Framework for the development of performance measures for sustainable asset management practice in road transportation

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Abstract

The road transportation sector in many countries is faced with the need to simultaneously address two overarching challenges; the need to undertake effective asset management, with the broader need to develop business processes, while embracing sustainability principles. This paper presents a systematic approach for integrating sustainability principles into road asset management practice using performance measures. The key feature of this approach is that it moves away from the traditional approach of a road asset management perspective concerned with physical assets, and instead promotes a holistic view of all tangible and intangible assets relevant to road transport. Additionally, the sustainability evaluation has been extended to cover six relevant dimensions including economic, financial, technological, social, corporate and environmental.

The paper also presents a framework for a sustainability performance measurement that can be used by road agencies to assess and monitor the performance of their asset management practice in a systematic manner. The proposed framework includes a set of goals, relevant to road transport asset management (RTAM), for each of the six sustainability dimensions. Each goal is further defined by a set of objectives, indicators, and performance measures that are relevant to the different aspects of RTAM.
Keywords: performance measure, road asset management, sustainable transportation, multidimensional sustainability.

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1 Introduction

Asset management has been playing a major role in the business world and changing shape in different ways in response to challenges. Among these challenges, sustainable development has become a guiding principle for the transportation industry worldwide. Emerging climate change, resource shortages, financial limitations and increased energy costs are creating a global challenge and a growing need to adopt a sustainable asset management practice. The aim of this study is to integrate sustainability concepts into the framework of RTAM to improve sustainability performance within the Australian road transport industry.

The main objective of this study is to identify and develop performance indicators and relevant measures to assess and monitor sustainability performance of RTAM practice. A key aspect is the development of a sustainable performance measurement framework to incorporate performance measures relevant to each phase of the asset management framework. These measures will ensure that asset management practice is sustainable in every aspect and that potential risks are well managed in every phase of the asset management process.

The proposed framework addresses the sustainability of all assets including physical, human, financial, information, and intangible assets, which are important aspects of an integrated RTAM. Further, it adopts a multidimensional sustainability concept and includes six dimensions of sustainability namely; environmental, social, economic, corporate, financial, and technological.

2 Integrating a sustainability concept into the RTAM framework

Presented in this section is the systematic approach adopted in this study to integrate sustainability principles into the asset management process of RTAM. It starts with the definitions adopted for sustainability and road asset management.

2.1 Definition for asset management

The definitions within ‘Asset Management’ and ‘Transport Asset Management’ adopted by road agencies vary and change over time. For this study, the British Standard Institute Publically Available Specification (BSI PAS-55) definition has been adopted, which provides a more focused definition for quantifiable businesses and services than those reported in [1–4]. It states the following: “asset management is systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks, and expenditures over their life cycles for the purpose of achieving its organizational strategic plan” [5]. The PAS-55 definition implies that there are another four categories of assets that have to be managed in order to achieve an organization’s strategic plan than the

physical assets. These categories are the human, financial, intangible, and information assets, which can be explained as follows [5].

- Human assets – including corporate assets such as ownership, managers, employees, contractors and suppliers, motivation, communication, roles and responsibilities, knowledge, experience, leadership and team work.
- Intangible assets – social impacts, reputation, image, morals and constraints.
- Financial assets – life cycle cost, capital investment criteria, operation cost, value of asset performance
- Information assets – condition, performance, activity and cost and opportunity assets.

2.2 Multidimensional sustainability for RTAM

Zietsman and Rilett [6] proposed a definition for sustainable development that addresses the basic principles of sustainability related to transportation. These principles are described below and have been taken into account at all stages of this study, particularly in the development of the sustainable performance measurement framework.

- Intergenerational equity – there should be an equal distribution of resources between communities and generations to fulfill current and future requirements.
- Multidimensional – social equity, economic development and environmental stewardship are interrelated and must be simultaneously addressed.
- Dynamic – necessary to adapt the changing needs of societies and generations over time.
- Continuum – sustainability is not represented by a discrete indication and it should be integrated into each of the others by various degrees of sustainability.

