Reliability Assessment of Design Practice: Road Design Projects in Ethiopia

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Abstract—

Despite the increased road network in the last decade, the reliability of design on road projects has become a concern which results in a considerable changes to most projects in Ethiopia. This leads to inaccuracy of design outputs due to lack of proper investigation of the site conditions in relation to ground conditions, road geometry, hydrology or provision of proper drainages, surveying, pavement, etc. The design/supervision institutions used to manage such inaccuracies during the design review process of ongoing road projects. These revisions usually impose contractual implications to running projects and result in considerable increment in project cost and completion time.

As such, dealing with the common design defects that have been appearing on road projects becomes a crucial matter so that possible mitigation measures shall be in place. Consequently, the reliability assessment of design practice in Ethiopia is being addressed through this paper. The research methodology followed to assess the exiting situation consists of conceptual review from different literatures and also devised a questionnaire for primary data collection. Then, descriptive statistics was made for the analysis of one-hundred twelve respondents’ opinions from totally eighty-six surveyed road projects. The study assessed road projects that were commenced between 2006 and 2015. The data shows 88.1% of the responses confirmed that road projects were subjected to design review and related impacts on the road projects physical progress and contractual implications. Actually, design revision appears to be a common practice on most road projects though it should not entitle projects to considerable variations or changes as a result of design errors and lack of prior detail investigations.

Upon this research result, it has been drawn some of the recommendations to rectify the existing design practice. These include regular evaluation of professionals’ experience and competency, usage of automated and advanced data collection techniques to foresee the existing site conditions in-depth, encouraging design exceptions practice with appropriate functional and safety measures and screening prior to procurement of works for nonconformity of design deliverables. The above four major aspects have to be worked on as they are being directly influencing the quality of designs in highway projects in general.

Keywords: Reliability assessment, design practice, professionals’ experience, automated data collection.

I. INTRODUCTION

A. Background

Reliability of road design has become a usual problem and continual concern that initiated researchers and stakeholders to study in Ethiopian construction industry. Road Construction projects usually face design changes and problems at the implementation stage. These problems are a customary phenomenon in which clients and contractors lose their interests while executing most contracts in the country. As a result of this fact, most of the time project managers underestimate or overestimate the contract time and cost. This dilemma in attaining tolerable changes to design outputs has arisen a considerable attention towards studying on the reliability assessment of road design practice in Ethiopian phenomenon.

It is also important for the studies to be conducted on related to reliability of design practices that need to be taught at research institutions and universities to search for sound solutions to the existing/ challenging situations for the upcoming projects in the country. Provided that the significant impact of construction segment on the Ethiopian economy and the interest of international and local construction companies in that construction market, this study attempted to assess the reliability assessment of road projects’ design practice in the country that will play a role in minimizing design discrepancies at a considerable level in the industry.

Understanding the important role of research and development in the growth of the country, the Ethiopian Roads Authority, ERA, has established a Research and Development Directorate (RDD) which is responsible for conducting researches that can support the Road Sector Development Program (RSDP) through identifying, investigating and mitigating road construction and maintenance problems. The scope of the directorate is not limited and can also conduct researches that are believed to support the development of the country at large.

Subsequently, ERA is sponsoring master’s degree program students in five programs. These students are expected to work in the road sector after graduation and thus it will be important they work on road and related projects in their
C. Scope and Limitations of the Study

The scope of this research project is limited to on-going road projects in Ethiopia. This is made, due to the fact that, the necessary and relevant primary information can be easily obtained from currently undergoing road projects to achieve the desired result of the study. The Reliability Assessment of Design Practice: Road Design Projects in Ethiopia indicates that the results obtained in this research do not necessarily govern all projects in the country but it can be taken or considered as a representative sample for the existing situations. Thus, independent study/research should be made on different project types to investigate in detail for the design practices. The data for this study was gathered through primary data survey through questionnaire and observations. Project information/ data of eighty-six road projects were obtained from different construction companies in Ethiopia. The projects are constructed at different areas of the country. The organizations are employers, designers and contractors. The sample projects were commenced during 2006 and 2015. The projects were constructed by different contractors either local or foreign origin.

The study population will try to encompass the different road projects that have been recently accomplishing. The selected projects expected to be constructed by ERA, all regional roads authorities and private clients based on the available information for the purpose of this study. The sample size will be determined in the due course of time while conducting the research.

Quality of design on road projects is affected by numerous factors apart from the design institutions experience. Quality of designs also may vary according to project category, complexity and location. One of the biggest challenges encountered in the study has been the difficulty to get recorded data and unwillingness of some staff members of the companies to provide all the necessary information during data survey.

D. Problem Statement

The following question is the main focus of interest in this research: How easy is it to improve in designing roads in order to minimize considerable variations due to design review at the implementation phase?

The above mentioned research problem has been taken into an account for identification of the study topic. The outputs of highway design have been usually subjected to inaccurate quantities, incomplete design, conflicting between contract documents, inaccuracy or error within the design, unclear specification of products, missing items from the bid documents, discrepancy among different disciplines of design and short durations of design consultancy services, etc which happen to most road projects and creating design related challenges in most cases as this can be confirmed from the history of road projects. Hence, it is apparently evident that most road projects are suffering from poor quality of highway designs and related issues. This paper aims at conducting in-depth study with both primary and secondary data gathering devices to obtain the required responses of the study area for the identified problems and then the findings will attempt to make a conclusion and proper recommendation while presenting this research report.

Further, the following features of challenge areas have been identified that will be addressed in the study:

- Competent application of highway design practices throughout the highway projects life cycle is vital to obtaining the goal of a quality highway designs.
- Although extremely important and often overlooked; project design conditions have to be studied in-depth and
monitored very well at design stages for highway projects.

- By concentrating either solely within the reliability of design process or on the entire design and construction phases, reduction of errors can only benefit the project’s outcome.
- Unforeseen site conditions/events have been mainly considered as one of the principal reasons for the design changes.
- Procurement/delivery system of design and construction projects with design institutions and supervision consultant respectively, perhaps these require a thorough technical evaluation criteria based on their respective performances in a systematic manner in order to effectively administer highway projects.
- If there existed some design standard parameters’ discrepancies; which have been considered to be misleading to designers while doing designs require prompt actions for the changing and dynamic variables.
- Some important control points that would have been incorporated in the earlier time but that have been newly introduced as additional control points during implementation phase sometimes result in a considerable scope/character changes in some cases.

E. Organization of the Research

The study is logically organized into six chapters. The first chapter deals with introduction, which includes background, objective of the study, scope and limitation of the study and problem statement. The second chapter contains literature review part that encompasses related manuals, papers and relevant manuals. The third chapter addresses about the methodology of the research being followed. Chapter four talks about data presentation and analysis of the results. Finally, chapter five talks about the discussion of the results and chapter six contains conclusion and recommendation of the study.

II. LITERATURE REVIEW

This chapter explains some of the earlier studies, practices and manuals related to highway designs that take part in undertaking this research. Existing highway design practice in Ethiopian environment has a wide range of conditions and has diversified effect on the implementation of most contracts. Few studies have attempted to directly assess the design associated issues and look into different features that lead to improving highway design outputs, reviewing the procedures and standards of previous experiences in order to achieve the desired goal or quality design.

Therefore, this paper investigates in detail by concentrating on the current situations in Ethiopia for design reliability issues and frequent departure of design elements that required to be updated for highway projects. The literature review is divided into seven major sections: Description of design manual, Factors affecting geometric design and operation of toll roads, Quality management system for highway design, deterministic design, Reliability-based design and robust design, the cost of bad design, Good design – fundamentals, and Project development manual.

A. Description of Geometric Design Manual

The part of the literature discusses about the design manual components in the design development of a highway projects. The following four elaborations that used in different countries discussed about design manual situations adopted and mainly focused on geometric design manual for highway designs are addressed. The geometric design aspect is selected for this particular study. This part of the design has been selected because of the fact that this has been usually affecting projects’ cost, comfort and safety from the practical point of view. Thus, the geometry of roadway has been mainly contributing to the determination of different features of earthworks, pavement layers and crossing structures. Hence, other countries experiences in this aspect are important features that will help in updating design manuals for the conditions based on its applicability for the Ethiopian environment.

Geometric Design Manual of Ethiopian Roads Authority (ERA) 2013

The Geometric Design Manual of ERA-2002 [2] was prepared under the direction to establish basic design techniques for economical design of highway geometric including typical sections, horizontal and vertical alignment, and design of junctions. The procedures for the geometric design of roads presented in the manual have been applicable to trunk roads, link roads, main access roads, collector roads, feeder roads and unclassified roads. The use of the procedures described in the manual help in achieving reasonable uniformity in geometric design for a given set of Ethiopian conditions. Furthermore, ERA released the updated version of the manual in the year of 2013 [2] based on local experiences and foreign expertise for the usage in the sector.

Geometric design was defined as a process whereby the layout of the road through the terrain is designed to meet the needs of the road users. The principal geometric features are the road cross-section, horizontal and vertical alignment. Appropriate standards and combinations of geometric design elements are required to fulfill the under mentioned objectives:

- Topography, land use and physical features,
- Environmental considerations,
- Road safety considerations,
- Road function and control of access,
- Traffic volume and capacity,
- Design speed and other speed controls,
- Design vehicle and vehicle characteristics,
- Economic and Financial considerations, and
- Alternative construction technologies.

Notwithstanding the above, there may be circumstances where the designer will be obliged to deviate from these standards. For instances, the inclusion of a switchback and the use of a gradient greater than the desirable value are considered as departures from standard. In such cases and other departure the designer requires obtaining written approval from ERA. The designer shall submit the following information to ERA:

- The number, name, and description of the road,
- The facet of design for which a departure from standards is desired,
A description of the standard, including normal value, and the value of the departure from standards,
The reason for the departure from standards, and
Any mitigation to be applied in the interests of safety.

