Identifying and prioritising technologies for mitigation

- *A hands on guidance to multi-criteria analysis (MCA)*

UNEP DTU Partnership

September 2015

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Acknowledgements

We would like to thank Sara Trærup and Riyong Kim Bakkegaard who wrote the technology prioritisation guidance for adaptation technologies, which served as an inspiration for this publication.

We would also like to thank Sara Trærup, Prakriti Naswa and Jorge Rogat for providing reviews for this note.

Authors

Contents

Chapter 1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) aims to stabilise greenhouse gas concentrations in the atmosphere "at a level that would prevent dangerous anthropogenic interference with the climate system" (UN, 1992). In recent years, a goal to limit the long-run the temperature rise to below 2°C from the pre-industrial period average global temperature was agreed. Developing countries have emphasised the role of technologies, capacity, and finance for achieving the climate targets. Implementing mitigation technologies in developing countries can also contribute achieving their development priorities. Technology development, transfer, and diffusion is thus an area of increasing priority on the international agenda.

Mitigation actions need to be mainstreamed within the development agenda of the countries; therefore, technologies that reduce greenhouse gas emissions should also have economic, social and environmental co-benefits. Therefore methodologies that rely solely on costs for carbon reduction e.g., marginal abatement cost curves are not sufficient. Similarly, techniques such as cost benefit analysis, which can integrate a range of costs and benefits, require monetisation of all the benefits to enable comparison; however monetisation of all the benefits is not easy (Salling and Pryn, 2015). Multi-criteria analysis is often used by decision makers to identify the most preferred option, to rank options or to short-list a set of options. It allows the decision maker to analyse all the benefits and costs without relying on monetisation.

This guidance describes the process of conducting a technology prioritisation exercise using multi-criteria analysis. The objective of this guidance is to support consultants, decision makers, and technical experts in conducting and facilitating the prioritisation of mitigation technologies. It has been primarily written for those working on Technology Needs Assessments during Phase II of the TNA project.

The guidance is complemented by an Excel tool[1] that provides a template for following this guidance and makes the background calculations for the process automatic. The Excel tool can be used to rank the technologies, and to carry out a sensitivity analysis.

What is mitigation technology?

Mitigation technology encompasses technologies and practices that can lead to a reduction in greenhouse gas (GHG) emissions or increase the capacity of carbon sinks to absorb GHGs from the atmosphere (IPCC, 2007). The definition of mitigation technology varies across sectors. An overview of the most common mitigation technologies by sector is available with the TNA Technology Guidebooks[2] and on Climate Techwiki[3].

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[1] It can be downloaded from http://www.tech-action.org/Resources

[2] Available for Agriculture, Transport, and Building sectors. These publications can be found on http://www.tech-action.org/Publications/TNA-Guidebooks

[3] A platform that offers detailed information on a broad set of mitigation and adaptation technologies: http://www.climatetechwiki.org/

Chapter 2. Multi-Criteria Analysis for prioritising mitigation technologies

This chapter provides a basic step-by-step guidance for conducting multi-criteria analysis (MCA) for the prioritisation of technologies for climate change mitigation.

MCA is a tool commonly used for decision-making process, including to rank options or to short-list a limited number of options. It allows combining criteria which are valued in monetary terms and others for which monetary valuations do not exist. In addition, MCA combines the use of both quantitative and qualitative criteria. MCA allows the use of a full range of social, environmental, technical, economic, and financial criteria.

MCA can thus provide a structured framework for comparing mitigation technologies across multiple criteria. MCA is a judgement based system. It is thus important that the framework reflects a well-balanced judgement of all the important stakeholders and be developed through a consensus process in consultation with all the relevant stakeholders. The inputs from stakeholders can be obtained through personal communications, interviews and/or in a workshop setting.

The steps presented in this publication for undertaking the MCA follow the approach described in Dodgson et al. (2009):

1. Establishing the decision context, i.e. identifying the objectives and determining the relevant stakeholders;
2. Identifying the options, i.e. the mitigation technologies which will be compared;
3. Identifying the criteria, i.e. the parameters used to evaluate the extent to which technologies contribute in achieving the objectives;
4. Describing the expected performance of each option against the criteria.
5. 'Weighting', i.e., assigning a numerical value (the weight) to each of the criteria to reflect their relative importance over the other criteria to the decision;
6. Combining weights and scores;
7. Examining the results;
8. Conducting a sensitivity analysis.

The interrelationships of the steps above are shown in Figure 1. It is usual in conducting an MCA to go back to previous steps and make adjustments.

