ASSESSING SUSTAINABILITY OF ROAD PROJECTS IN SRI LANKA

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ABSTRACT

Road construction is a continuously evolving notion and a key player in nation's economy. It has been identified as causing a range of countless environmental, social and economic impacts. Hence, there is a dire necessity of Sustainability Assessment (SA) in road construction. Many developed countries have their own rating systems for assessing road construction although this is lacking in developing countries. However, a commonly accepted assessment method for road construction over its life cycle is not available up to date. Addressing these gaps, this paper presents a framework for SA in road projects in Sri Lanka pertaining to construction activities associated in road life cycle under the three pillars of sustainability; i.e. Environmental, Social and Economic. A comprehensive literature survey was executed exploring road sustainability impacts and measures globally. An expert survey was carried out under two rounds with three professionals in road construction and sustainability to verify literature findings, and to explore more sustainability impacts and measures in road construction in Sri Lanka. A framework was developed including 10 major road sustainability impacts, 13 sub-impacts and 29 measures in a hierarchical structure. A pairwise comparison was carried out for the elements in the framework distributing 32 questionnaires among professionals. Collected data were analysed using Analytic Hierarchy Process (AHP). Analysed results weighted each element with a score resulting "Standard of living (0.2362)" and "Resource usage (0.2228)" as the most significant impacts where "Measures of improving Accessibility (0.1205)" as the most significant measures in the framework.

***Keywords**: Life Cycle; Road Construction; Sustainability Assessment; Sustainable Development.*

1. INTRODUCTION

Sustainability as an evolving notion is presently pointed out as a global issue that requires a concentrated global solution (Ugwu *et al.,* 2006). It is almost always addressed under three dimensions: environmental, social and economic which is usually referred as triple bottom line of sustainability (Goel, 2010, Simpson *et al*., 2014). Road construction as an evolving sector and a key player in nation's economy has been identified as causing a range of countless environmental and socio-economic impacts.

Horvath and Hendrickson (1998) found one-kilometer (km) length of typical two lane road with flexible pavement consumes seven terajoule (TJ) of energy where Chu *et al*., (2007) found aggregate base can require 25,000 tonnes (t) aggregate material per km. Lepert and Brillet (2009) emphasized road projects utilize considerable land use with high resource consumption due to its geometry, pavement structure, surface condition and high energy input due to traffic congestion. Therefore, sustainability should be addressed along with road construction practices. Thereby SA methods are focused as a mean to analyze aforementioned impacts (Zhang *et al.,* 2013).

SA can be noted as any process that directs decision making towards sustainability (Gibson, 2006). Pears (2005) stated it is useful to look any industry at a life cycle perspective in SA. Rooshdi *et al.* (2014) revealed sustainable rating systems have become popular as green assessment methods in many nations. However, SAs are lacking in developing countries.

In Sri Lanka, there is no any such rating system developed for road construction so far. Environmental Impact Assessment (EIA) process is the general practice of SA of road construction in Sri Lanka which was introduced through the National Environmental Act (Central Environmental Authority, 2013). However, road SA is

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indispensable in any kind of economy especially in developing economies where construction is still in an evolution virtually (United Nations, 2013). Considering the above facts, this paper attempts to develop a SA framework to assess road construction practices in Sri Lanka.

Most of the rating systems focus on buildings and therefore development of a method for SA in infrastructure is a vital necessity. United Nations (2013) stated the contexts of developed and developing countries are different to each other. Therefore, the assessment methods launched in developed countries are not ideal to apply in developing countries. Moreover, a type specific environmental rating system in infrastructure is lacking worldwide (Jayawickrama *et al.*, 2013). In addition to that Gamalath *et al.* (2014) emphasized EIA which is used in infrastructure SA in Sri Lanka is not effective to assess a project accurately due to insufficient post monitoring plan and lack of incorporation of sustainable concepts. Thus, aiming inapplicability of road SAs found in developed countries into developing countries and the absence of type specific rating systems for infrastructure in developing countries, this research aimed to develop a framework for assessing sustainability in road projects in Sri Lanka .

