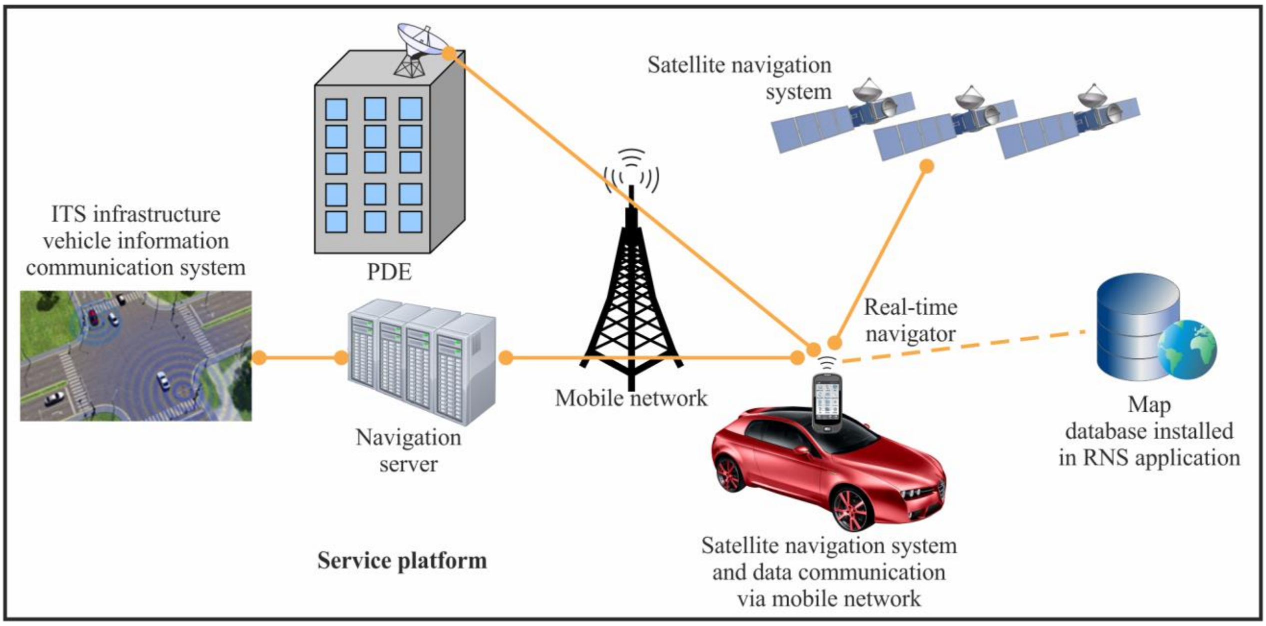


Figure 6-1 – Overall mechanism of RNS

The satellite plays a role by informing the vehicles about their position through the information transmitted by the satellite and received by the navigation devices at the user's domain. For the service to work, the satellite navigation system information, i.e., the position data, needs to be forwarded to the PDE server via the mobile network.

RNS can be offered via smart phones or other portable devices on which RNS application and map data can be downloaded and installed on these devices.

7 General approach to assess the environmental impacts of ICT service

[ITU-T L.1430] refers to Part I of [ITU-T L.1410] which provides guidance on assessing energy and GHG impacts of various ICT services and can be applied to assess those of RNS, i.e., the first order effects. Part II of [ITU-T L.1410] provides guidance on assessing the net result of energy and GHG impacts produced by use and application of RNS, i.e., second order effects, between RNS and its reference product system.

If energy and GHG impacts of an RNS are quantified as a voluntary accounting project and reviewed by a self-evaluation activity, Part II of [ITU-T L.1410] may be referred to. If they are required for a formal certification, [ITU-T L.1430] should be referred to.

This Supplement to [ITU-T L.1430] provides guidance only on assessing the net result of energy and GHG impact produced by use and application of RNS in the service use stage.

7.1 Methodological limitations

The methodology used to calculate the fuel consumption, and hence the GHG abatement in this guidance, has the limitation that it uses an indirect measurement approach to derive the actual fuel consumption in both the baseline scenario and the project activities. When applying this approach, a sensitivity analysis related to the lack of direct measurements needs to be performed in order to make any conclusions.

NOTE – Direct measurement of fuel consumption requires relevant trackers to be installed on the vehicles under the project monitoring scheme. However, it may be complicated to install fuel consumption trackers in a sufficient number of vehicles for cost reasons. The quantification methodology for the direct measurement of fuel consumption is out of scope of this version of the document but may be included in a later revision.

7.2 Introduction to RNS-related GHG projects

GHG projects can be defined as the activity or activities that alter the conditions identified in the baseline scenario and cause GHG emission reductions or GHG removal enhancements without compromising on the achievement of intended functional units. The project activities to reduce GHG emissions include the reduction, removal and increased storage of GHG emission in the atmosphere.

According to [ITU-T L.1430], an ICT project can be defined as a GHG project which incorporates and/or handles ICT goods, networks and services (GNS) to reduce GHG emissions, increase the storage of GHG, or enhance GHG removals. ICT projects can decrease the level of energy consumption or increase the energy efficiency where resulting energy savings may be translated into GHG emission reductions by using appropriate conversion factors. RNS enhances the fuel efficiency of the vehicles which follow the routes recommended by RNS, thereby reducing fuel consumption and GHG emission. GHG project mechanisms related to RNS are illustrated in Figure 7-1, and specific project descriptions are listed in Table 7-1 below.