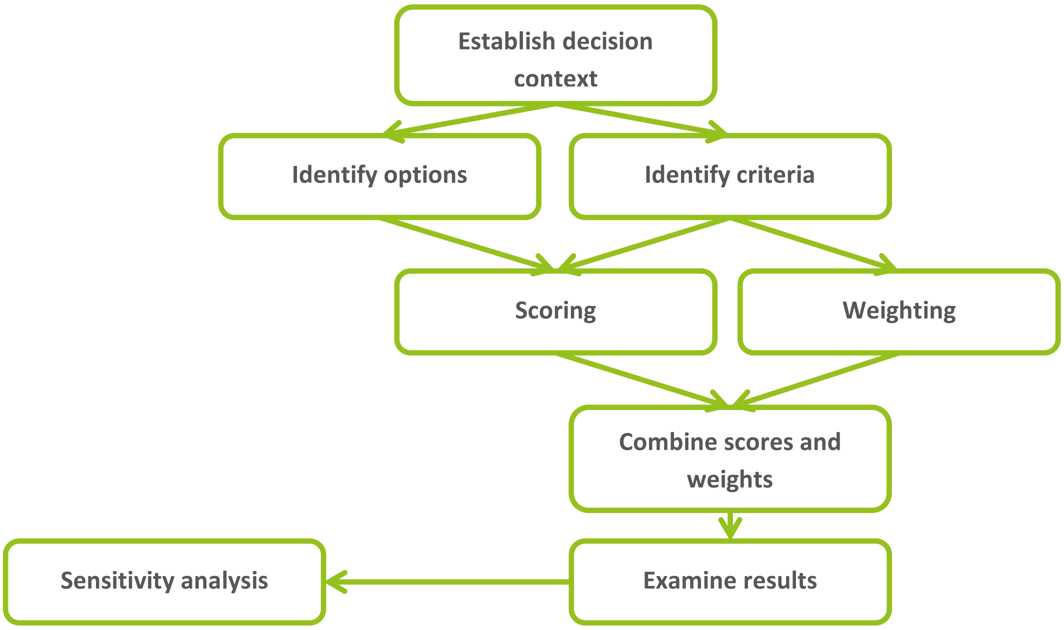

Figure 1: Steps in multi-criteria analysis

Throughout this note, each step of the prioritisation process is exemplified using experiences from conducting a Technology Needs Assessment (TNA) for mitigation as well as via stylised examples. In TNA, technologies are prioritised at a sectoral level. Therefore, the exemplification in this note is of technology prioritisation within a sector.

Step 1: Establishing the decision context

As a first step in the process of prioritising technologies, the context in which the decision takes place should be established. Dodgson et al. (2009) define the decision context as the economic, political, social and technological environment that surrounds the decision. However, other categories such as institutional or environmental could be included in the decision context according to the national framework.

A good decision making process requires identifying clear objectives. The objectives should be specific, measurable, attainable, realistic, and timely. In the case of mitigation technologies, the prioritisation process is undertaken in the context of climate change and development priorities of the country. The objectives defining the decision context can thus be framed in terms of economic, social or environmental goals taking into account the national context related to climate change and sustainable development.

The objectives can be established in two steps. First, the consultant can establish the objectives by reviewing climate or development national/sectoral strategies and plans. It has to be noted that these objectives may have already been determined by decision makers in the national or sectoral strategies or plans. Second, the consultant should submit the objectives established for comments, discussion and decision to the TNA sectoral workgroup. The establishment of the TNA sectoral workgroup in itself is a key task for establishing the decision context[4].

[4] For further details, including a description of roles, refer to UDP publication *Organising the National TNA Process: An Explanatory Note*. It can be found on http://www.tech-action.org/Publications/TNA-Guidebooks.

Context and objectives of the transport sector in Sri Lanka

The Sri Lankan Government's new National Development Framework ("Mahinda Chintana: Idiri Dakma" - Vision for a New Sri Lanka, (2010) aims at accelerating growth, with particular emphasis on equitable development, recognizing that there has been a perpetuation of income disparities both among income earners and across geographic regions. It focuses on three main areas: (i) achieving more equitable development through accelerated rural development; (ii) accelerating growth through increased investment in infrastructure; and (iii) strengthening public service delivery.[5]

Sri Lanka prioritised Transport, Energy and Industry as the three priority sectors for mitigation. This prioritisation was based on first identifying sectors based on development priorities and then identifying sectors that had high relevance for GHG mitigation and contribution to development priorities. In terms of GHG accounting transport is counted within the energy sector and accounted for around 50% of energy related GHG emissions in year 2000. Lastly, the sectors were further narrowed down based on their contribution for sustainable development. Transport sector is important on account of its importance for addressing challenges related to pollution, poverty reduction and improving competitiveness of economy and these are well laid out within the Sri Lanka Strategy for Sustainable Development (SSLD).