2. METHODOLOGY

This research focuses on "new road constructions" within Sri Lankan context and it addresses only the construction activities associated with road projects over its life cycle. The SA framework addresses both the environmental, social and economic lines of sustainability. The objectives of this study justify the use of mixed research approach as the most suitable research approach to the study. Since road construction is not similar as other industries, the respondents for the data collection were selected based on purposive sampling method. Thus, the experts and professionals who have experience and knowledge on road construction and sustainability were employed in this study.

The study begun with an expert survey with three professionals under two rounds. It was conducted to filter road sustainability impacts and measures found in literature to the Sri Lankan context while exploring more impacts and measures. The survey aimed to develop the hierarchy for the framework by grouping filtered road sustainability measures under applicable road sustainability impacts.

The questionnaire survey of this study was arranged to conduct over four different questionnaires: questionnaires A, B, C and D. Data collected through questionnaire were analyzed using AHP technique. Questionnaire A consists of pairwise comparisons on road sustainability impacts/ sub-impacts where questionnaires B, C and D consist of pairwise comparisons on sustainability measures under environmental, social and economic aspects respectively. Since AHP technique was employed in many studies with a small sample group; five respondents (Al-Harbi, 2001; Peterson *et al*., 1994), seven respondents (Armacost *et al*., 1994) and the like, 8 number of questionnaires were collected in this study under each questionnaire type. Though the employed sample size in this study is smaller, it is adequate to represent the population because the sample size is not critical in AHP analysis if the representativeness of the sample is secured to speak for the population.

3. LITERATURE REVIEW

3.1. SUSTAINABILITY AND SUSTAINABLE DEVELOPMENT

Sustainability is the challenge of current century which does economic development in a way that reduces environmental impacts while improving social needs (Newman, 2015). Sustainability can be outlined under three aspects namely economic, environmental and social which are usually referred to as triple bottom line of sustainability (Goel, 2010; Robins, 2006). Among them most of the times environmental dimensions are considered as most prioritized components in Sustainable Development (SD) before taking economic and social dimensions in to consideration (Egilmez and Tatari, 2012). But the aforementioned three dimensions are interrelated and therefore when looks for SD both should be simultaneously evaluated (Rosa, 2011; Satolo and Simon, 2015).

3.2. SUSTAINABLE DEVELOPMENT IN ROAD CONSTRUCTION

Roads can be identified as one of the largest and complex mega projects in the construction industry which influenced to millions of general public at the project end (Flyvbjerg, 2014). Roads have various impacts towards environment, social and economic sustainability (Thrope, 2012). Those issues which associate in road projects emphasized the necessity of addressing sustainability in road construction. Sarsam (2015) outlined three attributes a road might embedded as a "sustainable road". Those are; lower level of impact to the environment, more positive outcomes to the society and lower level of life cycle cost.

3.3. ROAD LIFE CYCLE AND CONSTRUCTION ACTIVITIES

Life cycle of a road is analyzed by Stripple (2001) under three main stages. Those three phases are construction phase, operational and maintenance phase and final disposal phase. The first phase, construction phase includes removal of buildings, topsoil, vegetation around the construction area and removal of unsuitable soils such as soft soils (Birgisdóttir, 2005). Further to the author it includes construction of the road structure: sub grade, sub-base, base course and wearing course. In addition to that it associated with activities like construction of drainage systems and adding different road equipment, signs, safety fences, road lighting and so on (Birgisdóttir, 2005). The next phase, operational and maintenance stage includes maintenance of pavement, clearing road verges and maintenance of road equipment like activities which are necessary to keep a road in an acceptable condition during its service time (Stripple, 2001; Birgisdóttir, 2005). When considered about the final phase of the life cycle, mostly there is no end life to an old road because when the road is at its end phase, the practice is replacing or reconstructing the old road with a new roadway instead of removing (Stripple, 2001).