The designer must submit all major and minor departures from standards to respective ERA regional directorate for evaluation. If the proposed departures from Standards are acceptable, the departures from standards will be submitted to the quality assurance, road inspection and safety directorate for final approval.

Geometric Design Presented by Said M. Easa

Said M. Easa, published by the Transportation Association of Canada (TAC, 1999) [8] presented fundamentals of highway geometric design and their applications that include highway type, design controls, sight distance, and simple highway curves that influence the design of four basic highway elements: horizontal alignments, vertical alignments, cross sections, and intersections. The design of complex highway curves, three-dimensional alignment design, sight distance needs for trucks, design considerations for different road projects, and economic evaluation was presented based on available information. Emerging design concepts, including design consistency, design flexibility, safety audits, human perception, and smart design, were also described. Geometric design guidelines promote safety, efficiency, and comfort for the road users. But, it was addressed that a good design will not be guaranteed by strict application of the guidelines. Then, the following key ingredients were noted as requirements:

1. Consistency: Geometric design should provide positive guidance to the drivers to achieve safety and efficiency and should avoid abrupt changes in guidelines. Highways must be designed to conform to driver expectations.
2. Esthetics: Visual quality can be achieved by careful attention to coordinating horizontal and vertical alignments and to landscape developments. The process can be greatly aided by using computer perspectives and physical models.
3. Engineering judgment: Experience and skills of the designer are important in producing a good design. Considerable creativity is required in developing a design that addresses environmental and economic concerns.

The researcher recommended future researches in geometric design will likely involve a number of areas, such as human factors, smart technologies, design consistency, design flexibility, and reliability analysis. Particularly, He noted that the link between geometric design and human factors (which contribute to 90% of road collisions) will require a significant research effort to improve our understanding of the close link between how roads are built and how people use them. The dynamic nature of geometric design will aid such developments.

Geometric Design Practices for European Roads

Jim Brewer, John German, Ray Krammes, Kam Movassaghi, John Okamoto, Sandra Otto, Wendell Ruff, Seppo Sillan, Nikiforos Stamatiadis and Robert Walters, June 2001 [10] on Geometric Design Practices for European Roads, reviewed and documented European procedures and practice in roadway geometric design and context-sensitive design (CSD), in which a balance was sought between safety and mobility needs and community interests. The U.S. group visited sites in Sweden, Denmark, the Netherlands, England, and Germany, and met with numerous representatives from transportation and highway ministries, research organizations, and consultants. The CSD approach was noted as a practice in several European countries, which used in the roadway geometric design concepts and tools to address mobility, safety, and community issues. It was experienced that European agencies might offer to U.S. practitioners’ valuable new insights and concepts on such issues and practices. Such concepts might be transferred or adapted to the U.S. environment to enhance the knowledge base regarding CSD and roadway geometric design.

Design Flexibility

All countries visited utilize guidelines for roadway design that have been considered central to the design philosophy, and all have a design exception process through which to address departures from guidelines. It was also apparent that all these countries have or are currently revising their design guidelines, which have been more focused on addressing road purposes and creating a uniform appearance for each road category. This experience encouraged the practitioners to understand the value of design flexibility and exceptions. Generally, they noted that countries were protected from legal liability regarding design defects. However, the exceptions of England, where litigation generated by departures from design guidelines has been expanding; most of the litigation has been settled out of court. In the countries visited, the guidelines issued by the national highway authorities have been usually considered to be recommendations for any projects under the authority of local governmental agencies. This provided great flexibility in designing to meet local needs and conditions.

Connecticut Department of Transportation - Highway Design Manual

The Connecticut Highway Design Manual – 2013 Edition (including revisions to February 2013) (U.S. customary units) [9], developed to provide uniform design practices for preparing roadway plans. The manual presented most of the information normally required in the design of a typical highway project. The highway designer should attempt to meet all criteria presented in the manual; however, the manual should not be considered a standard that must be met regardless of impacts. Consequently, the Connecticut department adopted revised limits for geometric design criteria for projects on existing highways that were, in many cases, lower than the values for new construction. The criteria set out based on a sound, engineering assessment of the underlying principles behind geometric design and on how the criteria for new construction could be legitimately modified to apply to existing highways without sacrificing highway safety. The criteria were intended to find the balance among many competing and conflicting objectives.

It was addressed that if the manual used conscientiously and diligently, it would provide a significant benefit to designers in selecting cost-effective designs meeting the objectives of community and the department. Beside to this, public involvement must be established early in the design process so that a common goal would be achieved that will ultimately make highway projects to be successful. Throughout the design process, a designer may need to use
the flexibility provided by the manual to produce a design solution that satisfies diverse and occasionally conflicting interests.

To aid in building an understanding of sensitivity and flexibility in design, it was mentioned that the designers should be familiar with the studies and should consider applying some of the design tools included in the studies to other projects within sensitive areas. Furthermore, it was given that if the application of the minimum design criteria results in unreasonably high construction costs or extreme impacts to the surrounding environment, the design exception process can address the use of lower than minimum design values on a case-by-case basis. The designer should realize the following factors when applying the design criteria in the manual:

1. Trigger Values. The designer will be evaluating the existing geometric design against the criteria. If an existing geometric design feature does not at least meet the lower criteria, the designer must evaluate the practicality of improving the feature.

2. Improvement Level. The department determined that, once the decision was made to improve a geometric design element, the level of improvement should be compatible with the project objective.

Project Evaluation

It was stated that the designer should also note that, in some cases, the department will allow the acceptance of geometric design values that may be considerably below those for new construction/major reconstruction (e.g., for horizontal and vertical curves). In addition to this, several other factors must be considered in a highway projects and the designer should conduct applicable technical evaluations using appropriate department units as may be necessary. The possible technical evaluations are listed below:

- Conduct Field Review,
- Document Existing Geometrics,
- Crash Experience,
- Speed Studies,
- Traffic Volumes,
- Early Coordination for Right-of-Way Acquisition,
- Pavement Condition,
- Geometric Design of Adjacent Highway Sections,
- Physical Constraints, and
- Traffic Control Devices.

B. Factors affecting Geometric Design and Operation of Toll Roads

Christopher Poe, Texas Department of Transportation Research and Technology Implementation Office, Austin, Texas 78763-5080, published in September 2010 [1], identified the potential factors that could impact truck use of toll roads or managed lanes. He noted that characterizing and making toll road attractive to the users’ identification of geometric and operating factors have been crucial to truck drivers and operators in terms of safety and efficiency. The factors were organized around industry needs (e.g., safety, travel reliability), facility design characteristics (e.g., access, ramp design, system connectivity), operating characteristics (e.g., signing and pavement markings), and corridor operating characteristics (e.g., traffic, congestion). While many of the surveys conducted for the study with truck drivers and trucking companies had different focuses, there were some consistent answers on what geometric design elements are important to truck drivers. Lane width, shoulder width, signing, pavement markings, ramp and interchange design, and supporting parking facilities were mentioned as important factors to trucking operations. Truck drivers also gave consistent answers on their frustration with congestion, speed differentials, and lane restrictions. Truck drivers supported truck only facilities, but their preference was for these facilities to exclude passenger cars, charge reasonable or no tolls, and remained congestion free.

The researcher prepared guidelines to help transportation planners, highway designers, and transportation operations professionals determining that geometric design and operational factors importance in order to attract the trucking and freight industry to toll roads.

C. Quality Management System for Highway Design

Quality Management Systems for Highway Design, May 2008 [3], a standard that provided the requirements of the overseeing organizations of England, Scotland, Wales and Northern Ireland in respect of quality management systems applicable to the design of highways. It provided interpretation and guidance on ISO 9001:2000 for highway designers including advice on the development and use of competence management systems. The standard provided interpretation of how a QMS based on ISO 9001:2000 is designed, presented, implemented, measured, monitored and developed and how these arrangements are addressed to suppliers. This will be achieved by providing guidance on:

- what the organization expects designers to include in their QMS;
- the requirements of ISO 9001:2000 in relation to highway design;
- appropriate levels of responsibilities and competence to meet the objectives of the organization and to control the design process;
- how to achieve customer (including end user) satisfaction;
- the continual improvement of the QMS in order to improve its effectiveness;
- the various forms of procurement used by the organization; and
- incorporating specific project related matters into a quality plan.

It was indicated that designers required to plan and develop the processes for product realization. Product delivered to customers, including the organization, will typically include surveys, reports, approval in principle documents, design risk assessments, requests for departures from standards, drawings, specifications, calculations, bills of quantities, various forms of certification and like items. The standard classified such product as design product resulting from a design production process. Design planning for individual projects must include the following items which shall be identified in quality plans as suggested in the standard:

- project-specific processes, their interdependence and organization;
- resources and required competencies (design team personnel, suppliers, support and
• administration);
• processes required for checking and review of design production (verification, validation and design review);
• management of scope of work, programme and budget;
• monitoring, inspection and test activities; and
• processes for design change control during design production and post design (during construction).

Control of Nonconforming Product

This organization needed confidence that the product would meet requirements and that the systems and controls identified in the product realization process would perform this. However, there will be instances when this is not achieved. The standard suggested for the sake of customer satisfaction the organization required:
• any nonconformity in the product to be identified as soon as possible after delivery;
• that it was advised of any nonconforming product that had been delivered to it, other customers or interested parties; and
• where appropriate, the systems and processes be reviewed to prevent recurrence of the nonconformity.

Guidance on the Use of Competence Management Systems

The standard presented guidance as part of the competence management system, mentioning that the designers required to:
• demonstrate the identification of activities and the competencies required for these activities;
• ensure that personnel used on the organization’s projects are competent to undertake the duties that will be assigned to them;
• demonstrate the methods used for the recruitment, training, development, monitoring and assessment of competent resources;
• evaluate the effectiveness of training and develop accordingly;
• undertake assessments of competency regularly at intervals appropriate to the specific task;
• demonstrate the maintenance and development of professional, technical and managerial capability;
• ensure the effective deployment of appropriately qualified staff;
• ensure that designers achieve consistent standards of competence appropriate to their work activities; and
• ensure that the particular safety requirements of the customer and statute are met.