More specific objectives in the transport sector

Besides being a large GHG emitter, transport is also the largest consumer of oil that Sri Lanka imports and therefore reducing import dependence is a related objective. Transport sector is also responsible for more than 60% pollution in Colombo and therefore another objective that was identified for this sector is pollution reduction.

Step 2: Identifying the options

This step aims to identify the options to be evaluated, in this case, the mitigation technologies that will be assessed. The output of this step is a long list of technologies established for each sector considered in the TNA process.

The identification of technologies for climate change mitigation in a particular sector can be informed by existing studies, e.g. national and local development plans, low carbon strategies, etc. The consultants can do a desk review of such documents to identify possible options for technologies. Other sources of information on technologies can be: the TNA sectoral technology guidebooks for mitigation[6], global databases on technology such as Climate Techwiki, IEA Technology Perspectives, etc. Once the consultant has completed this desk review and established a long list of technologies for a sector, the list should be circulated to the members of the sectoral workgroup. Based on feedback from experts within the workgroup, additional technologies can be included into the long list. The sectoral workgroup feedback and discussions should eventually lead to a refined long list of 10-12 technology options. The technologies included in the long list will be evaluated in the subsequent steps.

The consultant should prepare technology fact sheets for each of these technology options. Technology fact sheets are useful tools for providing most important information about a technology in a concentrated form to the stakeholders. An example of a technology fact sheet is given in Annex A.

[5] For more information, see Sri Lanka country report (Wickramasinghe, 2011) It can be found on http://www.tech-action.org/Participating-Countries/Phase-1---Asia-and-CIS/Sri-Lanka

[6] Available for Agriculture, Transport, and Building sectors. These publications can be found on http://www.tech-action.org/Publications/TNA-Guidebooks

Identifying a long list of technologies for transport sector in Sri Lanka

The number of vehicles imported and used in the country has seen a significant increase during the last few years. Land transport plays an important part with a variety of vehicle technologies addressing the demand (Table 1).

Table 1: Road transport technologies in Sri Lanka

Vehicle	Fuel type	Contribution to Passenger/Freight Transport
Passenger Transport		
1. Buses	Diesel	48.3%
2. Cars	Petrol, Diesel, LPG, Hybrids	13.2%
3. Vans	Diesel, Petrol	12.6%
4. Three- Wheelers	Petrol/LPG, Diesel	11.8%
5. Motor bicycles	Petrol	6.5%
6. Railways	Diesel	4.3%
7. Lorries and other vehicles	Diesel, Petrol, LPG	3.3%
Freight Transport		
1. Trucks	Diesel	99%
2. Railways	Diesel	1%

The government is keen to reduce the demand for vehicles and reduce the externalities from their use and has accordingly enacted certain policies for the same. For example, the permitted age of imported used vehicles has been reduced from 3.5 years to 2 years; import of three wheelers with 2-stroke engines has been banned, etc.

The stakeholders identified a long list of technologies and measures that would help diversify fuel mix, reduce dependence on oil and reduce air pollution. The following technologies /actions were identified:

1. Shift of 5% of transportation of freight from roads to rail
2. Improved public transportation, especially in Colombo area: Introduction of a Bus Rapid Transit (BRT) system
3. Integration of Non-motorised transport methods in Colombo along with regularised public transport system
4. Improving the traffic signal system for synchronisation
5. Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles
6. Improvement of the condition of byroads
7. Electrification of the existing railway system
8. Promote and facilitate the import of low GHG emitting hybrid vehicles
9. Increase the use of cleaner fuel (i.e. Compressed Natural Gas (CNG) and biofuels)
10. Roadside tree planting and improving the overall roadside vegetation

Step 3: Identifying criteria

Criteria are the measures of performance by which the options will be judged. The identification of criteria against which technologies will be ranked should be based on a clear and transparent process. The workgroup members must understand the meaning of the criteria and how criteria are framed as well as the implied trade-offs.

The criteria are derived from the objectives identified in Step 1, which, in the case of an MCA process for prioritisation of mitigation technologies, are related to climate change and development priorities of the countries.

The criteria might be divided into sub-criteria and thus be organised in different levels. These sub-divisions ease the understanding on how the objectives are translated into evaluation criteria. Criteria should be chosen and categorised based on the national context, considering the needs and objectives set for a particular sector. Sector objectives can serve as higher level criteria, and be subdivided into lower level criteria. For example, the top level objectives can be defined as: minimising costs, maximising social, economic and environmental benefits. For climate technology analysis, the criteria can be divided into broad categories relating to technology diffusion, sustainable development impacts, and climate impacts, as shown in Figure 2. MCA4Climate (http://www.mca4climate.info/) also has a generic framework that could be used as a starting point for defining criteria.