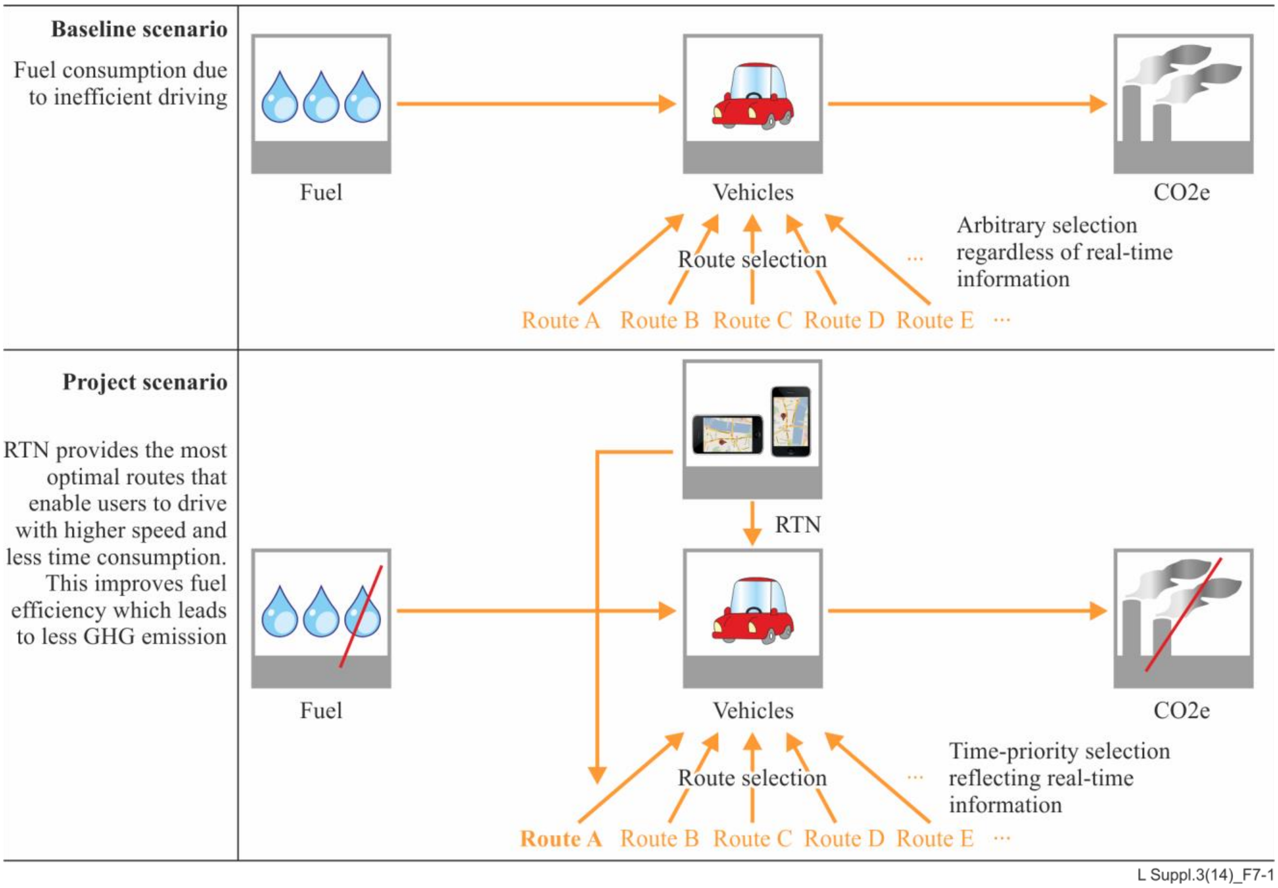


Figure 7-1 – GHG project mechanism – real-time navigation services

Table 7-1 – GHG project description – real-time navigation services

Typical project(s)	**Project activities**: – Installation of RNS in passenger cars and selection of the route by RNS.
Type of GHG emissions mitigation action	**Energy Efficiency**: – Reduction of fossil fuel use and corresponding emission through energy efficiency improvements.

Table 7-1 – GHG project description – real-time navigation services

Important conditions under which the methodology is applicable	– This methodology applies to passenger cars of the RNS users who are centrally controlled and monitored by a service provider; – The project activity is unlikely to change the level of service provided before the project activity; – The project activity does not change the fuel, vehicle, and driving pattern of drivers of the baseline activity matching to the project activity; – This methodology is not applicable to project activities in locations where the RNS is not provided and the navigated routes are not monitored; – The navigated routes (the time-priority routes) and the baseline routes (the distance-priority routes) that vehicles operate should be monitored with route characteristics (average speed reflecting traffic condition) as well as the level of service on each route.
Important parameters	**Monitored**: – Traffic/congestion condition expressed as the average speed on the route for the navigated route and the baseline route; – Actual average distance travelled on the navigated route; – Actual travel time spent to achieve the functional unit expressed from the starting point to the destination point; – Monitoring to ensure that RNS is operating correctly and has not been interrupted during the route navigation.

7.3 Defining the elements of the ICT service

The ICT service can be considered to comprise three main network elements listed in Table 7-2:

Table 7-2 – Elements of ICT service

Elements	Scope
End-user domain	All ICT equipment and related support equipment such as cabling, racking, etc. Customer domain constitutes part of ICT service that is normally deployed on the service provider's customer premises. For RNS, the navigation devices with satellite navigation system and location transmitters (smart phones or other PDA devices) are corresponding here.
Network domain	All the ICT equipment and related support equipment (cabling, racking, antennae etc.) used by the ICT service provider in delivering the service being addressed. For RNS, servers, databases, routers, wireless based stations, switches are corresponding here.
Service provider activities	Any activities and non-ICT support equipment necessary for the ICT service delivery. Activities include design, surveying, planning, logistics, deployment / installation, digging of trenches, mast erection, maintenance and technical support. For RNS, probe fleets to update the map database can be addressed here.

8 RNS project planning

8.1 Identifying RNS project activity

An RNS project is defined as a project that provides an RNS service to a certain group of users for a certain time period. For assessment purposes, the project and the baseline performance needs to be monitored to objectively track the project activity and baseline activity.

An RNS project can be a project with a geographic boundary in which RNS service is provided to the service users whose travel log can be monitored and validated by an RNS provider's monitoring system.

The project activity is defined as a specific action or intervention by ICT mitigation technology within a project targeting GHG emissions' reductions, removals or storage. Activities such as project planning and monitoring are not seen as project activities in this sense. See [ITU-T L.1430] for details.

RNS intervenes in the drivers' route selection processes by providing real-time traffic information. Compared to the baseline scenario in which drivers decide their own routes without any real-time traffic information, an RNS project scenario, as illustrated in Figure 8-1, improves the quality of their route decisions, thereby achieving the enhanced transportation efficiency, transparency and speed of process.

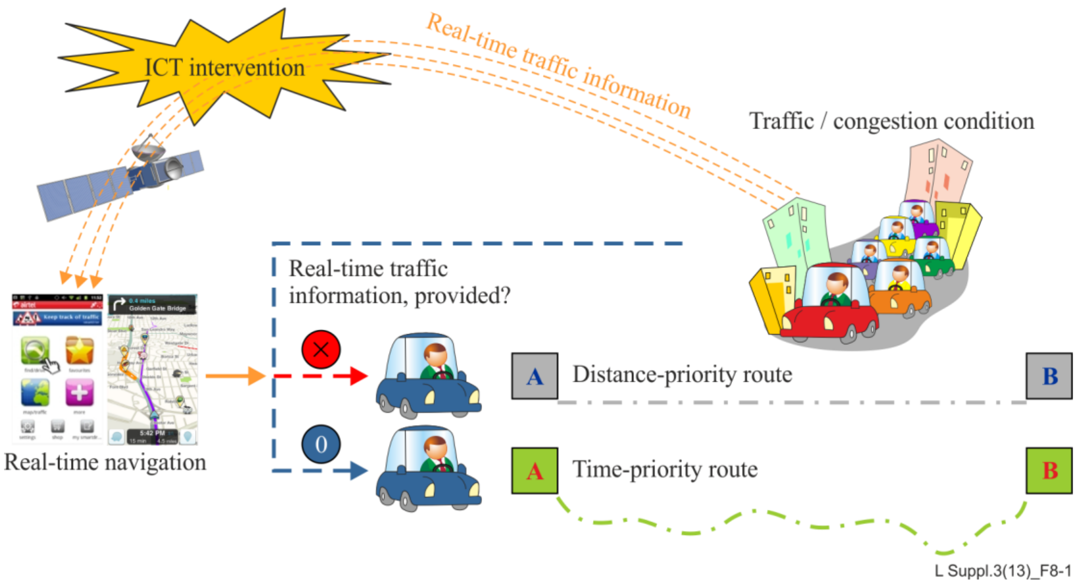


Figure 8-1 – RNS project activity compared to baseline scenario

8.2 Defining the assessment boundary of an RNS project

The project boundary can be set by the RNS geographic area of the service provider. Generally, the geographic boundary can be aligned to city, region or national level where RNS and the monitoring plan can be provided, used and implemented without any technical limitations.