Many studies highlighted variety of sustainability impacts which can account under road construction as discussed in Table 1. Therefore, as Sarsam (2015) and Pears (2005) depicted assessing road sustainability characteristics and implementing them during its life cycle is significant.

3.4. ROAD SUSTAINABILITY ASSESSMENT

SA method presents whether the expected progress has been made while bringing out decisions on present and future situations on SD (Brandon and Lombardi, 2011; Hacking and Guthrie, 2008). Poveda and Young (2015) revealed two questions which must be answered prior to assess sustainability. First what is to be measured and second how to measure. Thereby this study was organized to measure sustainability in road construction exploring road sustainability impacts and measures (measures refer the steps which can take in road construction to achieve sustainability).

3.5. ROAD SUSTAINABILITY IMPACTS

Exploring various sources available in global context such as Civil Engineering Environmental Quality Assessment and Award Scheme (CEEQUAL), New York State Department of Transportation (NYSDOT), Illinois Department of Transportation (IDOT) and Illinois Joint Sustainability Group (IJST) and the like, Table 1 below consolidates environmental, social and economic sustainability impacts connected with construction activities. By means of construction, those impacts can be taken into consideration when developing the SA framework for road construction. The impacts addressed in the first column of Table 1 are described henceforth.

Impacts due to land use - According to Jayawickrama *et al.* (2013), future availability of productive land is determined the way that land is utilized. The impact to the land can be considered in two forms as land use in terms of area and land composition (Jayawickrama *et al.*, 2013)

Impacts due to resource usage - In the Envision rating system the impacts cause due to material usage, water utilization and energy usage are embedded under the main category named resource allocation (ISI, 2016).

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Table 1: Sustainability Impacts Accountable in Road Construction

Sustainability impacts		**Sustainability**			**Sources**										
		Environmental sustainability	**Social Sustainability**	**Economic Sustainability**	Gudmundsson (2004)	Litman and Burwell (2006)	CEEQUAL (2010)	NYSDOT (2010)	Muench *et al.* (2011)	IDOT and IJST (2012)	Jayawickrama *et al.* (2013)	Rooshdi *et al.* (2014)	Bueno *et al.* (2014)	Almahmoud and Doloi (2015)	ISI (2016)
Land use	Land use in terms of area	√	×	×	√	×	√	√	√	√	√	√	√	×	√
	Land use in terms of quality	√	×	×	√	×	√	√	√	√	√	√	√	×	√
Resource usage	Material usage	√	×	×	√	√	√	√	√	√	√	√	√	×	√
	Energy usage	√	×	×	×	√	√	√	√	√	√	√	√	×	√
	Water efficiency	√	×	×	×	√	√	√	√	√	√	√	×	×	√
Waste	Solid waste	√	×	×	√	×	√	√	√	√	√	√	×	×	√
	Liquid waste	√	×	×	√	×	√	√	√	×	√	√	×	×	√
	Gaseous waste	√	×	×	√	√	√	√	√	√	√	√	√	×	√
Noise and vibration		√	√	×	√	×	√	√	√	×	×	√	×	×	√
Biodiversity		√	×	×	√	√	√	√	√	√	√	√	√	×	√
Standard of Living	Capital performance	×	√	√	×	×	×	×	×	×	×	×	×	√	√
	Phycological comfort	×	√	×	×	√	×	×	×	×	×	×	√	√	√
	Integration with community	×	√	×	×	√	√	×	×	×	×	×	√	√	√
Community mobility and access		×	√	×	√	√	×	×	√	√	×	×	√	√	√
Health and safety		×	√	×	√	√	√	√	×	×	×	×	√	√	√
Culture		×	√	×	×	×	√	×	√	×	×	×	×	√	√
Direct cost	Initial cost of construction	×	×	√	√	×	×	×	√	×	×	×	√	×	×
	Operational and maintenance cost	×	×	√	√	×	×	×	√	×	×	×	√	×	×

Impacts due to resource usage - In studies, the impacts due to resource consumption are discussed in three forms; impacts due to material, water and energy. In the Envision rating system the impacts cause due to material usage, water utilization and energy usage are embedded under the main category named resource allocation (ISI, 2016).