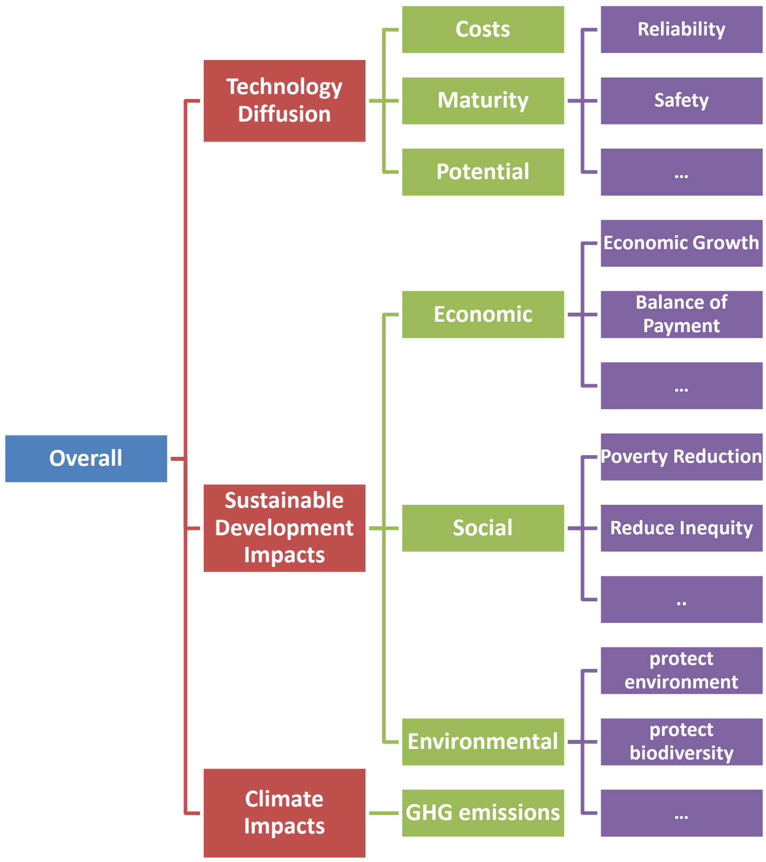

Figure 2: An example framework for organising criteria

It is essential that the lowest level criteria in the chosen framework are operational. In other words, it should be possible to measure or judge how well technologies perform on these criteria.

The sub-division of criteria into sub-criteria helps with:

- Ensuring that all the objectives defined during step 1 are captured by the criteria/sub-criteria;
- Verifying that criteria are independent of the other criteria and there are no redundancies;
- Checking that all criteria are well-defined and operational;
- Easing the process of assigning weights to the criteria and sub-criteria.

Criteria should be selected through a participative process[7]. The consultants are expected to facilitate the discussion. The initial list of criteria can be obtained through brainstorming and all suggestions can be noted down to come up with a long list of criteria so that all the points of view expressed by the stakeholders are integrated. The list can then be shortened and organised through discussions. The number of criteria should be as low as is enough for making a well-founded decision. For the prioritisation of technologies within TNA, it is recommended to select up to 7-10 relevant criteria.

Criteria selection for Transport Sector in Sri Lanka

Sri Lanka categorised criteria into costs and benefits (Table 2). The costs were defined as the cost for construction of 1km of the infrastructure. The benefits were categorised into economic, social and environmental which were further sub-categorised. The criteria selected reflect the objectives of reducing oil demand, reducing air pollution and reducing CO_2 emissions, as well as contribution to social and economic development.

Table 2: Criteria used for prioritising transport sector technologies in Sri Lanka

Category		Criteria
Costs		Cost US $ million per km
Benefits	Economic	Employment generation (EG)
		Per Capita fuel saving (FS)
	Social	Health benefits (H)
		Sustainability (S)
		Time efficiency (TE)
	Environmental	Reduction of CO_2 emissions (CO_2)
		Improvement of Air quality (AQ)
		Noise reduction (NR)

[7] For details on stakeholder engagement, refer to the guidenote on *Identification and Engagement of Stakeholders in the TNA Process.* It can be found on http://www.tech-action.org/Publications/TNA-Guidebooks.

Step 4: Scoring of technologies

In this step, the performance and subsequently the score of each technology are evaluated against each lowest level criterion.

To begin the scoring process, the performance of each technology option has to be evaluated against each of the criteria. This can be summarised in a performance matrix with technology options in rows, and criteria in columns. Each cell describes the performance of an option against a criterion (Table 3). The performance can be described qualitatively, contain expert judgements and quantitative data.