8.3 Determining the baseline and project activity

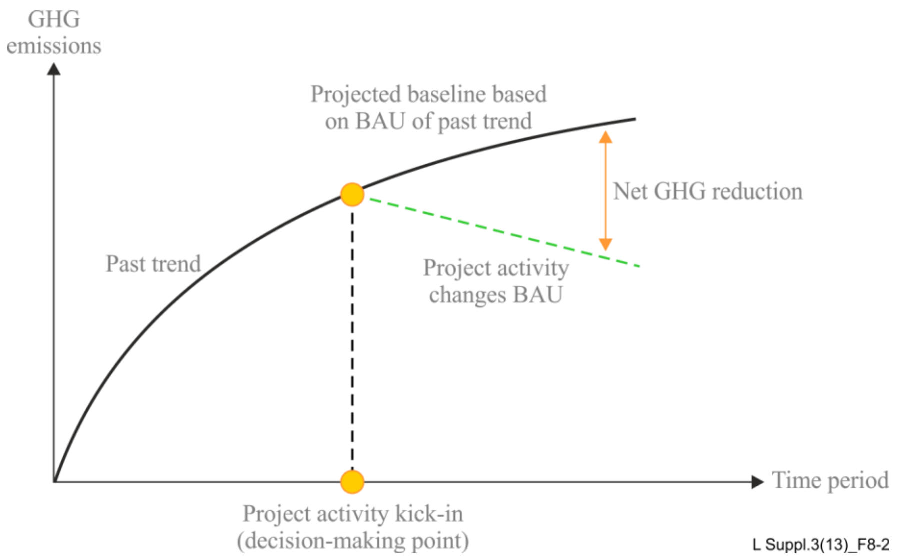
This clause provides procedures to estimate baseline and project emissions that are associated with the fuel consumption of vehicles. Table 8-1 below demonstrates 1) general considerations and check points required for developing baseline and 2) the implications of RNS in a GHG project.

Table 8-1 – Checkpoints for baseline development and implications for GHG project of RNS

Checkpoint for baseline development	Implications for GHG project of RNS
Project description, including identified GHG sources, sinks and storages, and/or energy consumption sources, generators and storages.	The GHG sources for an RNS project include vehicles that consume various types of fossil fuels, at least including gasoline, diesel and LNG. A few GHGs such as CO_2, CH_4 and N_2O are emitted by consumption of those fuels and resulting GHG emissions can be estimated by applying the relevant conversion factor.
Existing and alternative project types, activities and technologies providing equivalent types and levels of activity of products or services to the project	RNS intervenes in a driver's route selection process providing real-time traffic information. An alternative project can be another conventional distance-priority navigation system which provides only the shortest distance route regardless of any real-time traffic information. This distance-priority route is the optimal baseline scenario since it can be assumed that a reasonable drivers without real-time traffic information prefers to rationalize their limited resources (time and fuel consumption) by choosing the shortest route on a map. Matching the distance-priority route as the baseline scenario to the time-priority route selected by RNS as the project scenario, the conservativeness of the GHG emission reduction by the project activity can be upheld[1].
Data availability, reliability and limitations	Without ICT technology it is very difficult to develop a set of reliable baseline data of each project activity, because the project activity involves millions of route selection decisions by millions of service uses reflecting an ever-changing real-time traffic situation. However, ICT enables the baseline scenario activity to be generated and the relevant data to be analysed and stored simultaneously to the project activity.
Other relevant information concerning present or future conditions, such as legislative, technical, economic, socio-cultural, environmental, geographic, site-specific and temporal assumptions and projections	The baseline is derived from the project activity conditions by using the same destination and reflecting the same real-time traffic information at the time of the route selection. The mismatch risks include the mismatch in fuel types, vehicle profiles, drivers' eco-driving patterns, between the project and the baseline scenario.

A typical GHG project sets a baseline by the development of a baseline scenario. This baseline scenario is usually developed based on reliable statistics from past years. The baseline scenario is affected by the project activity intervention and the project scenario generates the net reduction in GHG emission compared to the baseline scenario over the project period, as illustrated in Figure 8-2.

1 It should be noted that not using a navigation system could be also considered as reference candidate as well; however, a distance-priority route also fulfils this purpose because it represents the reference scenario without a navigation system. A distance-priority route is selected based on the conservative principle.



NOTE – Business as usual (BAU)

Figure 8-2 – GHG comparison between typical baseline scenario and project scenario

Whereas the GHG emission reduction in an RNS project is also calculated by comparing the project scenario to the baseline scenario, the only difference is that the GHG project of an RNS generates the baseline scenario and the project scenario simultaneously when each project activity is involved.

Important parameters such as distance travelled, travel time and average speed can be monitored for both scenarios due to ICT technology excellence in data gathering, analysis and storage as shown in Figure 8-3 below.

Compared to the conventional baseline scenario generated from past statistics, the baseline scenario based on RNS has a better ability to reflect relevant traffic conditions, because the baseline scenario is generated under the same traffic situation at the driver's route decision point.