Impacts due to waste - The waste release in road construction is discussed in CEEQUAL manual in three forms as solid waste, liquid waste and gaseous waste (CEEQUAL, 2010).

Noise and vibration - construction can cause considerable nuisance to the natural and social environment (CEEQUAL, 2010).

Impacts to the biodiversity- Constructions are being identified as one of the root causes which damage and destroy the wildlife habitat and the species diversity (CEEQUAL, 2010).

Impacts to the standard of living - Impacts to the standard of living is addressed under three sub-impacts; capital performance, psychological comfort and integration with community. The study of Almahmoud and Doloi (2015) on "social sustainability in construction" addresses capital performance as satisfying the needs of community through providing job opportunities, generating investment opportunities and the like. Psychological comfort refers comfort of the mind, promote equity and satisfying territorial needs of the community. Integration with community refers to engaging community with the project.

Impacts to the community mobility and access - The accessibility performance of the project along its lifecycle is addressed under this heading (Almahmoud and Doloi, 2015). According to the authors a social sustainable project should not interrupt to accessibility and those should allow secure and safe open paths.

Impacts to the health and safety - The construction projects should adhere with health and safety requirements (Almahmoud and Doloi, 2015). According to Bueno *et al*. (2014) the impact to the health and safety due to road construction can be classified under social as well as economic sustainability impacts.

Impacts to the culture - According to the Greenroads Manual culture refers to community values, cultural awareness and art (Muench *et al.*, 2011).

Direct cost - The direct cost is considered under two sub impacts. Firstly, the initial cost of the construction address cost associated in the initial phases, material extraction to end of construction phase where the operational and maintenance cost refers to construction costs associated with road operational and maintenance phases (Bueno *et al*., 2014).

3.6. ROAD SUSTAINABILITY MEASURES

Sustainability measures provide significant involvement towards establishing greener construction practices. According to Montgomery *et al.* (2014), project specific measures to be implemented to mitigate negative environmental and socio-economic impacts of a project. Exploring the available literature, Figure 1 summarises road sustainability measures acknowledged in road related sustainable rating systems and various studies worldwide with the intention of achieving road sustainability.

1. Reduce landscape degradation
2. Avoid impacts to high quality undeveloped lands
3. Reduce excavated material taken off site
4. Avoid impacts to sites with threatened or endangered species
5. Minimize spreading of invasive species
6. Protect wildlife and its habitat
7. Planting trees, shrubs and/or native plants
8. Use locally produced or regional materials
9. Use recycled materials
10. Reduce energy consumption
11. Use renewable energy
12. Reduce water consumption
13. Monitor water quality parameters
14. Control run off water (Having catchments, drainage systems)
15. Reduce equipment emission
16. Incorporate sustainable lighting
17. Reduce community disruptions
18. Provide views of scenery/ visual enhancement
19. Incorporate required sound /noise level during working time
20. Minimize dust
21. Provide buffer between road and high quality wet land
22. Balance the earthwork
23. Protect the culture
24. Having road side maintenance plans
25. Accommodate safe pedestrian access
26. Provide income generation methods to the community

Figure 1: Road Sustainability Measures

Sources: (CEEQUAL, 2010, 2016; IDOT and IJST, 2012; ISI, 2010; Muench *et al*., 2011; NYSDOT, 2010; Rooshdi *et al.,* 2014)