Table 3: Example performance matrix (devised by authors for illustration purposes)

Option Unit /Scale	**Capital cost/ per unit yield** USD/ton of crop yield	**GHG Emission reductions** $kgCO_2e$ ton	**Water savings** High /Low	**Crop Yield** 5 point scale
A	350	150	High (2)	Increases (4)
B	200	100	Low (1)	Strongly Increases (5)
C	250	200	Low (1)	No Change (3)
D	225	175	High (2)	No Change (3)
Preferred Value	Lower	Higher	Higher	Higher
Data sources	Technology provider, specifications	Tech. specifications, modelling	Expert judgement	Expert judgement/ monitoring data

The performance will be assigned through a participative process (organised in workshops held in the sectoral workgroups) where the TNA consultant will play the facilitator role.

To allow the comparison of different criteria that are assessed using a variety of units and scales, it is important to arrive at one common scale of measurement, in other words, to normalise the values in the performance matrix. This will result in a scoring matrix, in which the scale is the same for all criteria: 0-100. For each criterion, the most preferred option will have a score of 100, while the least preferred will have a score of 0. The scores for the remaining options will reflect differences in the strength of preference. The values in the performance matrix can be normalised using formula (a) if the preferred value is higher, and (b) if the preferred value is lower:

$$Y_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} * 100 \quad \text{(a)}$$

$$Y_i = \frac{X_{max} - X_i}{X_{max} - X_{min}} * 100 \quad \text{(b)}$$

Here: Y_i – score of option *i;* X_i – performance of option *i;* X_{max}, X_{min} – the highest and the lowest performance among all the options. Repeat the process for each criterion.

The normalised scores can be calculated from the performance matrix by the consultant and presented in the form of a matrix to be discussed again among stakeholders. When an indicator is based on a qualitative scale in the performance matrix, it may be useful to adjust the normalised scores by using stakeholder judgements. For example, the water savings are given on a qualitative scale in Table 3 above. After normalisation, options A and D would have a score of 100, and B and C a score of 0. Technologies A and D can be examined closer to determine which of them would be better for water savings, e.g. technology A may be found to be better for water savings than technology D, and stakeholders can decide to give a slightly lower score to option D (see Table 4). Similar comparison and adjustment can be done for technologies B and C.

Table 4: Example scoring matrix (devised for illustration purposes, from Table 3)

Option	**Capital cost/ per unit yield increase**	**Emission savings**	**Water savings**	**Crop yield**
A	0	50	100	50
B	100	0	**0→20**	100
C	66.67	100	0	0
D	85	75	**100→80**	0

The consultant is expected to build consensus[8] within the workgroup members around a particular score for each technology on the respective criterion. To reach a score for each of the criteria and technologies, it is recommended to have the group discussing and voting on one criterion at a time. Disagreement has to be recorded and later analysed by carrying out sensitivity analysis (see Step 8).

[8] For greater understanding of how to build consensus, engage with stakeholders and handle disagreement, you can refer to the guidenote on *Identification and Engagement of Stakeholders in the TNA Process.* It can be found on http://www.tech-action.org/Publications/TNA-Guidebooks.

Scoring the options in the transport sector in Sri Lanka

As a first step, the stakeholders had a preliminary discussion on the 10 selected technology options and only 7 were carried forward for performance evaluation and scoring. The three options were not included since two of them were covered in the energy sector analysis, and the third was deemed too immature and uncertain to evaluate.

From the different criteria, the consultants were able to provide quantification for costs and these costs were later normalised into a score on a scale from 0 to 100 and vetted by the stakeholders. The remaining criteria were directly rated by stakeholders using judgement on a scale of 0 to 100. The normalisation procedure for the cost criterion is shown in Table 5.

Table 5: Performance and scores in terms of cost for transport sector options in Sri Lanka

Tech No	Technology option	Cost/km US $ million	Calculation (formula (b))	Normalised Score
1	Shift of 5% of transportation of freight from roads to rail	5	$\frac{5-5}{5-0.16} * 100$	0
2	Improved public transportation, especially in Colombo area: Introduction of a bus rapid transit (BRT) system	3	$\frac{5-3}{5-0.16} * 100$	41.32
3	Integration of Non-motorised transport methods in Colombo along with regularised public transport system	0.17	$\frac{5-0.17}{5-0.16} * 100$	99.79
4	Improving the traffic signal system for synchronisation	0.6	$\frac{5-0.6}{5-0.16} * 100$	90.91
5	Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles	0.35	$\frac{5-0.35}{5-0.16} * 100$	96.07
6	Improvement of the condition of byroads	0.16	$\frac{5-0.16}{5-0.16} * 100$	100.00
7	Electrification of the existing railway system	0.75	$\frac{5-0.75}{5-0.16} * 100$	87.81