For instance, competency matrices were also prepared in the guidance based on the types of information required to assess competence issues (qualifications, skills, knowledge, understanding, experience, etc).

D. Deterministic Design, Reliability-Based Design and Robust Design

Wei Wang and Justin (Y.-T.) Wu, Southwest Research Institute, Sano Antonio [11], described that due to the inherent uncertainties or variabilities in loads, materials and manufacturing quality, variabilities are unavoidable in structural responses. To ensure the reliability of a structure, the uncertainties or variabilities must be considered during structural design. Through a simple cantilever box beam example, the concepts and practices of three design methodologies: deterministic design, reliability-based design, and robust design, were examined in the paper. Consequently, a particular attention was given to the meaning of robust design and its definition in the context of reliability-based design. Several robustness criteria were studied and proposed in an attempt to search for a proper objective function in a reliability-based design framework.

The paper illustrated that there exist uncertainties or variabilities in loading, material properties, geometry and other aspects of any structure. Such uncertainties thought to be classified as reducible or irreducible. These terms were explained as follows:
a. Reducible uncertainties are usually caused by lack of data, modeling simplifications, human errors, etc., and can be reduced through, among other things, collecting more data, better understanding of the problem, more strict quality control.
b. Irreducible uncertainties are caused by phenomenon of a random nature and can not be reduced by possession of more knowledge or data.

Because of the existence of such uncertainties in the life cycle of a structure the structural response and life also show scatter. To design structures that can perform their intended function with desired confidence, the uncertainties involved must be taken into account. The paper in turn addressed mentioning that traditional way of dealing with the uncertainties is to use conservative values of the uncertain quantities and/or safety factors in the framework of deterministic design.

Further, it was emphasized on a more rigorous treatment of the uncertainties can be found in reliability-based design philosophies that have been under development for the last half of a century and are gaining more and more momentum. More recently, the concept of “robust design” has become very popular as suggested by the author. However, he depicted that there was no universal agreement as to the meaning of “robustness,” let alone a quantifiable criterion. The paper investigated questions by designing a simple cantilever beam with all three methods. The questions include:
• Is it an entirely new design philosophy or is it part of reliability-based design?
• Can reliability-based design be replaced by robust design?
• What are the advantages and disadvantages of each of these design methodologies?

Robust Design

Recently, “robust design” has become a popular design philosophy among major manufacturers. Unfortunately, the author noted that there are many different opinions as to the meaning of robust design. A commonly used definition states that a robust design is a design that is insensitive (or less sensitive) to input variations. In other words, the best design is one which performs as expected in the face of both expected and unexpected variations; and it does so by virtue of the fact that the design is inherently insensitive to changes in the design parameters and service environment. While it is an attractive and powerful design concept, in practice it may be difficult (if not impossible) to achieve. For example, designs that are insensitive to all variations may be
excessively conservative and costly. This design characteristic may, in fact, be undesirable in many situations.

In practice, what the authors were really concerned with was making sure that expected variations do not result in unacceptable performance; and among such designs the most desirable design is the one that is least sensitive to unexpected variation caused, for instance, by unintended use of the product or lack of knowledge of the uncertainties. Therefore, a more practical definition for robustness may be that a robust design is a design whose performance is not unacceptably compromised by expected variations in parameters which are known to affect its performance, and is more tolerant to unexpected variations.

Both robust design and reliability-based design attempted to be dealt with uncertainties. Their differences and similarities are difficult and probably unnecessary to describe, since there is no universal agreement on the definition and practice of the robust design philosophy, and the range of reliability theory is ever expanding. The more important issue thought was to identify and combine the merits in both concepts.

In reliability-based design, all uncertain quantities are modeled as random variables (or processes if variation in time is important). If the statistical distributions of the input random variables are well established (i.e. when all uncertainties or variabilities are reducible (or expected)) then all of the uncertainties have been counted for in the design process and the result of reliability-based design would be robust by the more practical definition of robustness. When the distributions of the input random variables contain uncertainty due, for example, to lack of data or unintended usage, the safety index or computed reliability will be subject to error.

The question raised was how to ensure the robustness of the reliability-based design when distributions of the random variables contain uncertainties. One method in reliability theory to address such problems is to model the input uncertainties using random variables with random means and/or standard deviations. The problem with this method was pointed out that another layer of uncertainties may be introduced when defining the distribution of the mean of a random variable.

In place of this approach, the study looked into the uncertainties in the means and standard deviations of the input random parameters by using the concept of robust design. In the context of reliability-based design, a definition of robustness that can be translated directly into a design criterion is that a robust design is one that is least sensitive to the change in the statistics of the input random variables (such as the mean, standard deviation and type of a distribution) within acceptable range of cost. They called the design philosophy based on such a definition reliability-based robust design (RBRD).

The paper summarized the deterministic design, reliability-based design and robust design summarized in the following bulletins:

- The reliability-based design is the most robust and economical design when the statistics (such as the mean and standard deviation) of the input random variables are well defined.
- In the context of reliability-based design, robustness can be defined in terms of reliability being least sensitive to variations in the statistics (such as means and standard deviations) of the random variables while still meeting design cost and performance targets.

When the uncertainties in the statistical distribution of the random variables are thought to be significant, reliability-based robust design provides a useful design tool to minimize the impact of such uncertainties.

The design that minimizes the weighted average of the reliability sensitivity factors can be highly dependent on the weighting coefficients selected. In general, the weight coefficients must be selected to reflect the uncertainties in the distributions of the random variables.

E. The Cost of Bad Design

Dr Richard Simmons, published in 2006 by Commission for Architecture and the Built Environment (CABE) [6] and others worked hard to establish that good design adds value to public and private sector projects alike. Valuation and accounting methods often gave low priority to design quality as a generator of value for business and the case for good design has to be made over and over again. Nevertheless, they addressed about the other side of the coin? In other words, they inquired that 'What are the costs of bad design and what happens when places and buildings ignore character, continuity, legibility and all the other principles that underpin good design?' Badly designed places impose costs on their occupiers, their neighbors and on society. Before September 2004 CABE’s had already done a lot of research into the value of good design and there had more on the stocks. There is now a powerful body of evidence that good design has financial and social value.

The publications presented an overwhelming set of arguments to justify the hypothesis that good design sometimes (but not always) costs more initially, but that it adds value. It can often create value in locations where quality has not been the norm. It certainly reduces whole-life costs.

As ministers clearly made policy objective describing that good design is the necessitated norm. Meanwhile, when public money is being spent the National Audit Office stressed the value of good design, and focused the need to consider the improvement in whole-life costs that it delivers.

The author attempted to respond on what mean by 'What is bad design?' in his study and introducing its significance to society, the economy and the environment. He also described his frustration with waste as a taxpayer, and the persistent requests CABE receives to restate the value of good design. Good design is not a question of taste and style. It can happen in many styles and appeal to some tastes and not others. It can be judged whether or not a design is good by testing whether it is functional, whether it is durable and whether it is visually attractive. This does not exclude innovation. The principles they applied to judge good design allow for changes in technology and taste.

It has been well understood that the characteristics of good design can be known and applied though all developments consume resources and space that might be used for other purposes. Generally, they compensate for this by generating utility and value that accrue to the community as well as their owners.
The researcher addressed that Bad design produces significant negative external costs. Hence, he reiterated that the principle that bad design produces significant negative external costs seems to one to be sound. At last, the question of negative externalities was mentioned to be vitally important in explaining why the cost of bad design is not always taken into account when projects are planned.

F. Good Design: the Fundamentals

Richard Simmons [7], Chief executive, CABE, also prepared an essay published in 2008 on individual buildings and the built environment as an entire. Why does design matter – and what is the best way to achieve it? The essay presented why architecture and urban design are such important cultural assets, and why good design can be reached only if it has users in mind. Good design requires a good process, including a clear brief and adequate budget, along with strong leadership and the right regulation. He identified the following issues that make an organization fit for purpose to get good design after discussing with many design champions about their experiences and the environments in which they work. These include:

**Behavior:**
- Leaders with vision who know that better design improves results,
- Effective partnership internally and with the right public bodies and private companies,
- Knowledgeable, skilled and trained decision makers,

**Resources:**
- Design champions who can influence decisions,
- Strong public buy-in and appetite for design quality,
- In-house designers and/or a consultant design team with a brief to support the organization as client or decision maker,

**Processes:**
- Strong published policies and standards,
- Decision making that talks about and prioritizes good design,
- Robust procurement processes which set absolute minimum design requirements,
- Access to design review for key projects,
- Learning through scrutiny of decision making, and
- Post-occupancy surveys of projects.

G. Project Development Manual

Mary Ricard, Project Development Manual (PDM), updated on 07-AUG-2014 [4], provided guidance relative to the appropriate design year used for traffic forecasts for various project work types. The manual stated that the selection of the appropriate design year for traffic forecasts is a function of the project work type. The project types mentioned include: highway projects, pavement preventive and corrective maintenance, safety related work, 3R - resurfacing, restoration and rehabilitation, reconstruction and new construction, minor intersection reconstruction, major intersection reconstruction, bridge projects.

**Design Year**

Project work types and the provided design years for the traffic forecast to be used for project scoping and design. Some project work types require no traffic forecast. Others have the estimated time of completion (ETC) as the design year, or the ETC plus the specified time period (in years). Traffic forecast design years provide necessary information so that the designer can evaluate alternatives to address traffic and congestion issues. The selected design year is intended to cover the time period necessary to evaluate functionality over the expected service life of the project.

Zoning, land use and planning issues, as well as anticipated future traffic patterns are all relevant to traffic forecasting projections, and need to be appropriately addressed in the forecasting process.