Sustainability principles need to be combined with key principles and attributes of the asset management for better sustainability performance. Since the definition of asset management adopted in this study promotes a holistic view of all a system's assets then sustainability of RTAM performance can be considered multidimensional. The proposed six sustainability dimensions include the following with adopted definitions:

Environmental sustainability – it involves protecting natural resources, minimizing waste and air pollution, and maintaining of a variety of species and habitat through the RTAM process. This includes:

- minimizing resource consumption by improving material reuse and recycling, and by efficient usage;
- limiting air pollution and noise pollution;
- minimizing waste accumulation;
- reducing the impact of transportation activities on the ecological system.

Social sustainability – it is the ability of a community to provide a safe and healthy environment, while providing equitable and affordable services for their development. This includes:

- providing a safe, secure and healthy environment;

- maintaining equitable opportunities within different social levels, and providing affordable transport services;
- increasing community development by satisfying the basic accessibility needs of a society and its individuals.

Economic sustainability – it is concerned with the productivity of the asset systems for efficient services, improvement and economic development. This includes:

- building a transport system that is resilient in the face of climate change risks;
- providing efficient services;
- improving local development;
- providing an economically feasible and affordable transport system.

Corporate sustainability – it is concerned with stakeholder satisfaction and the implementation of a sustainable culture within the organization. This includes:

staff motivation and improvement of a target workforce within the organization;

- valuing and developing the competence and capabilities of staff;
- enhancing leadership and stakeholder relationships;
- implementing sustainable practices and regularly assessing cultures within the organization.

Financial sustainability – it is focused on investing in long and short-term resilience to key drivers of change. This includes:

- forecasting different financial needs and reserve funding;
- maximizing value for money for all stakeholders;
- minimizing unexpected financial shocks due to disaster situations.

Technological sustainability – it is focused on advancing technology in the asset management system and minimizing the use of obsolete technology. This includes:

- partnering with client and key stakeholders to create or find innovative products and processes for sustainable transport solutions.;
- improving the technological capabilities of an organization's assets.

2.3 Integrating sustainability concepts with the RTAM framework

To integrate principles of sustainability into the asset management process, the following steps were followed:

1. All processes and relevant tasks of RTAM practice were identified.
2. The risks associated with each task due to internal or external drivers were identified.
3. For each identified risk, the relevant sustainability dimension was established and suitable performance indicators were identified.

To achieve the above, Austroads integrated asset management framework was used as a guide [1]. It comprised three main parts, including strategic planning, asset management actions, and performance feedback. These stages were subdivided into seven phases including define objectives (phase 1), form asset strategies (phase 2), develop investment programme (phase 3), identify asset

requirement (phase 4), implement work programme (phase 5), audit (phase 6) and review (phase 7). Austroads reports [1, 7] were used to identify all processes and tasks involved in these phases and their interactions. Possible internal (e.g. knowledge gap, resistance to change) and external drivers (e.g. climate change, legislation requirements) and associated risks that may influence the different processes/tasks were identified. This helped in establishing sustainability dimensions relevant to each phase. Good practice examples for mitigating the risks were documented, which helped in identifying suitable performance indicators and measures relevant to the applicable sustainability dimensions.

3 Framework development for sustainability performance measurement of RTAM practice

The approach and methodology proposed in this study for developing the framework combine concepts from the following three frameworks namely: The theme-based or impact-based framework described in [8, 9] the influence-based framework described in [8, 10], and the goal-oriented framework described in [9]. Figure 1 shows the proposed conceptual framework for developing performance measurements for RTAM. To simplify the application of this framework to the seven phases of the asset management cycle, the latter has been represented by four focus areas as presented below. This helps simplify linking the indicators to the different activities in the different phases.

1. Planning (L1) – Phases 1 and 2
2. Programming (L2) – Phases 3 and 4
3. Implementation (L3) – Phase 5
4. Performance feedback (L4) – Phases 6 and 7

The fundamental components of the framework outline the process for developing sustainability performance measures in five steps as described below.