4. RESEARCH FINDINGS

4.1. EXPERT SURVEY FINDINGS

The expert survey findings revealed both the sustainability impacts/sub-impacts and measures discovered under literature survey (refer Table 1 and Figure 1) can be considered in Sri Lankan context when assessing sustainability in road construction. Additionally, the survey identified measures namely, "Avoid liquid waste from equipment and machinery", "Having standard measures to increase public and worker health and safety" and "Dispose waste to suitable locations". Thus, the expert survey concludes 10 major road sustainability impacts with several sub-impacts and 29 road sustainability measures for the road SA framework. Moreover, the expert survey findings disclosed the relationship among road sustainability measures with each sustainability impact, sub-impact. That structured the hierarchy for the framework and it is shown in Figure 2.

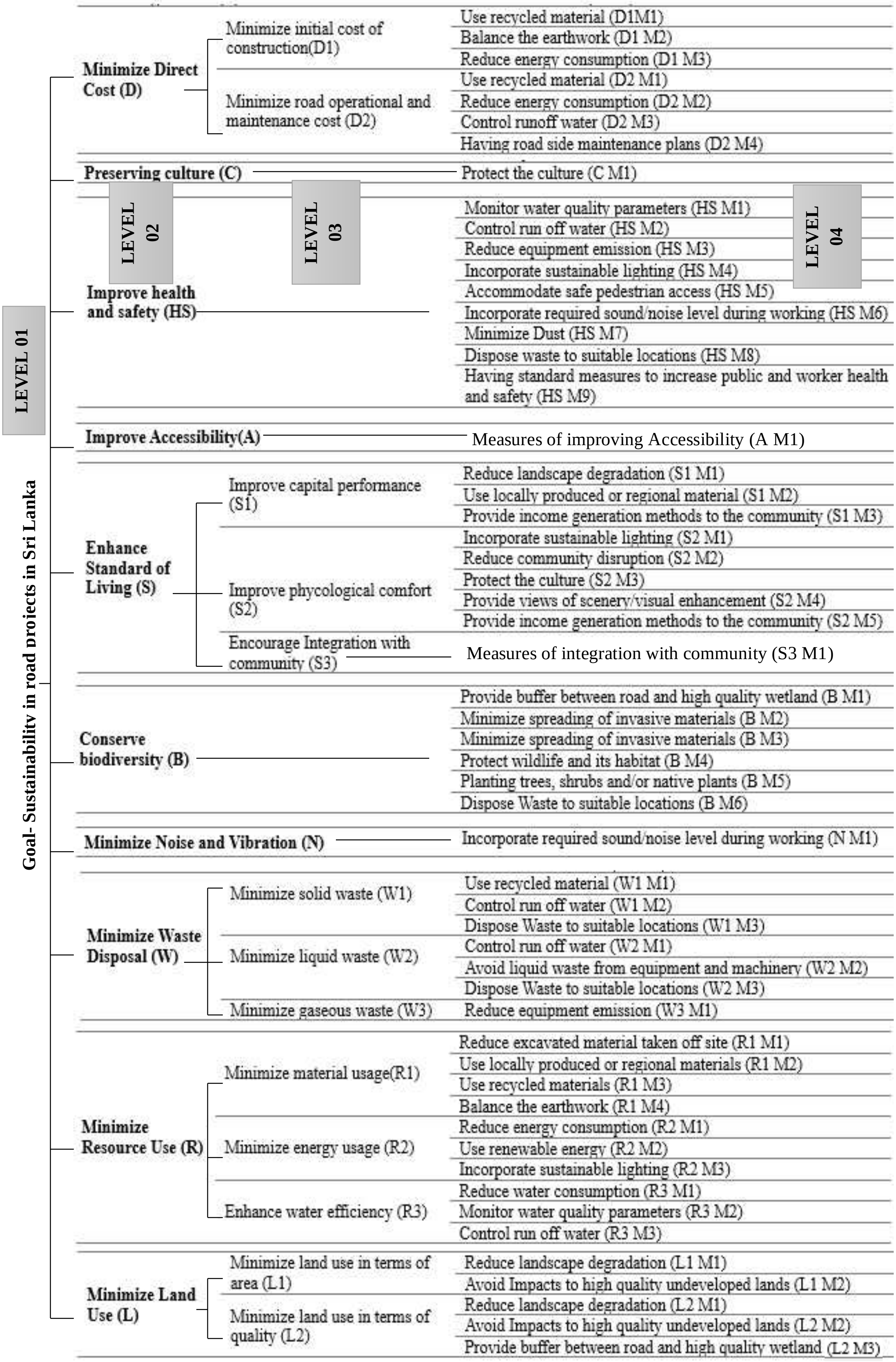

Figure 2: Structure of the Road SA Framework

The hierarchical structure ensured four levels to the framework, goal at the top level or the first level, main road sustainability impacts at the second level, sub impacts of road sustainability at the third level and road sustainability measures at the bottom level or the fourth level.

4.2. QUESTIONNAIRE SURVEY FINDINGS

The questionnaire survey findings were analyzed using AHP technique. The results of relative weightages for each road sustainability impact, sub impact and measure (elements of the hierarchy) were calculated using the geometric mean of individual's results. The weighted scores for each main impact, sub impact and measures under AHP analysis are depicted in following Table 2.

Table 2: Weighted Scored under AHP Analysis