**Purpose of Standardized Design Approval Document Formats**

Scoping and Design Approval Documents, New York State Department of Transportation, February, 2008 [5], which mentioned that the design approval documents were required to be produced in the applicable standard formats to assure that all relevant issues have been considered and addressed, and to facilitate reviews by functional units, regional quality control units, advisory and regulatory agencies, the public and decision makers. In essence, the design approval document serves as a checklist of issues considered during preliminary design, and helps assure that the necessary studies and coordination have been completed or sufficiently advanced and evaluated prior to the granting of design approval.

The document talk about the efficiency of the overall process to be improved by using standardized design approval documents as described here under:

Decision makers and reviewers, including outside agencies, can find their areas of interest without the necessity of reading the entire report, thus saving decision makers time and reducing review turnaround time,

Word processing programs and report shells can be used by both staff and consultants. Electronic scoping documents can easily be used by the design approval document preparers,

Where separate scoping reports are required, the guidelines for the format and content of project scoping reports have been developed with the intent that they document scoping and follow a format similar to the design approval document. The scope approval document should be included as part of the design approval document. The project objectives, design criteria, feasible alternatives and scoping cost estimate developed in the scoping stage form the basis for project design and are carried into the design stage, and

Documents are kept concise and focused on key issues.
III. METHODOLOGY

The research methodology being employed to achieve the intended objective of the research project in general, is a literature survey pertaining to design reliability studies, manuals, guidelines and primary data surveying on selected sample size of ongoing federal road projects to obtain the required information through questionnaire on variety of practices in road construction sector. Accordingly, the adopted methods are organized as follows:

A. Site Selection and Scope of the Study

The study population will try to encompass the different federal ongoing road projects that focused on the last ten years for the commencement time of road projects. The selected projects either expected to be constructed by ERA, all regional roads authorities or private clients based on available information for the purpose of this study.

B. Data Collection

Once the population size or the study area is identified, questionnaire format is prepared and distributed in order to obtain the required information. At this stage, gathering of quantitative data (facts and figures) and qualitative information from recently completed and all ongoing road projects were surveyed. Then views and opinions of the respondents were identified and scrutinized accordingly for the study.

C. Site Visits and Case Study

During the course of data/information gathering, it was proposed to obtain the actual conditions from site visit observations, interviews and remarks of professional on the selected sites which in turn assumed to strengthen the collected data during analysis part of the research. However, this could not happen since the collated primary data, from totally 112 respondents on 86 different road projects, was found to be sufficient to conduct this research project through data analysis and discussion. Then, recommendations of the implantation strategy are drawn from the conclusion of this paper in order to achieve the desired design reliability practice in the road sector.

IV. DATA PRESENTATION AND ANALYSIS

The topic provides data presentation and analysis from questionnaire. The purpose of the study is to assess the current design practice on road projects in Ethiopia. The descriptive statistical analysis method is being employed for quantitative study and frequencies or percentages of the collated opinions are also used from the output of SPSS Software in this paper. Plus, the qualitative explanations of the surveyed road projects are also indicated in this chapter. The primary data used for this study were collected from three types of respondents such as Employer’s, Consultant’s and Contractor’s representatives. These three groups were selected because surveying and presenting the opinion of these groups is believed to be relevant in providing a meaningful part to study the problem in a proper manner. Therefore, the study tries to analyse the questionnaires collected separately. Respondents were made aware of the objective of the study so that they could give genuine and necessary information thereby contributing towards resolving the design quality related problems in the industry.

A. General Information of the Surveyed Road Projects

A number of questionnaires were prepared with a content of fifteen major points and distributed to stakeholders (Employers, Consultants and Contractors). These three parties are directly involved in the process of related assignments and responsibilities. Among the totally distributed questionnaires, it is found that 112 were responded and returned. Of these responses, 58 questionnaires were filled out by Employers’ representatives, 44 of them were filled out by Consultants’ representatives and 10 of them were filled out by Contractors’ representatives. The gathered data reveal that projects under review for this study were commenced for the implementation period in between 2006 and 2015 years. The original or contract amounts of the whole road projects were surveyed for this study as depicted in the acquired information. Whereas, only 67.9% of the respondents figured out citing that the revised contract amount of the projects’ was provided from the respective projects experience of up-to-date information. In other words, 32.1% of the respondents did not provide the projects’ revised amount as requested. Similarly, the original or contract duration of the entire road projects were surveyed as indicated in the reactions. While the majority (74.1%) of the respondents disclosed that revisions of contract duration were experienced on these road projects so far.

The basic contract information of the road projects from which the required and specific information were gathered through various tools of the study are treated accordingly and indicated as follows.
design reports for the design changes and modifications to most road projects can be mentioned as a principal factor causing for contractual and related complications on those road projects.

In connection to the above clarification, this study uses the data acquired from 59 road projects, which are indicated under Sr. No. 3 and 4 of the table 1 for the assessment of design parties to go in line with the objective of the study. Thus, the following analysis mainly focuses on these road projects for the sake of having a proper representative of the sample in the data analysis part. On the other hand, the total number of responses found from these 59 road projects was 76 and data analysis depends on this sample size for the assessment of the current design practice. However, it is also pertinent to mention that the study uses the whole collated data (112 responses) for analyzing about the general requirements such as proposing possible tools and guidelines for future implementation strategy purpose in order to improve quality of design deliverables on the highway design processes.

The obtained data reveals that both local and foreign contractors usually face design changes and variations during implementation phase that usually supposed to incur additional cost and time to ongoing projects. The cost variations computed from the revised amount of a given project exceeds remarkably that are usually associated with design errors and revisions while performing the works on the ground.

The road standards that were mainly adopted for ERA projects depend on the ERA manuals to classify and categorize the Ethiopian road standards as revealed from the opinion of the respondents. Most of these standards followed for the design and execution of the surveyed road projects consist of AASHTO standards that ERA manual 2002 specifies and make a reference to most technical aspects of the design. The nature of the projects’ road standards under investigation contain the following responses on the provided standard types. These include:

- DS1 for one responses,
- DS3 for eighteen number of responses,
- DS4 for forty five number of responses,
- DS5 for twenty four number of responses,
- DS6 for five number of responses,
- DC3 for one response,
- DC4 for one responses, and
- The remaining fourteen responses did not provide their feedback as requested.

In general, the overall project information gathered as indicated in the Table-1 summarizes the opinions of respondents. It also describes that most road projects faced design related changes during implementation time due to various reasons. This implies that the study on the reliability of design practice of road projects is timely concern that requires an improvement and/or minimize such occurrence of unreliability of designs in the future.

---

Table 4.1 Basic contract information of the road projects based on the respondents’ opinion

<table>
<thead>
<tr>
<th>S/No</th>
<th>Description</th>
<th>No. of Reply</th>
<th>No. of no reply</th>
<th>%</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Road projects’ investigated</td>
<td>86</td>
<td>-</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Design and build (DB) projects investigated</td>
<td>24</td>
<td>-</td>
<td>27.90</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Unit-rate contract (local) type investigated road projects</td>
<td>31</td>
<td>3</td>
<td>36.00</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Unit-rate contract (foreign) type investigated road projects</td>
<td>28</td>
<td>3</td>
<td>32.60</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Design change impact on cost: Yes responses</td>
<td>51</td>
<td>29</td>
<td>45.54</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>Design change impact on cost: No responses</td>
<td>32</td>
<td>-</td>
<td>28.57</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Design change impact on time: Yes responses</td>
<td>34</td>
<td>31</td>
<td>30.40</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Design change impact on time: No responses</td>
<td>47</td>
<td>-</td>
<td>42.00</td>
<td></td>
</tr>
</tbody>
</table>

* Most of the respondents of DB projects did not provide their responses including some other projects.

From Table 4.1, it can be clearly inferred that the project delivery system like DB projects usually impose the responsibility of design service to the contractor and the employer is not actually liable for the design changes that are likely to occur while expediting contracts. Moreover, this has remarkably reduced the associated claims that would emerge as a result of design changes and modifications for the turnkey procurement methods. Among 86 road projects, 27.9% of the projects under survey represent DB projects which considerably eliminate the design change related issues that most contracts in reality have been suffering from during the implementation stage. Bearing in mind this fact, this study do not incorporate the design related practices of DB projects as the objective of the study was aimed at improving the design practice that impose responsibility on the employer for lack of accuracy and reliability of designs during implementation stage.

Beside to the above, other contract types of road projects have been incurring for both cost and time overruns. This has significantly hampered the smooth operation of the day to day activities, which mainly stems from the design related problems. In addition, this ultimately has been resulting to uneven relationship between the contracting parties and in some instance it has been reflecting the technical capacity of consultants in providing quality deliverables and outputs in line with the requirement. Late provision and submission of
Table 4. 2 Respondents’ opinion about same consulting firm managing both design and supervision services.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>7</td>
<td>9.20</td>
</tr>
<tr>
<td>No</td>
<td>68</td>
<td>89.50</td>
</tr>
<tr>
<td>No response/feedback</td>
<td>1</td>
<td>1.30</td>
</tr>
<tr>
<td>Total</td>
<td>76</td>
<td>100.00</td>
</tr>
</tbody>
</table>

From Table 4.2, it can be understood that the majority of road projects were conducted by different consultants for design and supervision services. In other words, 89.5% of the respondents replied that the design and supervision consultants for a particular road project were provided to different companies or entities. However, only 9.20% of the responses reflected that both design and supervision services were given to the same company and only one respondent (1.3%) among the responses indicated no reply as forwarded on the request. Thus, it has to be seen in detail whether the different companies being involved on the above specified services that have been conducted at different periods would contribute for the change in designs and also would result in lack of reliability of the original designs or not. In fact, ERA has been taking a serious measure against wrong design outputs provided by the consultants to the extent that those firms will be allowed to participate in any service procurement of ERA for certain period of time. Besides, ERA has been taking an appropriate measure against professionals or individuals being involved in such design deliverables and they get penalized and debarred for certain time so that they could not participate in the production of design deliverables and activities as well. Though the aforementioned efforts were made to rectify the design related problems in the road sector, most road projects have been still suffering from unreasonable changes in the design during works expedition. The changes are usually associated with additional cost and time from the envisaged scope of the works during the implementation stage.