- Step 1: Define sustainability dimensions – The conceptual framework defines the six dimensions of sustainability, including economic, social, environmental, corporate, financial and technological. The theme-based framework was used to define the multidimensional sustainability concept.
- Step 2: Define sustainability goals – In this step, each sustainability dimension was defined by the expected common sustainability goals. A goal-oriented framework was used to interconnect sustainability dimensions with relevant sustainability goals. The defined goals should be achievable, well balanced and need to cover the basic principles of sustainability and asset management. A comprehensive literature review resulted in identifying a set of 13 generic goals for transportation agencies to address the principles of asset management sustainability. The sustainability dimensions and proposed respective goals are listed in table 1.

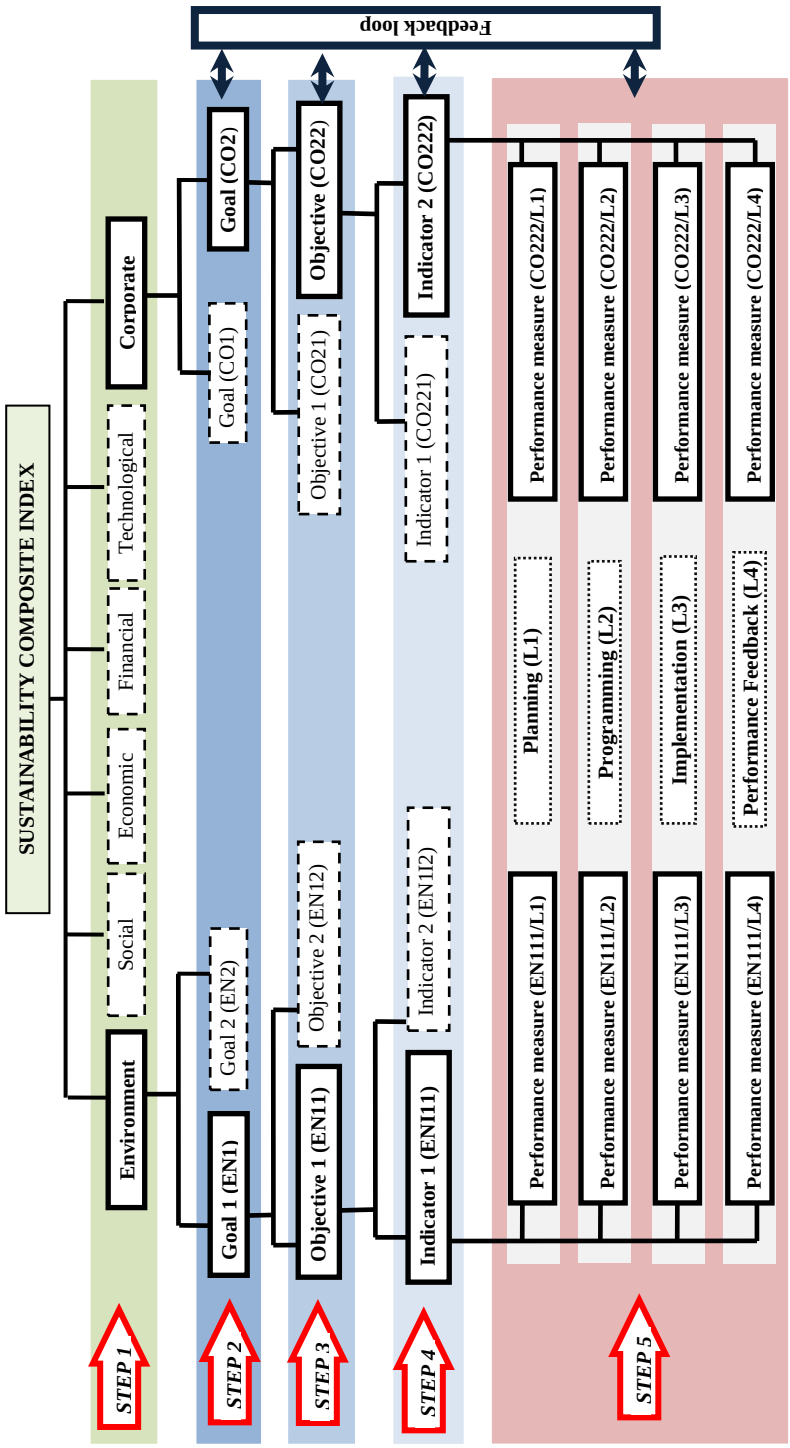

Figure 1: Conceptual framework for developing performance measurement for sustainable RTAM.

- Step 3: Define sustainability objectives – the goals were further deconstructed into achievable objectives that must be fully associated with the organization's strategic plan. The objectives are more specific than the goals and lay the foundation for links with the performance indicators. The proposed objectives are common to all focus areas of the asset management cycle (See example in Table 2 for objectives relevant to social sustainability goal SO1).
- Step 4: Define performance indicators – in this step, each objective was further classified into performance indicators. The indicators are used to interlink common objectives and performance measures at different operational levels within the transportation organization. The indicator refers to variables used in monitoring performance, which become performance measures when compared against benchmark values.
- Step 5: Define performance measures for different operational levels – each indicator was linked by one or more performances measures for the different focus areas of asset management (L1, L2, L3, and L4). An influence-based framework was used to define performance measures for the different levels. Ideal performance measures are easily understood, providing a clear indication of movement towards an established goal, and can be tracked using accessible and available data. The selection of appropriate performance measures is an important and challenging task and it can be applied over different timeframes (long