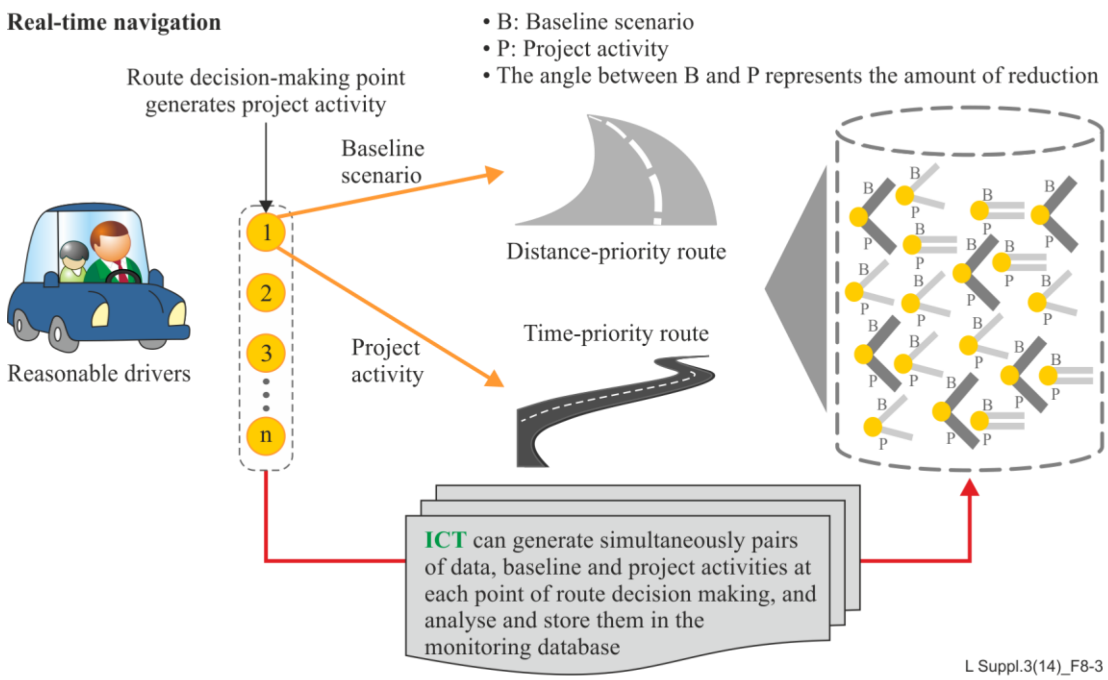


Figure 8-3 – Comparison between baseline scenario and project activity when RNS is implemented

8.4 Consideration of life cycle assessment

In alignment with [ITU-T L.1430], the GHG and energy effects of the ICT GHG projects should preferably consider the entire life cycle assessment (LCA) but may be quantified focusing only on the most significant stage (i.e. the use stage). The consistency principle of quantification should be applied in both baseline and project scenarios.

In case project programs do not require life cycle perspective besides the use stage, other stages in the life cycle could potentially be excluded. This Supplement focuses only on the net result of energy and GHG effects of the RNS projects in the use stage. However, this Supplement recommends [ITU-T L.1410] for any considerations for further LCA.

8.5 First order effects of RNS

The assessment of first order effects is not the direct focus of this Supplement. Therefore it is briefly described by the definition and the reference to Part I of [ITU-T L.1410].

First order effects are defined as the direct environmental impacts related to the ICT service offering. They can encompass all negative environmental impacts during each stage of the life cycle of each ICT service element necessary for the service delivery.

GHG and energy effects when using RNS relevant goods, networks and services as described above should preferably be quantified by taking into account their LCA. In this case, by following the consistency principle of ICT GHG project accounting, baseline emissions and project emissions are assessed in the same manner in line with Part I of [ITU-T L.1410] as outlined in clause 7.4 of [ITU-T L.1430].

First order effects of RNS include emissions related to the equipment mentioned in Table 7-2 above. A main challenge related to the assessment of RNS is allocation of the impact of shared equipment to the service. The shared equipment includes satellite navigation system, shared servers, databases and other equipment in the network and service provider domains. For the network and service provider domains, [ITU-T L.1410] provides the guidance for the allocation. For the satellite navigation system, it seems reasonable to consider it as infrastructure and leave it outside of the system boundaries.

[ITU-T L.1410] provides more detailed guidance related to the assessment of the first order effect.

8.6 Second order effects of RNS project activity

In this Supplement, second order effects considers both positive and negative effects since the use and application of the ICT project may generate both environmental load reduction and increase.

8.6.1 Positive second order effects

The mechanism of positive environmental impacts of ICT can be categorized into replacement of environmentally-burdening activity with more environmentally-friendly activity, increased efficiency, increased transparency, increased speed of transactions or process, rapid market clearing, long-tail effects, etc. where a project scenario and reference scenario for comparison are defined.

These are all positive environmental effects via ICT service. [b-SMART 2020], published in 2008, defined the ICT enabling effect, which is a positive second order effect, as the ability of ICT solutions to facilitate emissions reductions by means of improved visibility (increased transparency), more efficient management or optimization of processes, and behavioural change as a result of better quality information for the decision process.

A positive second order effect is a reduction in GHG emission compared to the baseline scenario as a direct result of ICT service use. For RNS, the positive second order effect occurs when fuel consumption in transport is decreased by using RNS.

RNS intervenes in a driver's route selection decision with transparent traffic information and recommends to the driver a time-priority route among various alternative routes. Without transparent traffic information, it is assumed that a reasonable driver would choose the distance-priority route, which is the shortest route to the destination. If there is no congestion, RNS chooses the distance-priority route, which is the same as what the baseline scenario would suggest, neutralizing the GHG emission reduction effect of RNS. However, as the level of congestion increases in the shortest route, i.e., the distance-priority route, RNS analyses and compares the estimated travel time reflecting traffic conditions of the next shortest routes, and chooses the route that offers the shortest travel time.

As illustrated in Figure 8-4 below, each time the driver enters the destination into RNS, a time-priority route is generated which could be compared to the distance-priority route which would have been selected without the use of RNS. The distance-priority route could thus be seen as the baseline when assessing the time-priority route.

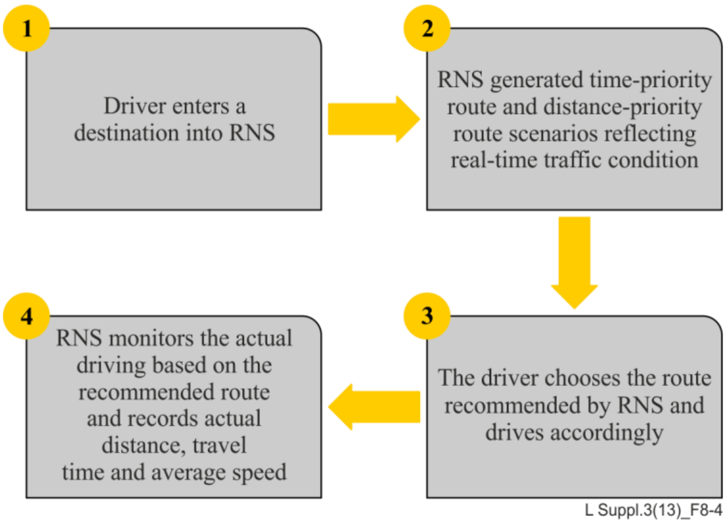


Figure 8-4 – Procedures of RNS

The average speed of the time-priority route, which RNS recommends, is expected to be faster than the average speed of the distance-priority route.

The increased speed of the route might result in enhanced fuel efficiency, thereby causing GHG emission reduction corresponding to the amount of fuel savings. This relationship is illustrated in Figure 8-5.