Table 4. 3 Design service duration

<table>
<thead>
<tr>
<th>Duration in Cal. Days</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Valid Percent (%)</th>
<th>Cum. Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>56 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>4.20</td>
</tr>
<tr>
<td>90 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>8.30</td>
</tr>
<tr>
<td>240 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>12.50</td>
</tr>
<tr>
<td>260 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>16.70</td>
</tr>
<tr>
<td>270 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>20.80</td>
</tr>
<tr>
<td>365 days</td>
<td>5</td>
<td>8.50</td>
<td>20.80</td>
<td>41.70</td>
</tr>
<tr>
<td>420 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>45.80</td>
</tr>
<tr>
<td>480 days</td>
<td>2</td>
<td>3.40</td>
<td>8.30</td>
<td>54.20</td>
</tr>
<tr>
<td>540 days</td>
<td>2</td>
<td>3.40</td>
<td>8.30</td>
<td>62.50</td>
</tr>
<tr>
<td>547 days</td>
<td>2</td>
<td>3.40</td>
<td>8.30</td>
<td>70.80</td>
</tr>
<tr>
<td>600 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>75.00</td>
</tr>
<tr>
<td>730 days</td>
<td>3</td>
<td>5.10</td>
<td>12.50</td>
<td>87.50</td>
</tr>
<tr>
<td>910 days</td>
<td>1</td>
<td>1.70</td>
<td>4.20</td>
<td>91.70</td>
</tr>
<tr>
<td>1095 days</td>
<td>2</td>
<td>3.40</td>
<td>8.30</td>
<td>100.00</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>40.70</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

The above Table 4.3 shows that out of 59 respondents for different road projects, only 40.70% (24) respondents filled out the duration of design services for each road project. However, 59.30% (35) respondents did not provide the duration of design service that was allotted for the project.
Figure 4.2 Bar chart representing design service contract durations for different road projects

Figure 4.2 indicates one year (365 calendar days) was the most frequently used for design service duration by the respective consultants which accounts 20.83% (5 road projects) of the total number of road projects (59) surveyed under this study. Furthermore, Figure 4.2 reveals that different road projects took from 56 calendar days to 1095 calendar days (three years period) based on the complexity and size of the projects for the detail design and tender document preparations. For instance, eight different projects, each accounting for 4.17% of the surveyed data (each 24 projects), took 56, 90, 240, 260, 270, 420, 600 and 910 calendar days respectively as presented in Figure 4.1. Again, eight road projects, two of these projects having 8.33% of the surveyed data, took 480, 540, 547 and 1095 calendar days respectively as shown in Figure 4.1. 730 calendar days were allocated for three road projects which accounts for 12.50% of the surveyed data.

Table 4.4 Adequacy ratings based on the respondents’ opinion for the allotted time for design service of road project.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sufficient</td>
<td>10</td>
<td>16.90</td>
<td>16.90</td>
</tr>
<tr>
<td>Moderately Sufficient</td>
<td>6</td>
<td>10.20</td>
<td>27.10</td>
</tr>
<tr>
<td>Insufficient</td>
<td>15</td>
<td>25.40</td>
<td>52.50</td>
</tr>
<tr>
<td>No response</td>
<td>28</td>
<td>47.50</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4 depicts that 31 road projects which represent 52.50% of the data and showed different ratings on the amount of time allocated for the service contract of the respective projects. Among these responses, 25.40% indicated that the specified time was not adequately provided, while 16.90% and 10.25% indicated that the given duration was sufficient and moderately sufficient respectively for the projects.

**B. Current Design Practice and Situation**

The current design practice and situation of road projects can be assessed based on the provided information for the root causes of design discrepancies through a survey conducted on various aspects.

Figure 4.3 Design review practice during implementation stage of road projects

Table 4.5 Design review practice during implementation stage of road projects

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>52</td>
<td>88.1</td>
<td>88.1</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
<td>6.8</td>
<td>94.9</td>
</tr>
<tr>
<td>No response</td>
<td>3</td>
<td>5.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

From both Figure 4.2 and Table 4.5, 88.1% (52) of the respondents announced that the road projects faced design review during construction time regardless of the detail design services made before the tendering stage and commencement of the works. However, very limited number of the respondents 6.8% (4) publicized that there was no design reviewing made on the surveyed road projects and the remaining 5.1% (3) of the responses forwarded their views without any feedback on the request. As such, the reliability assessment of design deliverables to Ethiopian road projects need to be studied in-depth through research so as to find an appropriate strategy for the resolution of habitually appearing design discrepancies and changes in the environment.
Table 4.6 Response on the road segment subject to horizontal alignment change while reviewing designs

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>6</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Partly Stretches (Less than 5km)</td>
<td>23</td>
<td>39.0</td>
<td>49.2</td>
</tr>
<tr>
<td>Stretches b/n 5KM and 15KM</td>
<td>18</td>
<td>30.5</td>
<td>79.7</td>
</tr>
<tr>
<td>Most Stretches</td>
<td>4</td>
<td>6.8</td>
<td>86.4</td>
</tr>
<tr>
<td>Entire Route</td>
<td>2</td>
<td>3.4</td>
<td>89.8</td>
</tr>
<tr>
<td>No response</td>
<td>6</td>
<td>10.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.6 shows 10.2% (6) of the projects encountered no horizontal alignment shifting where as 39.0% (23) and 30.5% (18) projects were re-aligned for partly stretches (less than 5km) and stretches between 5km – 15km respectively. Beside to this, 6.8% (4) and 3.4% (2) of the road projects came across most stretches and entire route change for the horizontal alignment respectively. But, 10.2% (6) projects’ respondents did not mention anything on line shift of the roadway.

Table 4.7 Projects associated with increment in cost due to horizontal alignment change

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>23</td>
<td>39.0</td>
<td>39.0</td>
</tr>
<tr>
<td>Moderately Significant</td>
<td>18</td>
<td>30.5</td>
<td>69.5</td>
</tr>
<tr>
<td>Significant</td>
<td>8</td>
<td>13.6</td>
<td>83.1</td>
</tr>
<tr>
<td>Highly Significant</td>
<td>2</td>
<td>3.4</td>
<td>86.4</td>
</tr>
<tr>
<td>No response</td>
<td>8</td>
<td>13.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.7 depicts 39.0% (23) of the road projects under survey did not encounter cost implication as a result of change in horizontal alignment. However, 30.5% (18), 13.6% (8) and 3.4% (2) of the road projects were influenced by line shifting to the extent of moderately significant, significant and highly significant respectively. Table 4.7 also describes that 13.6% (8) of the respondents’ did not reflect their perception on cost related impact due to horizontal alignment changes to road projects.

It was also noted in the following table 4.8 that include some of the factors influencing horizontal alignment change on road projects.

Table 4.8 Factors affecting horizontal alignment

<table>
<thead>
<tr>
<th>No.</th>
<th>Factors</th>
<th>Frequency of the responses</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>To achieve the best/ economical route and environmental considerations</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>To traverse through additional control points</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>To maintain design elements: min. radius, traffic volume, design speed, vehicle, etc</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Slope stability problems and/or land slide areas</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Soil type and climate</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>To adapt with topographic features of the area</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Drainage structures like bridges, culverts, retaining walls, etc</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Due to wrong surveying control points (GPS, BMS, etc)</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.8 portrays that to achieve best economic and environmental considerations, to modify drainage structures, to maintain design elements and to adapt with topographical features of the area are the most frequently influencing factors for line changes in horizontal direction. On the other hand, other factors like slope stability problems, soil type and climate, traversing through additional control points and wrong in surveying control points are found to be the less frequently appearing on road projects.

Furthermore, the respondents forwarded more factors that have been affecting horizontal alignment changes on the surveyed road projects. These include:
- To avoid the demolishing of religious built up areas,
- Some road projects experienced minor line shift so as to improve the geometry road based on site conditions,
- Decreasing the quantity of high retaining wall and excavation of earthworks against the original design,
- Avoiding excessive side cuts,
- Presence of high tension tower along the road stretch,
- To avoid removal of high tension electric system, buildings, safe public clinics, religious compound, safe and suitable access for local dwellers at town and village sections,
- Interference of two huge man canal and two control points that require raising the grade by 2m,
- To avoid demolishing of the existing pipeline and airport fence,
- Due to right of way (ROW) obstructions and to save public infrastructures,
- To reduce the quantity or volume of works,
- To avoid extension of some culverts as value engineering,
- When gradient exceeding the absolute maximum value,
Table 4.9 Response on the road segment subject to vertical alignment change while reviewing designs

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>6</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Partly Stretches (Less than 5km)</td>
<td>26</td>
<td>44.1</td>
<td>54.2</td>
</tr>
<tr>
<td>Stretches b/n 5KM and 15KM</td>
<td>11</td>
<td>18.6</td>
<td>72.9</td>
</tr>
<tr>
<td>Most Stretches</td>
<td>7</td>
<td>11.9</td>
<td>84.7</td>
</tr>
<tr>
<td>Entire Route</td>
<td>2</td>
<td>3.4</td>
<td>88.1</td>
</tr>
<tr>
<td>No response</td>
<td>7</td>
<td>11.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.9 indicates 10.2% (6) of road projects encountered no vertical alignment shifting where as 44.1% (26) and 18.6%(11) projects were re-graded for partly stretches (less than 5km) and stretches between 5km – 15km respectively. Besides, 11.9% (7) and 3.4% (2) of the road projects came across most stretches and entire route change for vertical alignment respectively. But, 11.9% (7) projects’ respondents did not mention any on re-grading of the roadway.