term, medium term and short term), for different types of analysis (planning, operational or strategic), different levels of analysis (project, corridor, network or regional), and relevant sustainability dimensions [11, 12]. For example, asset management at the strategic level is focused on the long term planning of each asset group, and tactical asset management is used to determine which assets should be replaced in the programming level [13, 14]. Therefore, the applicability of a sustainability indicator needs to be carefully considered at the different focus levels, and measures need to be changed accordingly. Different sustainability measures can then be defined for a performance indicator for better sustainability evaluation; see example in Table 2.
- The feedback loop was used to redefine indicators for unmatched conditions by altering the indicators, objectives and goals. It can be used to address the changing needs of road asset management due to the risks to sustainability associated with external and internal drivers.

A comprehensive review of the literature resulted in identifying a large number of performance measures (540) that are relevant to the thirteen sustainability goals. To make the framework more practical and simplify its application, the number of proposed performance measures was reduced by selecting measures that are common for each indicator across all four focus areas. Figures 2a, 2b, 3a, 3b, 4a, and 4b present the final performance measurement frameworks and proposed measures for t, environmental, social, corporate, economic, financial, and technological sustainability respectively.

Table 1: Defined goals for the six RTAM sustainability dimensions.

Sustainability Dimensions	Goals
Environment (EN)	EN1 – Conserve energy and natural resources EN2 – Minimize emission and noise pollution EN3 – Minimize waste accumulation EN4 – Enhanced bio diversity and proper functioning of eco- system
Economic (EC)	EC1– Maximize economic productivity by improving assets efficiency EC2– Ensure economic Development
Social (SO)	SO 1– Enhance public health, safety, and security SO2– Ensure equitable and affordable service SO3– Ensure community development
Corporate (CO)	CO1– Improve quality of life of agency's employees CO2– Improve sustainable culture within organization
Technological (TE)	TE1– Ensure technological advancement
Financial (FI)	FI1 – Improve organization financial affordability

Table 2: Possible objectives, indicators and measures for example goal-Enhance public health, safety and security (SO1).