Step 5: Assigning weights

When all technology options have been scored on a scale of 0 to 100 against all criteria, the scores still cannot be combined, because some criteria may be considered of higher importance than others. Weights are numeric values assigned to each criterion to reflect the relative importance of one criterion over the other criteria. When assigning weights two principles should be followed. Firstly, the importance of the criteria in the decision context should be considered. For example if the economic growth criterion is valued more than the environment criterion, then the weight for the former will be higher than the latter. Secondly, it is important to consider how the performances 'swing' between the most preferred option (score 100) and the least preferred option (score 0) across criteria[9]. According to the second principle, if the range between performance of the most preferred and the least preferred technology options is low on a criterion, then this criterion will have a lower weight.

There are many methods to assign weights to the criteria: simply giving equal weights, using statistical or participatory methods. Since TNA is a participatory process, and it is very important to take into account all stakeholders' views, a method that is often used to assign weights in TNA is budget allocation method. In this case, the allocation of weights is conducted through a participatory process. Stakeholders are given a budget of 100 points, which has to be divided among all the criteria. Stakeholders decide on the distribution of this budget taking into account the principles described above. Stakeholder opinions can be obtained via a discussion with an aim to arrive at a consensus, or noted down anonymously and averaged by facilitator/consultant. In both cases, discrepancies or diverging opinions should be noted down for sensitivity analysis (Step 8). The process of assigning weights is much more manageable with fewer criteria, as well as if the criteria are categorised (Step 3). If there is only one level of criteria, weights can be assigned directly (e.g., Table 6).

Table 6: Example of assigning weights at one level (devised for illustration purposes)

Criteria	Weight
Capital cost/ per unit yield increase	22
Emission savings	35
Water Saving	25
Crop Yield	18

When criteria are organised into categories/tree, the weighting procedure is as follows:

1. Weights are assigned first to the top level criteria (Table 7) categories (sum = 100)

Table 7: Example of assigning weights to top level categories (devised for illustration purposes)

Criteria category	Weight
Cost	20
Economic impacts	30
Social impacts	30
Environmental impacts	20
Total	**100**

2. Weights are assigned to criteria within each top level category (sum = 100 within category)

3. Overall weight for each lowest level criterion is obtained by multiplying weight within category by weight assigned to higher category. At the end of this procedure lowest level criteria weights should add up to 100 (Table 8)

[9] Swing weighting can be used to take this into account, and is briefly explained with an example in Annex B.

Table 8: Example of assigning weights within categories (devised for illustration purposes)

Criteria category	Criterion	Weight within category (%)	Overall Weight (%)
Costs (20%)	Cost of Energy Conversion Facility	100	100%*20%=20%
Economic impacts (30%)	Local Economic Benefits	66 (2/3)	66%*30%=20%
	Local Share of Technology	33 (1/3)	33%*30%=10%
Social Impacts (30%)	Direct Employment	30	30%*30%=9%
	Skill & Capacity Development	30	30%*30%=9%
	Energy Security	40	40%*30%=12%
Environmental Impacts (20%)	GHG Emission Reduction	40	40%*20%=8%
	Positive Local Environmental Impacts	60	60%*20%=12%
Total			**100%**

The example above shows criteria organised into two levels of categories. If there are more levels, the process (steps 2 & 3 above) is repeated until the lowest level criteria have been assigned weights.

Weighting of criteria in the transport sector in Sri Lanka

The weighting was done at the lowest level resulting with a much higher weight for the benefits as compared to the costs, as there are more sub-criteria in this category.

Table 9: Criteria with their weights for the transport sector in Sri Lanka

Category		Criteria	Weight Factor
Costs		Cost US $ million per km	13.2
Benefits	Economic	Employment generation	7.9
		Per Capita fuel saving	13.2
	Social	Health benefits	10.5
		Sustainability	10.5
		Time efficiency	10.5
	Environmental	Reduction of CO_2 emissions	13.2
		Improvement of Air quality	10.5
		Noise reduction	10.5

Step 6: Combining weights and scores

In this step, the weights and scores for each of the technologies are combined to calculate an overall value: the total weighted score of each technology.

The total weighted score of a technology is a sum of its scores for each criterion multiplied by the corresponding weights.