Main impacts	Priority vector	Final weight (X1)	Rank	Sub-impacts	Priority vector (X2)	Final weight (X1X2) = X4	Rank	Measures	Priority vector (X3)	Final weight (X4X3)	Rank
L	0.0304	0.0304	9	L1	0.4130	0.0125	2	L1 M1	0.5838	0.0073	1
								L1 M2	0.4162	0.0052	2
				L2	0.5870	0.0178	1	L2 M1	0.1521	0.0027	3
								L2 M2	0.3886	0.0069	2
								L2 M3	0.4593	0.0082	1
R	0.2228	0.2228	2	R1	0.4871	0.1086	1	R1 M1	0.1667	0.0181	3
								R1 M2	0.1782	0.0193	2
								R1 M3	0.1639	0.0178	4
								R1 M4	0.4912	0.0533	1
				R2	0.2060	0.0459	3	R2 M1	0.3610	0.0166	2
								R2 M2	0.2237	0.0103	3
								R2 M3	0.4153	0.0191	1
				R3	0.3069	0.0684	2	R3 M1	0.4741	0.0324	1
								R3 M2	0.2983	0.0204	2
								R3 M3	0.2276	0.0156	3
W	0.0673	0.0673	6	W1	0.6183	0.0416	1	W1 M1	0.4332	0.0180	2
								W1 M2	0.1127	0.0047	3
								W1 M3	0.4541	0.0189	1
				W2	0.2655	0.0179	2	W2 M1	0.1102	0.0020	3
								W2 M2	0.7389	0.0132	1
								W2 M3	0.1508	0.0027	2
				W3	0.1162	0.0078	3	W3 M1	0.0076	0.0076	1
N	0.0326	0.0326	8					N M1	0.0326	0.0326	1
B	0.1096	0.1096	4					B M1	0.1198	0.0131	5
								B M2	0.3461	0.0379	1
								B M3	0.1018	0.0112	6
								B M4	0.1731	0.0190	2
								B M5	0.1356	0.0149	3
								B M6	0.1236	0.0135	4
S	0.2362	0.2362	1	S1	0.4805	0.1135	1	S1 M1	0.2392	0.0272	3
								S1 M2	0.3418	0.0388	2
								S1 M3	0.4190	0.0476	1
				S2	0.1731	0.0409	3	S2 M1	0.0632	0.0026	5
								S2 M2	0.4150	0.0170	1
								S2 M3	0.1180	0.0048	4
								S2 M4	0.1206	0.0049	3
								S2 M5	0.2833	0.0116	2
				S3	0.3464	0.0818	2	S3 M1	0.0818	0.0818	1
A	0.1205	0.1205	3					A M1	0.1205	0.1205	1
HS	0.1072	0.1072	5					HS M1	0.0597	0.0064	8
								HS M2	0.0548	0.0059	9
								HS M3	0.1647	0.0177	1
								HS M4	0.0698	0.0075	7
								HS M5	0.1617	0.0173	2
								HS M6	0.1520	0.0163	4
								HS M7	0.1590	0.0170	3
								HS M8	0.1041	0.0112	5