Objective	Indicator	Focus area	Potential performance measures
SO11: Improve safety and security requirements	Safety improvements	Planning	• Change in number of road crashes • Change in the percentage of projects where non-infrastructure based safety countermeasures were selected as part of the project • Funding Improvements of traffic safety related R&D
		Programming	• Number and proportion of projects evaluated for effect on crashes • Improve project safety evaluation method based on the substantial safety versus nominal safety
		Implementation	• Change in number and severity of crashes • Number of project address the safety concern at the corridors level
		Performance feedback	• Change in number and severity of crashes • Change in accident cost • Number of safety related complains
SO12: Minimize safety issues related to poor performance of the transportation infrastructure	Safety condition of infrastructures	Planning	• Overall rating of road infrastructures
		Programming	• Number of project evaluated based on infrastructures performance
		Implementation	• Pavement skid resistance • Bridge health index
		Performance feedback	• Overall safety improvements in the infrastructure performances

4 Conclusion and scope for future work

In this paper, a framework has been proposed to measure the performance of asset management practice in addressing sustainability. It adopts a holistic view of RTAM practice and includes six defined dimensions of the sustainability concept to address the emerging challenges. The proposed sustainability performance measurement framework, and the approach to measure development, are generic and can be adopted by any road agency. The proposed

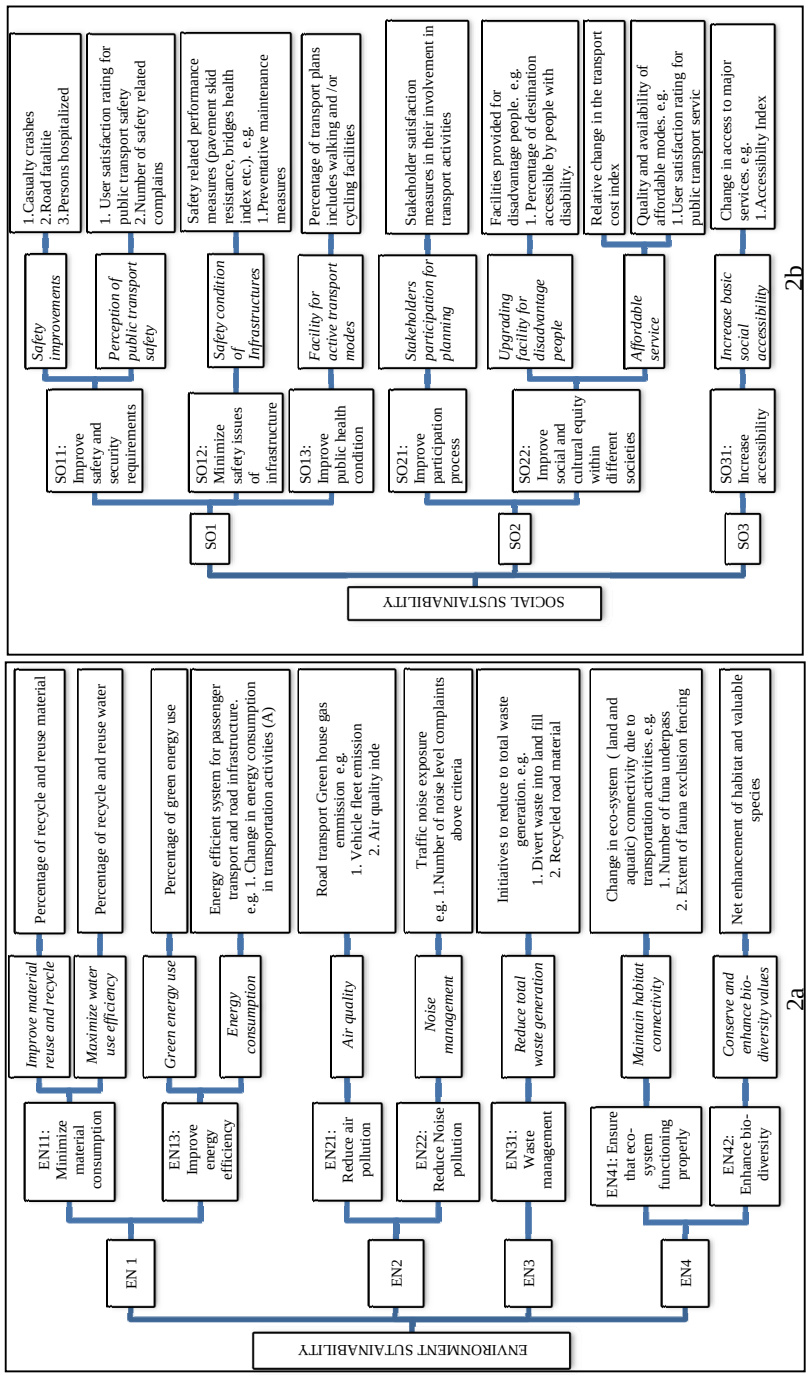

Figure 1: Performance measurement framework for environmental and social sustainability

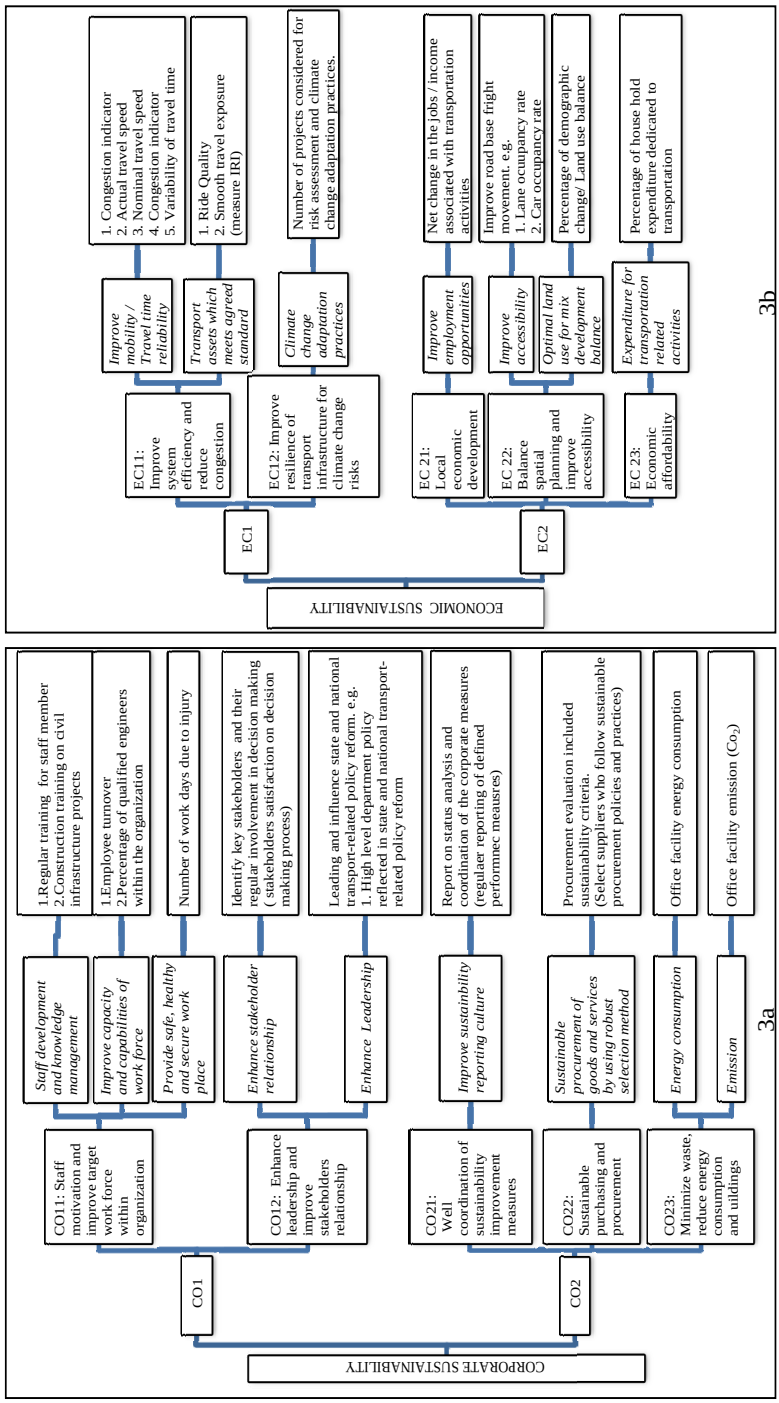

Figure 2: Performance measurement framework for corporate and economic sustainability