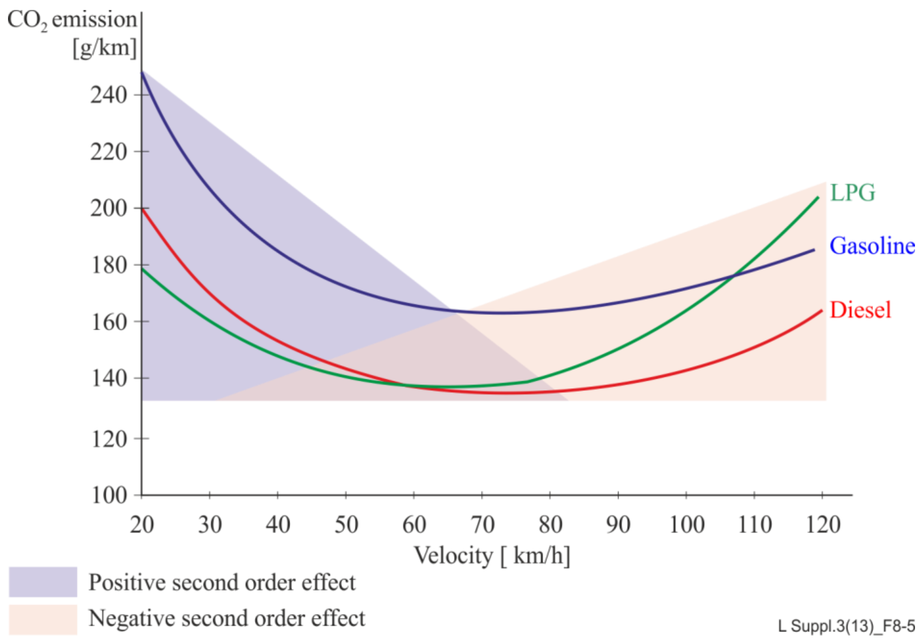


Figure 8-5 – Relationship between velocity and GHG emission by fuel types (source: Copert 4 model)[2]

The marginal positive second order effect of speed on GHG emissions becomes greater in lower average speed area, which means that the more the congestion appears, the more effectively the time-priority route reduces GHG emissions per km.

8.6.2 Negative second order effects

A negative second order effect is defined as an increase in GHG emissions, caused by the use of RNS, which offsets some portion of GHG emission reduction by positive second order effect.

A negative second order effect is an immediate effect that increases GHG emission immediately compared to the baseline scenario. For RNS, this type of negative effect emerges from additional use of transport fuel consumption due to detour routes that RNS navigates. Another example of additional use of transport fuel consumption is due to less eco-driving, for example from over-speeding, resulting in deteriorated fuel efficiency. This negative second order effect is expected to exist because RNS usually navigates drivers towards less congested roads, allowing more speeding than shown in congested routes.

8.6.3 Net second order effects

There is no doubt that less time spent in congested traffic and an overall increase in average speed over a route will enhance fuel efficiency, thereby emitting less GHG emission per unit distance (CO_2e/km). As shown in Figure 8-5 above, there exists an inverse relationship between GHG emission and the average route speed until the average speed reaches a certain speed level (around 80 km/h in the graph above). The area which this inverse relationship holds is shown as an enabling speed area.

However, if the average speed exceeds the certain speed level (around 80 km/h), the direct relationship replaces the inverse relationship converting the positive second order effect into negative second order effect. This means that if the average speed over the less congested route is

2 This relationship curve between velocity and GHG emission by fuel types is shown only for illustration. The actual relationship between velocity and GHG emission will be different depending on the vehicle, fuel efficiency technologies adopted and typical driving behaviour.

faster than the certain speed level, the actual GHG emission per unit distance can rather be increased.

Also, it should be noted that RNS recommends a time-priority route, which could result in a longer distance travelled. This additional distance, compared to the distance-priority route, will lead to additional GHG emissions. This additional GHG emission should be counted as a negative second order effect as well.

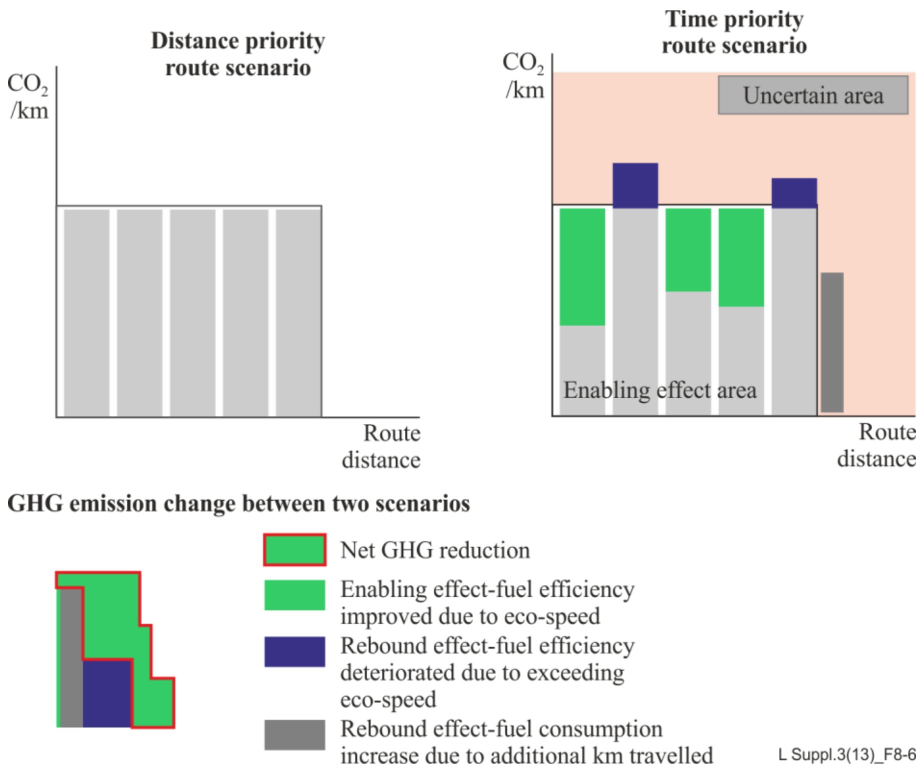


Figure 8-6 – Potential positive and negative second order effects by RNS compared to the baseline

Figure 8-6 above demonstrates the potential GHG emission changes in RNS project activity separated by positive and negative second order effects that are compared to the GHG emission from the baseline activity.

The increased average speed due to the time-priority route selection by RNS reduces CO_2 emission per km as long as the average speed stays in the eco-speed range. The positive second order effects of the project activity can be calculated by multiplying GHG emission reduction per km (compared to baseline) by the distance of the baseline route.

The negative second order effects of the project activity should also be calculated and deducted from the positive second order effects. There are two kinds of negative second order effects: 1) that related to speed, and 2) that related to additional distance.

The negative second order effect can be calculated by multiplying the GHG emission increase per km (compared to baseline) by the distance travelled with the speed over the eco-speed range for 1), and by multiplying the additional distance travelled greater than the baseline route, by the average GHG emission per km of this additional range of travel distance for 2).

8.7 Other effects

Longer-term negative effects are defined as non-immediate GHG increases in the baseline scenario as a result of ICT service implementation and use. They are often the result of cumulative impacts of larger-scale adoption. In RNS, an example of this effect could be spending more available time due to RNS with more GHG intensive activities.

Generally, these effects, which occur over a longer time horizon in more pervasive ways, are very difficult to track, assess and monitor. Therefore, they are usually disregarded in the quantification process of ICT's environmental impacts.