Table 4.10 Projects associated with increment in cost due to vertical alignment change.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>19</td>
<td>32.2</td>
<td>32.2</td>
</tr>
<tr>
<td>Moderately Significant</td>
<td>23</td>
<td>39.0</td>
<td>71.2</td>
</tr>
<tr>
<td>Significant</td>
<td>7</td>
<td>11.9</td>
<td>83.1</td>
</tr>
<tr>
<td>Highly Significant</td>
<td>3</td>
<td>5.1</td>
<td>88.1</td>
</tr>
<tr>
<td>No response</td>
<td>7</td>
<td>11.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.10 depicts 32.2% (19) of the road projects under survey did not encounter cost implication as a result of change in vertical alignment. However, 39.0% (23), 11.9% (7) and 5.1% (3) of road projects were influenced by profile change to the extent of moderately significant, significant and highly significant respectively. Table 4.10 also describes that 11.9% (7) of the respondents’ did not reflect their perception on cost related impact due to road profile changes to projects.

It was also noted in the following Table 4.11 that include some of the factors influencing vertical alignment change on road projects.

Table 4.11 Factors affecting vertical alignment

<table>
<thead>
<tr>
<th>No.</th>
<th>Factors</th>
<th>Frequency of the responses</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Due to change in horizontal alignment</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>To adapt with topographic features of the area</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Drainage structures like bridges, culverts, retaining walls, etc.</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>To maintain the design elements: gradient, K value, etc.</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Slope stability problems and/or land slide areas</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Due to wrong surveying control points (GPS, BMS)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Soil type and climate</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.11 depicts that due to change in horizontal alignment, adapting with topographical features and due to drainage structures are the most frequently inducing factors for grade level changes in vertical direction. On the other hand, other factors like maintaining design elements, slope stability and landslide problems, wrong surveying control points, soil type and climate are found to be less frequently causing vertical alignment changes on road projects.

Furthermore, some of the respondents forwarded more factors that have been affecting vertical alignment changes on the surveyed road projects. These include:

- To provide a better access to towns,
- Due to increased traffic flow, pavement surfacing was changed from double bituminous surface treatment (DBST) to asphalt concrete (AC),
- Due to lack of access as a result of deep cut sections in town areas,
- Due to significantly increased number of minor cross drainage structures on road sections,
- To minimize right of way (ROW) related issues and harmonize social factors like avoiding rock blasting activity in residence areas,
- Presence of unexpected or unforeseen irrigation canals that were observed during supervision or construction stage,
- To decrease quantity of earthwork,
- Due to excessive cut and presence of realignment due to interference of obstructions.
Table 4.12 Responses on the culverts schedule revision due to design review.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>47</td>
<td>79.7</td>
<td>79.7</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
<td>10.2</td>
<td>89.8</td>
</tr>
<tr>
<td>No response</td>
<td>6</td>
<td>10.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.12 reveals that 79.7% (47) of the respondents asserted the culverts schedule was revised during design review. However, 10.2% (6) of the surveyed data indicated no culvert schedule revision was experienced by the projects and also 10.2% (6) of the respondents did not mention any regarding the request.

Table 4.13 Responses on updating number and design of bridges during design review.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>22</td>
<td>37.3</td>
<td>37.3</td>
</tr>
<tr>
<td>No</td>
<td>31</td>
<td>52.5</td>
<td>89.8</td>
</tr>
<tr>
<td>No response</td>
<td>6</td>
<td>10.2</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.13 depicts that 37.3% (22) responses showed the road projects experienced revisions in number and design of bridge during re-design of the project design services. But, 52.5% (31) projects did not practice design reviews in relation to revisions in terms of quantity and parts design for the bridges. Further to this, 10.2% (6) respondents did not provide their response on the request.

From the totally surveyed road projects (59), ten road projects incorporated new bridges during construction. Among these projects, six road projects additionally introduced one bridge for each project to be constructed. Furthermore, among these road projects, two road projects additionally built three bridges for each project and also the remaining two road projects newly provided four bridges for each project during construction time.

Revision of bridge schedule for a given project was mainly associated with some of the major reasons noted from the responses which include hydrological, geotechnical and structural elements. Beside to these reasons, the respondents also reflected some of the facts that happened in the respective road projects. Of which the following reasons and circumstances of road projects can be explained as hereunder:

- Replacing the existing bridge structure,
- The existing bridge was found to be both geometrically dwarf and hydrological inadequate to accommodate the expected discharge during the construction stage,
- An introduction of a mirror image bridge from the existing bridge,
- For a given project, the original number of bridge was ten in the contract, however, after conducting a detailed investigation of these bridges it was decided to build only four of them. On the other hand, six of them were not appropriately treated and decided to be replaced by another minor drainage structures, which can accommodate the anticipated discharge for the specified design period.
- Due to geotechnical reasons (to get a better foundation material and stable river bank) one bridge was relocated to a distance of 300m on the upstream side. This change has reduced also the span length of the bridge.
- Due to impractical highway alignment of the design, one new bridge requires to be introduced.
- Due to change in highway profile during design review, the height of the bridge structure was reduced, and
- In the original design, it was decided to omit a bridge; however, it was lately recommended to be provided during construction time.

Table 4.14 Responses on the pavement design revision during design review.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>15</td>
<td>25.4</td>
<td>25.4</td>
</tr>
<tr>
<td>No</td>
<td>31</td>
<td>52.5</td>
<td>78.0</td>
</tr>
<tr>
<td>No response</td>
<td>13</td>
<td>22.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.14 shows that 25.4% (15) responses were found indicating the pavement design revision was made for the projects. Whereas 52.5% (31) responses indicated no design revision to pavement structures to the road projects plus 22.0% (13) responses did not reply any on the request.

The respondents who agreed on the pavement design revision explained that change in traffic volume and characteristics of subgrade materials are considered to be among the initiating factors for such amendments. Further to this, pavement design revision was made due to the following circumstances emerged on road projects:

- Upon the requirement of Employer, one third of a given road project in length was changed to rigid pavement,
- Along a steep section where the original design thickness was found to be insufficient, the Engineer issued a variation order to make a double asphalt layer on those sections,
- Pavement thickness change from 50mm to 120mm for steep slope sections to avoid premature pavement failure due to heavy loading and improve its performance as well,
- Unequal crust thickness (existing and widening) of base course and deletion of recycling the existing pavement,
- Considering the hot weather of the locality, the aggregate sizes for wearing course was changed from 9.5mm to 19mm,
- The asphalt concrete gradation was changed to coarser side based on Contractor’s proposal and subsequent Engineer’s review and approval on the same,
- Based on the increased length of steep section during design review,
- To comply with the given specification by utilizing the available construction materials, and
Fogy spray was made to increase the performance of DBST; however, no modification was made on the design of pavement structures.

Table 4.15 Responses on the circumstances of design departures on highway design

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12</td>
<td>20.3</td>
<td>20.3</td>
</tr>
<tr>
<td>No</td>
<td>43</td>
<td>72.9</td>
<td>93.2</td>
</tr>
<tr>
<td>No response</td>
<td>4</td>
<td>6.8</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.15 indicates that 20.3% of the respondents mentioned about the circumstances of design departures on road designs. However, 72.9% of the responses revealed that there was no circumstance found to depart from the set of design parameters or values in highway and related designs. Furthermore, 6.8% of the respondents on different projects reflected that they did not say any on the request.

Most importantly, it is found to be critical to know some of the frequently changing design features against the standard values. The following design features or elements have been departing from the standard figures repeatedly based on the obtained responses on the different circumstances of most road projects.

- Maximum vertical gradient (9% to 11%, 7% to 8.9% - 12%, 6% to 8%, 9% to 12%, 7% to 7% - 12%, 9% to 11.5% and 8% to 9.2%),
- Horizontal curve radius (175m to 100m – 150m, 85m to 30m – 70m, 30m to 25m – 28m, 85m to 50m, 85m to 30m, 50m to 30m),
- Minimum vertical gradient (0.5% to 0.1%, 0.5% to 0.2%, 0.5% to 0.3%),
- Road life time or design period,
- Road width,
- Design speed (40km/hr -50km/hr to 25km/hr – 35km/hr), and
- Change in nominal aggregate size.

For the above mentioned design elements, the respondents attempted to forward some of the reasons for such occurrences. The reasons for the departure in the maximum value of vertical gradient can be explained as follows:

- Due to drainage problem and to decrease excessive excavation or earthwork,
- Due to difficulty of the topography,
- Contract provisions for social and environmental impact,
- To reduce height of retaining wall,
- Back slope stability and right of way (ROW) obstruction, and
- Geometrical and geological reasons.

Plus, the following reasons were drawn for horizontal curve radius departures. These include:

- To reduce earthwork quantity,
- To avoid high fill and instability problems,
- To adapt with the terrain condition of the area,
- Contract provisions for social and environmental impact,
- The existence of very hilly area and deep excavation,
- Back slope instability and right of way (ROW) obstructions,
- Limited area or site constraints and to acquire an economical route, and
- Geometrical and geotechnical reasons of the area.

In addition to the above, the respondents recommended to reduce the quantity of embankment by lowering the minimum vertical gradient standard value, which was set as 0.5% (ERA Manual, 2002). Likewise, change in nominal aggregate sizes is found to be preferably revised to improve the performance of the pavement structure in hot areas.

C. Factors to Produce Good Designs

Here, the entire road projects under survey for this study has been assessed in order to have a comprehensive views that will help to obtain production of good design in the road sector. Therefore, the following data attempt to describe the nature of the responses.

Table 4.16 Response on the significance of consistency in producing a good design.