Score of option *i*: $S_i = \sum_{j=1}^{n} w_j s_{ij}$, where

- w_j - weight of criterion *j*, , s_{ij} - score of option *i* on criterion *j*

Table 10: Example overall score values

Option	Capital cost/ per unit yield increase	Emission savings	Water Saving	Crop Yield	Overall Score
	22	35	25	18	
A	0	50	100	50	51.50
B	100	0	20	100	45.00
C	66.67	100	0	0	49.67
D	85	75	80	0	64.95

This step can be performed by the consultant using an Excel sheet[10].

Combining weights and scores for the transport sector in Sri Lanka

After completion of scoring on all criteria on a scale of 0 to 100, the consultants multiplied the scores with criteria weights, which were given in %. The weighted score against each technology was put in the form of a matrix (Table 11) and the result was discussed with the stakeholders.

Table 11: Overall scoring matrix with weighted scores

Tech No	Weighted Scores										Benefits
		Environmental			Social			Economic			
	Weighted Cost	CO_2 Reduction /km	Air quality from cleaner fuel	Noise reduction	Health benefits	Sustainability	Time efficiency	Per capita fuel Energy saving	Employment generation	Total Score	
1	0	0	0	2.63	3.51	0	0.42	0	0	6.56	6.56
2	5.44	7.69	5	7.89	7.02	10.53	4.21	7.87	0	55.65	50.21
3	13.13	13.16	11	7.89	10.53	0	0	13.6	7.89	77.2	64.07
4	11.96	0	0	0	0	5.26	3.16	0	7.89	28.27	16.31
5	12.64	12.17	5	7.89	3.51	5.26	3.16	12.21	7.89	69.73	57.09
6	13.16	0	0	0	0	5.26	0,00	0	0	18.42	5.26
7	11.55	12.85	5	10.53	7.02	10.53	10.5	13.02	7.89	88.89	77.34
Weight Factor	*13.20%*	*13.20%*	*10.50%*	*10.50%*	*10.50%*	*10.50%*	*10.50%*	*13.20%*	*7.90%*		

[10] A template is provided on the TNA website http://www.tech-action.org/Resources, under Analytical Tools.

Steps 7 and 8: Examine results and conduct sensitivity analysis

The process undertaken in step 6 will result in a list of technologies with their corresponding total scores derived from their scoring against the criteria and weights given to each criterion, as identified by stakeholders. They can be ranked according to their total scores. The technology scoring the highest total weighted score is ranked as the most preferred technology, whereas the one with the lowest relative score is ranked as the least preferred option.

Once the list of ranked technologies has been established, the results should be shared with all stakeholders for discussion and analysis. The purpose is to see if these results are in line with the results which could have been expected taking into account the national context, and to detect any incongruity in the process. It is also an opportunity for the different stakeholders to express their views on the results and open these results for further discussion. At this stage a sensitivity analysis can be performed by changing the values of the weights assigned to the criteria, and see how the priority of ranked technologies is affected by these changes. The sensitivity analysis is of particular importance when there are strong disagreements among the stakeholders, for example on the weights assigned to one or few indicators. Similarly, a sensitivity analysis can be conducted on scores given to technology options, to test the effects of uncertainties in data, or discrepancies in value judgements.

The final refinement and sensitivity analysis – Sri Lanka transport sector

Sri Lanka team for prioritising the technologies calculated the benefits and monetary costs separately and the technologies that had a better benefit cost ratio were prioritised. In order to communicate the benefit cost ratio easily to stakeholders they made use of graphs (Figure 3).