9 RNS project validation

Project validation guidance from [ITU-T L.1430] applies to RNS projects. Refer to [ITU-T L.1430] for details.

Validating the model requires sampling of real data related to distance, time, and fuel consumption to see the actual relationship between velocity and GHG emission. After the project is registered, regular validation of the relationship is required to be conducted at an annual interval (either financial or calendar year).

10 RNS project monitoring

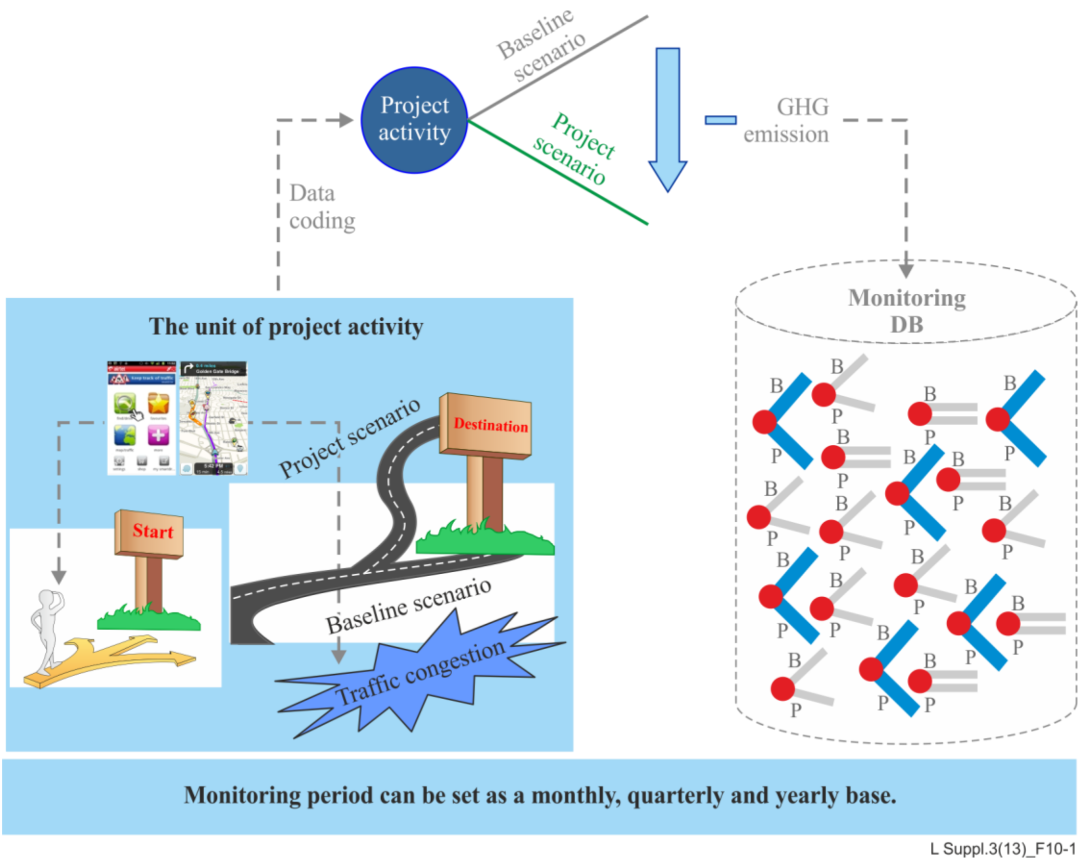


Figure 10-1 – Overview of RNS monitoring

The project proponent should establish and apply quality management procedures to manage data and information, including the assessment of uncertainty, relevant to project and baseline scenario.

As illustrated in Figure 10-1 and listed in Table 10-1, the following parameters for GHG emission calculation of baseline and project activities should be monitored.

Table 10-1 – Monitoring parameters

Parameter	Abbr.	Monitoring method / item
Estimated travel time in baseline route matching to the unit project activity	Tbl,i	RNS generated log data
Estimated distance travelled in the baseline route matching to the unit project activity	Dbl,i	RNS generated log data
Estimated average speed in the baseline route matching to the unit project activity	Vbl,i	RNS generated log data
Starting time (n = 0)	Hp,i,s,n	Driver log data in RNS for the recommended route
Actual arrival time to the measured point 'n'	Hp,i,a,n	Driver log data in RNS for the recommended route
Travel time between the measured point of 'n – 1' and 'n' of the unit project activity	Tp,i,n	Driver log data in RNS for the recommended route
Distance between the measured point of 'n – 1' and 'n' of the unit project activity	UDp,i,n	Driver log data in RNS for the recommended route
Average speed between the measured point of 'n – 1' and 'n' of the unit project activity	Vp,i,n	Driver log data in RNS for the recommended route
Electricity consumption	ECy	Measured by electricity meter
Net calorific value of for the vehicle and fuel type conservatively selected	NCVf	Country specific data or IPCC default value
CO2 emission factor for the vehicle and fuel type conservatively selected	EFCO2,f,y	Country specific data or IPCC default value
* Definition of subscripts. p: project activity i: ith route n: nth unit in ith route s: starting time a: arrival time f: fuel type y: year		

General requirements for ICT GHG project monitoring are specified in [ITU-T L.1430] and shall apply to the RNS project.

11 RNS Project quantification

Each route decision based on real-time traffic information provided by RNS generates a pair of data consisting of project activity and baseline scenario under the actual traffic condition.

The properties of paired data are as shown in Table 11-1.

Table 11-1 – Properties of paired data

	Paired data for the route	Project activity data	Baseline activity data
Data profile	Start point (geographic)	As input by the driver	Same as project activity
	Destination (geographic)	As input by the driver	Same as project activity
	Traffic condition	Real-time traffic condition of the selected route (The time-priority route)	Real-time traffic condition of the shortest route (The distance-priority route)
	Start time	When the start point registered	Same as project activity
	Arrival time	Actual destination arrival time	Estimated time by RTN reflecting the actual route traffic

The baseline and the project activity do not monitor fuel consumption of each route, but only distance, time and average speed.

Therefore, the fuel consumption in the project and in the baseline should be calculated by applying the standard velocity and fuel efficiency formula (SVFE) as described in Figure 11-1 below.

In developing the standard velocity and fuel efficiency formula, the following decision process should be considered.

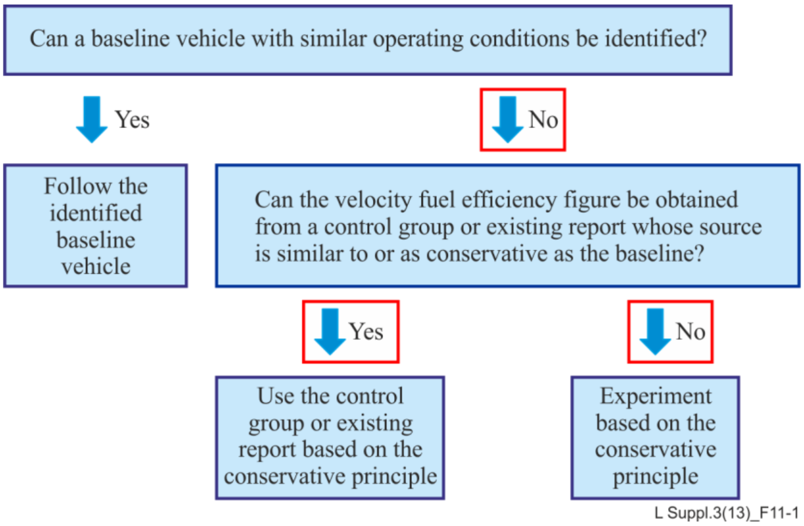


Figure 11-1 – Decision processes for developing SVFE formula

There exist many research activities which already have studied the relationship between velocity and fuel efficiency. Those research activities can be reviewed under the light of conservativeness and the credibility of the research institution, and can be used as a benchmark for the project.