<table>
<thead>
<tr>
<th>Response type</th>
<th>Frequency</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Significant</td>
<td>72</td>
<td>64.3</td>
<td>64.3</td>
</tr>
<tr>
<td>Significant</td>
<td>30</td>
<td>26.8</td>
<td>91.1</td>
</tr>
<tr>
<td>Not Significant</td>
<td>3</td>
<td>2.7</td>
<td>93.8</td>
</tr>
<tr>
<td>No response</td>
<td>7</td>
<td>6.3</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>112</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.4 Response on the significance of consistency in producing a good design.

From Table 4.16 and Figure 4.3, it can be inferred that 64.29% (72) respondents suggested about design consistency in producing a good design is very significant. Beside to this, 26.79% (30) of the respondents also replied mentioning that design consistency is significant to yield a good design. In spite of these, only 2.7% (3) and 6.3% (7) of the respondents suggested on the requirement of design consistency quoting that it is not significant and with no responses respectively.
Figure 4.5 Response on the significance of aesthetics in producing a good design.

Figure 4.4 states that the majority of the respondents (68.8%) mentioned aesthetics in producing a good design is significant. Furthermore, only 6.25% of the responses indicated that aesthetic provisions to be very significant. While, 15.18% and 9.82% of the respondents provided their responses by mentioning it is not significant and with no responses respectively for aesthetic aspect in contributing for the development and delivery of a good design.

Figure 4.6 Response on the significance of engineering judgement in producing a good design.

Figure 4.5 depicts that the majority of the respondents (77.68%) mentioned about engineering judgement as very significant part in producing a good design. Moreover, 15.18% of the responses indicated that this aspect has significant contribution towards the production of a good design. However, only 1.79% of the responses declared that it was not significant. The rest portion of the responses (5.30%) did not mention any reply in this aspect as requested.

Furthermore, the respondents forwarded additional ingredients that are considered to be crucial in contributing and achieving a good design. These ingredients can be mentioned as follows:

- Design period,
- Design time,
- Design cost,
- Site conditions,
- Drainage management,
- Unclear areas of highway related issues should be resolved,
- Good coordination between the designers of different disciplines,
- Accountability / commitment of the designers,
- Consistence of design speed shall amended depending on each project for specific conditions,
- Using operating speed as a design speed,
- Adequacy of allotted time for detail design preparations,
- Defined slope stability,
- Environmental and social considerations,
- Future usage of planning,
- Detailed study,
- Safety,
- Adequacy of the allocated cost for detail design,
- Side slope ratio for various cut and fill sections,
- Quantification of the designer to achieve the desired competency,
- GIS based modelling and analysis, and
- Client side technical staff requirement to review, check and approve designs.

Finally, some of the respondents remarked on the current design practice of road projects citing some of improvements that need to be made for ERA design manual 2002 or 2013 (or of any kind of design manuals applicable to the surveyed road projects). These are mentioned as follows:

- Minimum radius for horizontal curves of ERA 2013 manual on Table 8.1 has discrepancy with that of Table 8.5 and Table 8.6. Insufficient design time was given to a project.
- Both ERA 2002 and 2013 design manuals specify a minimum gradient of 0.5%. However, this has significant implication on incurring unnecessary cost and time as maintaining this threshold limit for gradients increases the cut volume or quantum of works in long stretches.
- It is not necessary at all times to follow manuals in all aspects but based on the actual conditions, vehicle types, terrain conditions and departure values shall be allowed with provision of appropriate mitigation measures for their consequences from the technical point of view.
- Highway safety and lighting manuals, mechanically stabilized earthwork designs and construction manuals shall be developed so that safety and cost effective methods of constructing road projects will be realized in the future.
### D. Ingredients for Dynamic Nature of Geometric Designs

Table 4.17 Responses on different factors that helps for dynamic nature of geometric design.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Rating</th>
<th>Freq.</th>
<th>Percent (%)</th>
<th>Cumulative Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>Highly Important</td>
<td>60</td>
<td>53.6</td>
<td>53.6</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>39</td>
<td>34.8</td>
<td>88.4</td>
</tr>
<tr>
<td></td>
<td>Not Important</td>
<td>3</td>
<td>2.7</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>10</td>
<td>8.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart technology</td>
<td>Highly Important</td>
<td>67</td>
<td>59.8</td>
<td>59.8</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>37</td>
<td>33.0</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>8</td>
<td>7.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consistency</td>
<td>Highly Important</td>
<td>67</td>
<td>59.8</td>
<td>59.8</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>37</td>
<td>33.0</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>8</td>
<td>7.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Highly Important</td>
<td>60</td>
<td>53.6</td>
<td>89.3</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>40</td>
<td>35.7</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td>Not Important</td>
<td>2</td>
<td>1.8</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>10</td>
<td>8.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability analysis</td>
<td>Highly Important</td>
<td>64</td>
<td>57.1</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>38</td>
<td>33.9</td>
<td>91.1</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>10</td>
<td>8.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>112</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.17 displays a summary of responses collated on five factors’ importance for the dynamic nature of geometric designs as described as follows. Firstly, out of the total respondents, 53.6% of the respondents revealed that human factor is a highly important component for the dynamic nature of geometric designs. Furthermore, 34.8% of the responses showed that it is an important factor. Whereas, 2.7% of the respondents mentioned that it is not an important parameter. The remaining portion of the responses (8.9%) indicated with no responses on the provided factor.

Secondly, 59.8% of the responses depicted that smart technology has to do its own part in achieving the dynamic nature of geometric designs and provided with a rank of highly important factor. Besides, 33.0% of the respondents disclosed that it is an important factor. However, 7.1% of the replies without any response on this factor.

Thirdly, 59.8% of the respondents similarly indicated that consistency is highly an important factor and also 33.0% of the responses stated that it is an important parameter for the dynamic nature of geometric designs. However, 7.1% of the responses did not provide any suggestion on the requirement of this element.

Fourthly, 35.7% of the respondents connoted that flexibility requirement is very important factor in meeting the dynamic nature of geometric designs. In addition to this, 53.6% of the respondents declared that it is an important factor. However, 1.8% of the responses indicated that flexibility is not an important element and 8.95 of the replies did not mention any on the request.

Finally, 57.1% of the respondents’ opinions suggested that reliability analysis is highly an important factor in obtaining the dynamic nature of geometric designs. Furthermore, 33.9% of the responses also revealed that it is an important factor. But, the remaining respondents’ 8.9% did not provide any information on the request.

Additional factors were also suggested by some of the respondents in order to improve the dynamic nature of geometric design on road projects. These factors include:

- Smart technology incorporation like soft wares and manuals,
- Vehicles performance,
- Server based design and construction control, and
- Consideration of dominant traffic type.

### E. Quality Management System

Figure 4.6 describes that 86.61% of the respondents pointed out the requirement of quality management system of highway designs need to be prepared as a guideline in order to improve the reliability of design practice in Ethiopian conditions. However, few of the respondents (7.14%) added by mentioning that it is not required to have a quality management system in the road sector and also few of the respondents (6.25%) did not provide their opinion on this matter.

![QMS requirement to improve reliability of design](image)
Table 4.18 Responses on different factors importance for quality management systems of designs.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Ratings</th>
<th>Percent (%)</th>
<th>Cum. Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control of nonconforming products</td>
<td>Important</td>
<td>56</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>56</td>
<td>50.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>112</td>
<td>100.0</td>
</tr>
<tr>
<td>Guidance on the use of Competency Management System</td>
<td>Important</td>
<td>50</td>
<td>44.6</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>62</td>
<td>55.4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>112</td>
<td>100.0</td>
</tr>
<tr>
<td>Standardizing design approval documents and formats</td>
<td>Important</td>
<td>89</td>
<td>79.5</td>
</tr>
<tr>
<td></td>
<td>No response</td>
<td>23</td>
<td>20.5</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>112</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 4.18 examines responses obtained on three factors that will assist in achieving quality management systems of designs. Among these responses, 50.0% of the respondents replied that control of nonconforming products is an important factor; however, 30.0% of the respondents did not provide their opinion on the request.

Moreover, 44.6% of the respondents agreed on the preparation of guidance on the use of competency management system so that quality management systems of designs will be ascertained. Whereas, 55.4% of the respondents did not support any of their ideas on this aspect.

At last, the majority of the respondents (79.5%) disclosed that standardizing design approval of documents and formats is an important aspect to be adhered to it so that it will improve the quality management systems of designs. But, only 20.5% of the respondents did not reflect any of their views on the request.

Notwithstanding the above, the respondents described the following things that are considered to be essential in improving design reliability practices on road projects in Ethiopia context. These include:

- Reliable and accurate data and maps aerial photos,
- Communication (feedback gaining system) need to be developed,
- Standard formats and documents including checklist and updated manuals that will help to improve quality of designs,
- Performance evaluation, quality and safety auditing practices along with taking corrective actions on the observed weakness,
- To create an ease environment through which communication between professionals will be established and design reliability will be achieved which provides cost effective and sustainable solutions to the development of road infrastructure,
- To establish coordination between professionals on various disciplines,
- To develop the capacity of ethical and accountable professionals by allocating sufficient time and the required fee for their services,
- Cost controlling system along with quality of end products,
- Guidance for check and balance, accountability and professional ethics shall be developed, and
- Establishing checklist in line with quality manuals development.

V. DISCUSSION OF RESULTS

A. General

As to practical observations from various road projects, it can be understood that most road projects have been unable to complete within the allocated budget and scheduled time. This mainly emanates from lack of trustworthiness of designs which in turn results to poor estimation of the project workload during the detailed design preparation. As a result of this fact, most road projects are subjected to design revision during implementation stage and sometimes fail to meet supplementary design revision along with the supervision assignment. Such design revision also usually lacks details and accuracy as it is being performed concurrently with construction work force and ongoing site activities. This mainly happens due to shortage of the required time to carry out a detailed design for such occurrences and also imposes difficulty to assess associated contractual implications as a result. This implies that design quality management shall be in place to avoid considerably huge implications as a result of design and related issues from the upcoming road projects.