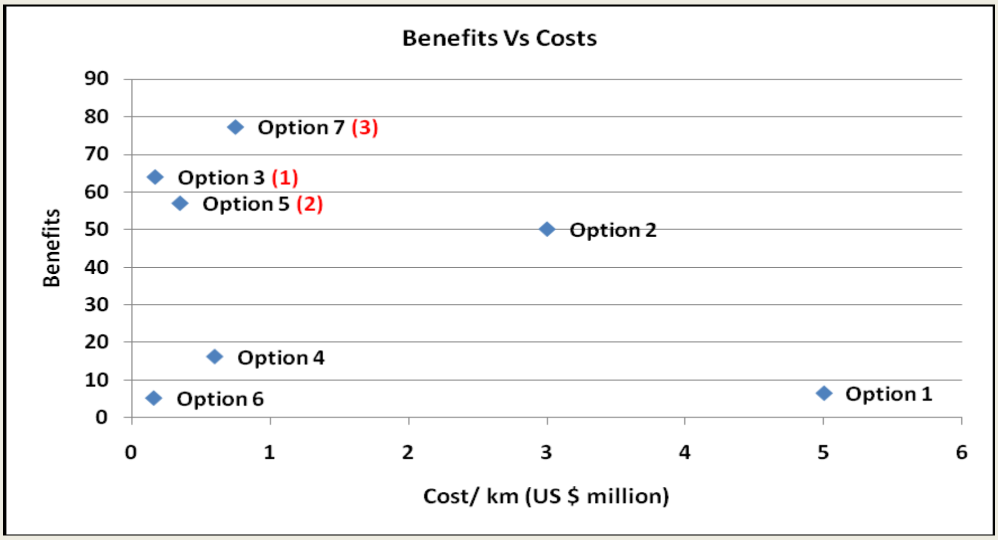

Figure 3: Benefit-Cost graph in Sri Lanka's transport sector

Differences in scores and weights were used to obtain alternative sets of results and presented graphically to stakeholders. The sensitivity analysis carried out subsequently did not show any significant changes to the results. Thus the following three technologies were chosen as the final prioritised technologies:

1. Integration of Non-motorized transport methods in Colombo along with regularized public transport system
2. Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles
3. Electrification of the existing railway system

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Annex A. Example of Technology Fact Sheet

MODAL SHIFT IN 5% OF FREIGHT TRANSPORT

1. Sector: Transport

2. Introduction: Transport sector is a major greenhouse gas (GHG) emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of land passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilises petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.

3. Technology name: Shift of ~5% of transportation of freight from roads to rail

4. Technology characteristics: Currently ~ 1% of freight transport is done using railways. Due to congestion and higher energy consumption and GHG emission in road transportation of freight, it is quite beneficial to move at least 5 percent of freight transportation to the railway system. Using rail for freight transport emits only 23 grams of CO_2 per ton-km travelled, while road transportation of freight emits 61 grams of CO_2 per ton-km travelled (ADB, 2010).

5. Country specific/ applicability: This is an achievable goal, especially through public private partnerships with the government Railways and relevant stakeholders from the private sector. Building new infrastructure for loading unloading purposes and any new development in the tracks involves an initial high cost, and proper planning is needed prior to establishing increased freight transportation through rail within the country, to avoid it being a loss.

6. Status of the technology in the country and its future market potential: The railway network in Sri Lanka was initially built and used only for transporting goods (i.e. plantation products), when the country was under British rule. The first railroad was built between Colombo and Kandy. Transporting such goods continued for many years, and over time with increasing population and traffic needs, rail transport became more passenger oriented. Sri Lanka had 32 percent of freight transportation through the railway system in 1979, and it has declined drastically since then (Ministry of Transport, 2008). The civil war during the last three decades severely affected the rail transport to more northerly areas. The draft national transport policy promotes increased use of rail for freight transport. With proper infrastructure development, it could attract more private sector partners for the use of railways for transportation, mostly for the transportation of export goods and containers needing more than 200 km domestic freight transportation.

7. Barriers: In Sri Lanka, freight transportation has drawn less attention compared to passenger transportation, even at policy level. There is limited availability of space and facilities for loading and unloading goods and parking of the container trucks close to the relevant railway stations. One important financial barrier for modal shift is the high investment required for infrastructure and intermodal facilities (as rail transport of freight still requires pre- and post-haulage by truck).

8. Benefits
a. Socioeconomic:
- Lower fuel consumption and higher energy efficiency.
- Reduced congestion, especially in more populated areas and during peak hours.
- Avoiding the traffic delay due to freight transporting trucks also causes a smoother flow of other vehicles and less idle time on the road

b. Environmental
- Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.

9. Operations: -

10. Costs: Modal shift from roads to rail requires high initial investment on developing infrastructure and intermodal facilities. However, the long-term benefits are higher.

Annex B. Swing Weighting

The swing weighting method (Dodgson et.al., 2009) is based on comparisons of differences, i.e., how does the swing of performance from 0 to 100 on one criteria compare to the 0 to 100 performance swing on another criteria. The stakeholders should take into account both the difference in performance and how much they care about that difference.

Table 12 shows the swing weight calculation procedure using two of the criteria (capital costs and emission savings) from the stylised example presented in Table 3 and 4. If there were only these two criteria for evaluation, the resulting swing weights would be 0.43 and 0.57. The example uses quantitative data to help explain the concept. However, the swing method is equally applicable to criteria with qualitative data.

Table 12: Example for calculating swing weights

Option	Capital cost/ per unit yield increase	Emission savings
Most Preferred option	B	C
Least Preferred Option	A	B
Difference in absolute values	=350-200 = 150	=200-100 = 100
Swing	=150/200 = 75%	=100/100 = 100%
Weight based on swing	= (75%/100%)*100 = 75	100
Normalised Weight or simply "criteria weight"	= 75/(75+100) = 0.43	100/(75+100) = 0.57

In practice where the number of criteria is more than 2, nominal group technique can be applied (refer Dodgson et. al., 2009) for explanation.