If it is necessary to develop the project SVFE formula, the following points, highlighted in Table 11-2, can be considered.

Table 11-2 – The elements and approach considered in conservative principles

Element	Criteria	Approach
Fuel type	• Gasoline • Diesel • LPG	Velocity and fuel efficiency formula generated for each fuel type and selected based on the conservative principle
Vehicle type	• Statistically significant control group • Vehicle age	• Host country statistics or IPCC or other international data • Equal or newer
Operating condition	• Traffic condition • Eco-driving pattern • Air-conditioning	• Equal or newer • Eco-driving complied • Air-conditioning not used
Conservative principle		

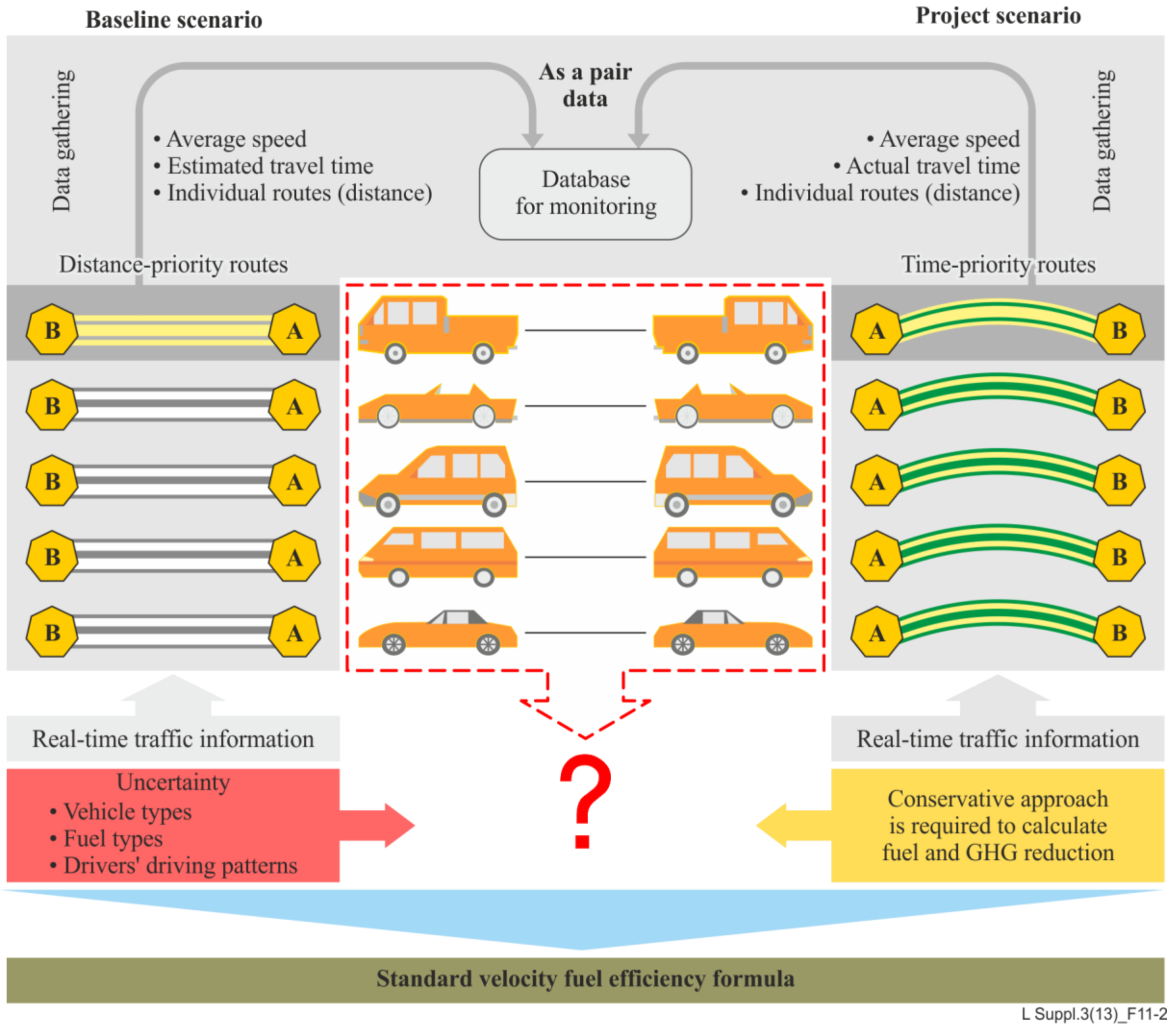


Figure 11-2 – The overall approach of standard velocity and fuel efficiency formula for RNS

As shown in Figure 11-2, the collected data for the baseline and project activity include the information of the time, the distance and the velocity of each route. The indirect fuel consumption should be calculated based on these data.

In order to calculate the fuel consumption, an SVFE formula should be developed in a conservative approach.

Figure 11-3 shows GHG emission efficiency, which has a direct relation to fuel efficiency, according to the velocity change.

Illustrative

Vehicle type	Fuel	Speed	CO_2 emission factor equation (Eco speed as 65.4 km/h)
Small size	Gasoline	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1313.7U^{-0.6}$ $Y(g/km) = 0.5447U + 78.746$
	Diesel	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1133.1U^{-0.587}$ $Y(g/km) = 0.6175U + 62.478$
Medium size	Gasoline	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1555.57U^{-0.578}$ $Y(g/km) = 0.0797U + 144.19$
	Diesel	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1818.1U^{-0.6643}$ $Y(g/km) = 0.3184U + 95.66$
	LPG	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1539.4U^{-0.5748}$ $Y(g/km) = 0.5056U + 117.39$
Large size	Diesel	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1970.1U^{-0.6187}$ $Y(g/km) = 0.1791U + 145.07$
	LPG	U < Eco speed (km/h) U ≥ Eco speed (km/h)	$Y(g/km) = 1849.8U^{-0.6164}$ $Y(g/km) = -0.1348U + 159.9$

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Figure 11-3 – GHG emission efficiency based on speed, vehicle and fuel types

SVFE formulas are separated by two different speed ranges: those below and those above the limit of eco-speed range. They are further divided by vehicle and fuel types as well (see Table 11-3).