Main impacts	Priority vector	Final weight (X1)	Rank	Sub-impacts	Priority vector (X2)	Final weight (X1X2) = X4	Rank	Measures	Priority vector (X3)	Final weight (X4X3)	Rank
								HS M9	0.0742	0.0080	6
C	0.0296	0.0296	10					**C M1**	0.0296	0.0296	1
D	0.0436	0.0436	7	**D1**	0.3137	0.0137	2	**D1M1**	0.1830	0.0025	3
								D1 M2	0.4913	0.0067	1
								D1 M3	0.3257	0.0045	2
				D2	0.6863	0.0299	1	**D2 M1**	0.1120	0.0034	4
								D2 M2	0.3068	0.0092	1
								D2 M3	0.2881	0.0086	3
								D2 M4	0.2930	0.0088	2

Based on the above findings the aim of this research, developing the SA framework for road construction practices in Sri Lanka was accomplished. According to the AHP results, the 10 major road sustainability impacts can be arranged pertaining to the scores as S, R, A, B, HS, W, D, N, L, and C respectively. According to the AHP weightages, “S” is as important as “R” making both almost equally important in achieving road sustainability. When it comes to combined weightages of each road sustainability measure “Measures of improving Accessibility (0.1205)” act as the most significant measure in terms of road SD.

5. DISCUSSION

Based on the findings on literature (refer Table 1) and the scores of each impact/sub-impact (Main impact and sub-impact score columns in Table 2), the percentages of the combined weightages of each pillar of sustainability are 40.38%, 45.91% and 13.71% for environmental sustainability, social sustainability and economic sustainability respectively. In fact, social and environmental sustainability aspects are seen to be almost equally significant than economic sustainability in terms of road construction. Further it distinguishes that social and environmental impacts are nearly three times significant than economic sustainability impacts. Thus, it can be noted that road constructions are immensely associated with impacts to the social and natural environments. The Green guide for roads rating system which was originated in year 2008 has allocated the highest points, standing at 45% (Simpson *et al.*, 2014) for the social sustainability. It can be noted that the arrangement of this proposed road SA framework is same as the arrangement of the Green guide for roads rating in terms of triple bottom line of sustainability concept. However, the scores embedded in major road sustainability impacts are differ in the proposed framework from the available road rating systems though the percentage of the combined scores given to the particular impact seems almost similar. That score difference of the major road sustainability impacts between the research findings and the current road related rating systems must have occurred as a result of; this research being based on a developing country’s context and almost all the other existing road related rating systems are being based on developed countries’ context.

6. CONCLUSIONS

This study attempted to develop a SA framework for road construction practices in Sri Lanka. Further, it provides an insight to the various researches on road sustainability. The literature noted that sustainability of any industry to be assessed over its life cycle. Further, the literature revealed when looking for SD the three dimensions of sustainability: environmental, social and economic should be simultaneously evaluated. Thus, this framework addressed sustainability in road construction at a life cycle perspective under triple bottom line of sustainability concept. The relative weights of elements in the framework demonstrate the level of significant of each impacts/sub-impact and measure towards SD along road construction practices. The results were proven road constructions are highly associated with impacts to social and environmental lines than economic line. Therefore, a noticeable attention should be given to natural and social environment when looking for SD over road construction practices.

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