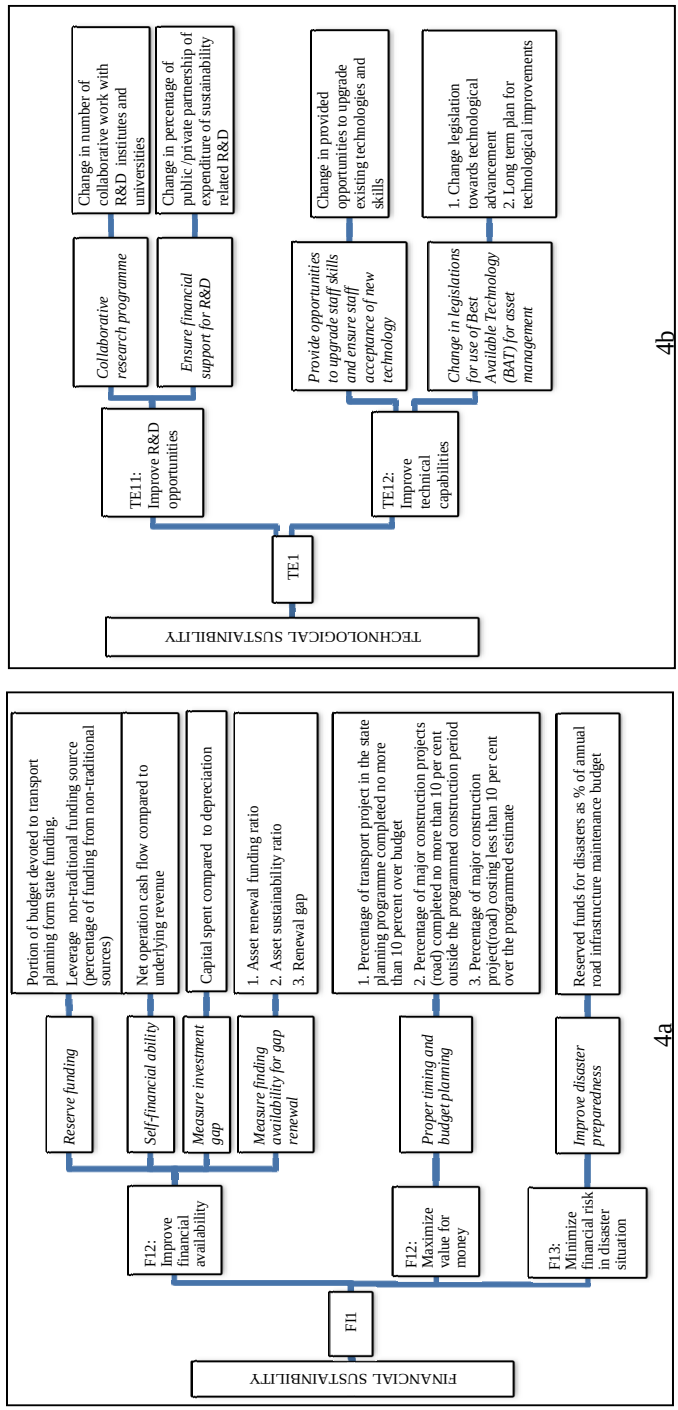

Figure 3: Performance measurement framework for financial and technological sustainability

goals, objectives and indicators are also generic and can be easily adopted by any agency or changed to suit an agency's strategic directions. The measures, however, can vary across agencies depending on availability of relevant data, information and acceptance by staff.

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