Among these formulas, the most conservative one can be used to calculate the project and baseline emissions by each speed range.

Table 11-3 – Standard velocity and fuel efficiency formula

Standard velocity and fuel efficiency formula		
Criteria	Velocity < eco-speed km/h	Velocity ≥ eco-speed km/h
Formula (Note)	Y(g/km) = a × V(km/h) – b	Y(g/km) = a × V(km/h) + b
NOTE – a and b are constants that vary depending on fuel and vehicle type. They can be obtained through empirical velocity and fuel efficiency studies.		

11.1 Calculation of baseline emissions

Baseline emissions for a project activity can be estimated by comparing the baseline activity data with the corresponding project activity.

When the distance priority route is selected as a baseline activity, the baseline activity data comprised of the starting place and time, and estimated arrival time to the destination under real-time traffic situations can be generated and collected in the database corresponding to the project activity.

Total travel time is estimated based on two parameters for the baseline activity: the starting time and the estimated arrival time to a destination. Also, the total distance travelled for the baseline route can be monitored as it is the shortest distance route to the destination; the total distance can also be divided by the total travel time to estimate average speed over the baseline route.

This average speed and total distance travelled for the baseline route is applied to the SVFE formula to generate the fuel consumption.

After the fuel consumption for each baseline route is estimated, the net calorific value for this fuel consumption is calculated, and accordingly the GHG emission is calculated based on CO_2e emission factor for each fuel type.

Detailed parameters and calculation are shown in Table 11-4.

Table 11-4 – Parameters and calculation for baseline emission

Parameter	Abbreviation	Calculation
Starting time	Hbl,s,i	Monitored
Estimated arrival time to destination	Hbl,a,i	Monitored
Total travel time	Tbl,i	Tbl = Ha,bl,i – Hs,bl,i
Total distance travelled for the baseline route	Dbl,i	Monitored
Average speed over the baseline route	Vbl,i	Vbl,i = Dbl,i/Tbl,i
Fuel efficiency for the vehicle and fuel type conservatively selected	FEbl,i	If Vbl,i< the Limit of eco-speed range, FEbl,i= a × Vbl,i – b If Vbl,i ≥ the Limit of eco-speed range, FEbl,i = a × Vbl,i + b
Fuel consumption for the vehicle and fuel type conservatively selected	FCbl,i	FCbl,i = FEbl,i × Dbl,i
Net calorific value of for the vehicle and fuel type conservatively selected	NCVf	Given
CO2 emission factor for the vehicle and fuel type conservatively selected	EFCO2,f,y	Given
Baseline emission for each unit of project activity	BEi	BEi= FCbl,i × NCVf ® EFCO2,f,y
* Definition of subscripts bl: baseline scenario i: ith route s: starting time a: arrival time f: fuel type y: year		

11.2 Calculation of project emission for each route

Emission for each unit project activity can be estimated based on the project activity data.

11.2.1 Estimation of project emission from first order effect

The first order effect of RNS related ICT GNS shall be calculated as outlined in [ITU-T L.1430] upon any necessity.

11.2.2 Estimation of project emission from second order effect

When the service user operates RNS and sets the destination, the starting time, the starting place and the destination are monitored as well as the actual arrival time to the segmented milestone (the measured point) to the destination which can be set based on a certain time interval. Travel time and distance between the measured points (n – 1 and n) can be calculated as well as the average speed between the measured points (n – 1 and n).

Each estimated average speed between the measured points (n – 1 and n) can be applied to the standard velocity and fuel efficiency formula to estimate fuel consumption for each measured points.

Then, the fuel consumption for each measured point can be summed up to the total route distance to calculate the total fuel consumption for the route of the project activity.

After the fuel consumption for each project route is estimated, net calorific value for this fuel consumption is calculated and accordingly GHG emission is calculated based on CO_2 emission factor for each fuel type.

Detailed parameters and calculation is shown in Table 11-5.

Table 11-5 – Parameters and calculation for project emission

Parameter	Abbr.	Calculation
Starting time (n = 0)	Hp,i,s,n	Monitored
Actual arrival time to the measured point 'n'	Hp,i,a,n	Monitored
Travel time between the measured point of 'n – 1' and 'n'	Tp,i,n	Tp,i,n = Hp,i,a,n – Hp,i,a,(n – 1)
Distance between the measured point of 'n – 1' and 'n'	UDp,i,n	UDp,i,n = Dp,i,n – Dp,i,(n – 1)
Average speed between the measured point of 'n – 1' and 'n'	Vp,i,n	Vp,i,n = UDp,i,n/Tp,i,n
Fuel efficiency for the vehicle and fuel type conservatively selected	FEp,i,n	If Vp,i,n < the Limit of eco-speed range, FEp,i,n = a × Vp,i,n – b If Vp,i ≥ the Limit of eco-speed range, FEp,i,n = a × Vp,i,n + b
Fuel consumption for the vehicle and fuel type conservatively selected	FCp,i,	$FC_{p,i} = \sum_{1}^{n} FE_{p,i,n} \times UD_{p,i,n}$
Net calorific value of for the vehicle and fuel type conservatively selected	NCVf	Given
CO2 emission factor for the vehicle and fuel type conservatively selected	EFCO2,f,y	Given
Project emission for each unit of project activity	PEi,	PEi,= FCp,i × NCVf × EFCO2,f,y
*Definition of subscripts p: project activity		

Table 11-5 – Parameters and calculation for project emission

Parameter	Abbr.	Calculation
i: ith route n: nth unit in ith route s: starting time a: arrival time f: fuel type y: year		

11.2.3 Estimation of total project emission

By aggregating all emissions from each route selection from the project activity, the project emission produced while using RNS is calculated.

Total project emission for each route selection of project activity (PE) = $PE_{i,}$ + $PE_{el,}$

Where;

PE_i = Project emission for each route selection of project activity (tCO_2e)

$PE_{el,}$ = Project emission from first order effect in year y (tCO_2e)

11.3 Calculation of GHG emission reduction of RNS project

During a certain period of monitoring, GHG emissions of multiple project activities should be gathered. Total GHG emission in the project activities and corresponding baseline activities should be estimated and GHG emission reduction by the project activities should be calculated.

Detailed parameters and calculation is shown in Table 11-6.

Table 11-6 – Parameters and calculation for GHG reduction

Parameter	Abbr.	Calculation
Monitoring period	m	
Nr. of project activities	i	
Total GHG emission in the project activities during the monitoring period	PEP,m	$PE_{p,m} = \sum_{1}^{i} PE_i + PE_{el}$
Total GHG emission in the baseline matching to the project activities during the monitoring period	$BE_{BL,m}$	$BE_{BL,m} = \sum_{1}^{i} BE_i$
GHG emission reduction in the project activities	$PER_{P,m}$	$PER_{P,m} = \sum_{1}^{i} BE_i - \left(\sum_{1}^{i} PE_i + PE_{el}\right)$
*Definition of subscripts p: project activity i: ith route n: nth unit in ith route s: starting time a: arrival time f: fuel type y: year		

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