Subsequently, this research project assessed the current design practice on the road sector through conducting a primary survey of on-going road projects. Beside to this, from the respondents’ opinion, it attempts to deal with the possible remedial measures in order to acquire a reliable design output in the future for the sector.

B. Current Design Practice

The design practice in the road sector has been assessed on road projects by involving those projects whose detail design and construction activities are being carried out at different stages. Accordingly, a survey on geometric, pavement, minor drainages, bridges, pavement and departure elements of designs were taken to comprehend the current situation when compared with original design. Among these components of design aspect, road geometry plays a vital role in determining project cost, time and quality of the completed road.

The geometric design of a road traverses through topographical feature of the area so as to meet the needs of the road users by following standards and geometric elements. However, in some cases, exceptions to standards are usually accustomed to be entertained by the designers. Hence, most literatures like manuals being used by most countries suggest to practice some standards to deviate from the provided values of parameters, provided that safety issues should not be compromised or sacrificed. The highway designers are expected to evaluate the existing geometric designs against the criteria. In case, the existing geometric design does not at least meet the lower criteria, the designer has to evaluate the practicality of improving the feature. Once the improvement of geometric design element was decided, the improvement level should be in line with the project purpose.
On the other hand, the road development program has been expanding by practicing the conventional ways of planning, designing, construction, operation and maintenance. However, this has to be supported by advanced technologies through conducting exhaustive research activities to improve the development of the sector in the country for the future. For instance, automated and advanced data gathering, advanced site investigations, traffic forecasting techniques, mechanistic empirical pavement design, usage of sophisticated highway design aids, advanced construction materials, pavement and bridge management systems, etc need to be in place so that road development shall be supported and sustained accordingly in the long run. These advanced technologies will have its own contribution for the input parameters that should be considered in advance and will ultimately improve the design philosophies to be adopted in the country too.

C. Fundamentals of Good Design

Good design requires a wonderful process, including a clear brief and adequate budget along with the right management practices in achieving the same. Literatures suggest that human behaviours, resources and processes have direct impact to every organization to produce a good design. Thus special emphasis has to be imparted in those issues in order improve the quality of designs in general terms.

How human behaviours influence in the production of quality design? Knowing the best design improves the results, this can be achieved through applying appropriate direction by experienced leaders. Beside to this, an effective partnership is very crucial both internally and with all stakeholders being involved in the sector. Furthermore, it is of paramount importance to see the level of manpower in terms of their knowledge, skill and training.

The resources and processes associated with the design are very useful for a good design. For instance, in-house designers’ involvement with a clear brief support employer or decision makers. The following processes are meant to be indispensable:

- Strong published policies and standards for the quality of design deliverables,
- Decision making that prioritizes good design, and
- Robust procurement processes in terms of design requirements.

D. Principal Factor for Geometric Design

The most prominent factor that determines the project route falls under the geometric designs. This indicates the designer has to pay a special attention towards the decisions to be made with respect of geometric elements. For instance, the horizontal and vertical geometries of a road contribute for cost, function, safety and environmental aspects of the road. ERA geometric design manual of 2013 has improved some of the parameters like minimum gradient on flat section can be reduced to 0.3%. However, the amendments do not fully address the challenges of the designers for design exceptions and it is anticipated to be submitted for the departures with the provision of the measures to be taken for safety and functional requirements of the road.

This indicates the designers shall consider the following important features in preparing the geometric design for road component. These include:

- Consistency of the data and values of design parameters,
- Human factor in making good engineering judgements,
- Replacing the conventional systems by advanced technologies,

Most importantly, the designers shall encourage the usage of advanced instruments which used to investigate the geotechnical related matters so that they could easily foresee the likely stratum underneath the surface before the commencement of excavation works. This absolutely helps to decide the reasonable road geometry and back slopes of the excavations during the design phase and give better estimation of earthwork quantities. In the contrary, test pit method of ground investigations usual found to be necessary for shallower depths of excavations but it fails to predict the conditions of a deep stratum.

E. How Easy to Manage Quality of Design?

Consequent to the government plan for the expansion of road network in the last two decades in the country, there have been challenges in the accuracy of estimations for the project cost and time. Among, these challenges lack of quality designs on road projects has a significant influence that most stakeholders in the sector have been trying to tackle with such emerging situations. Subsequently, this study attempts to assess these related problems and how to manage the considerable discrepancies on the original designs. Accordingly, it is suggested to implement the following:

- Professionals experience on various disciplines shall be sufficient and relevant to the assignment and also competency assessment has to be made and evaluated every specified time (may be for five years). Such evaluations can be done by engaging an international consultant having an experience in acknowledging and recognizing the professionals experience based on the past deliverables of design services.
- ERA standards both 2002 and 2013 manuals have set the procedures to be followed prior to applying the design departures from standards. This implies that the designer is anticipated to exercise the use of design flexibility as a better alternative provided that the safety aspects shall not be compromised. However, the actual practice does not fully utilize this procedure though the designers are facing design exceptions to the existing manuals. Thus, the use of design departure for certain elements can be a means for future updating of the manual to the prevailing topographical, function and safety concerns of the country.
- The nonconforming results of design deliverables have to be managed by taking corrective measures against such practices of the design institutions. This shall be achieved either by recruiting an experienced professionals for the various disciplines or assigning an independent consultant who can assist the Employer for detail design review process.

F. Implementation Strategy

The general purpose of assessing the design practice is to improve the philosophies for roadway design and project development and system that enhances community values
and integrates quality roadway designs into communities and the environment. These design philosophies have to do its own contributions in providing systematic and technical solutions to the project development process, safety improvements, roadway design concepts, geometric design guidelines, public involvement, and environmental commitments. Among the design philosophies as literature from United States pointed out a Concept Sensitive Design approach can be mentioned. A shift toward this philosophy was supported by Federal High Way Agency in U.S.

To achieve safety requirements, planners are ready to provide roadways that self-enforce speed reductions, potentially increase levels of congestion, and promote alternative modes of transportation. This approach contrasts with the U.S. design philosophy, in which wider roads are deemed safer, there is heavier reliance on signs to communicate the intended message, and there is a lower tolerance for congestion and speed reduction.

In connection to this, the following list of possible implementation strategies for enhancing existing project development and roadway geometric design practices shall be exercised.

During the conception stage of a project, it is a usual practice to consider lengthier sections, to allow for a more systematic impression and definition of needs and deficiencies throughout the entire system. Road authorities should, in urban areas, emphasize better integration of projects in communities by addressing the public’s concerns about speed management and aesthetics. Public and their representatives involvement is vital for a successful project, hence, this concept could be applied at the initial possible stage of a project in the country. Finally, the use of design workshops, in which all project alternatives are developed with public involvement, merits further examination, and could be transferable to Ethiopian practice.

The concept of simultaneously addressing safety issues when addressing capacity on two-lane roadways is indispensable aspect of the road geometry. This concept needs future studies for implementation to set and determine the specific design elements and guidelines. Self-explaining and self-enforcing roads are facilities designed for a specific purpose or function, and they address safety in an efficient way. This can be achieved by implementing an aesthetic approach to explain road function and enforce speed. Reliance on the roadway design to convey its operating speed is integral to this concept, which contrasts with the higher reliance on traffic signs to convey speeds as conventionally practiced.

Traffic calming strategy is an effective way of monitoring speed through town sections and requires a wider implementation in the country in order to considerably minimize traffic accidents by ensuring safe and comfortable movements. There are a variety of speed reduction levels through applying different devices on the carriage way. However, the calming practices are usually introduced during the operation stages after facing many crashes on the completed roads. This has to be avoided and the calming devices need to be introduced preferably during design stages or implementation stages of road projects.

It is well known that roundabouts are a very safe and efficient means of intersection control. Significant safety gains were achieved by implementing roundabouts instead of conventional intersections in cities, towns and necessary areas. Hence, the introduction of roundabouts has to be encouraged and shall be dominant over other intersection systems as long as the situation permits so as to utilize this modernized tool in the country. As such, road authorities and designers should consider implementing roundabouts as a preferable design and also as a means for improving traffic safety.

A significant emphasis on addressing the needs of pedestrians and bicyclists shall be in place in the country. This improves vehicle mobility along the road network as it makes drivers to move as quickly and freely as they want. This perception needs to be expanded to include all users, in order to address the safety needs of these at risk road users. Policy makers, road authorities and designers are essential in promoting the use of such modes of transport and should focus on providing bicycle and pedestrian networks in the country along with the development of the road sector.

The development of transportation projects and systems that enhance community values while integrating roadways into the environment is an everyday practice that all countries follow. Concern is given to the desires and needs of the community by inviting the appropriate stakeholders to participate in the development of a project, thus influencing some of the solutions so they are acceptable to the community. CSD implies a flexible application of the established geometric criteria in designing roadways. The use of innovative design to address local problems and provide solutions within the context of the area is essential to applying the CSD concept. The self-explaining, self-enforcing road is an example of such innovative design, because it encourages lower operating speeds for automobiles while incorporating safety and mobility for all transportation modes.

VI. CONCLUSION AND RECOMMENDATION

A. Conclusion

The results of the study depict that the design change has negative impacts on the predefined time and cost for 30.4% and 45.54% of the federal road projects respectively. 89.5% of the road projects’ detail design and supervision assignments were appointed with different consulting firms. The duration of design service provided to the design institutions is merely considered to be inadequate to conduct the detail investigations and to produce quality design. Under this circumstance and other factors, 88.1% of the road projects have experienced design review on ongoing road projects which usually hampers the progress of physical works due to untimely provision of revised detail designs and unreasonably increased or decreased quantum of works. Few of the road projects faced design exceptions during the production and implementation of some of the design parameters and suggested for usage of such departures without sacrificing safety aspects and upon consideration of the employer for further improvement of the manuals and to employ possible mitigation measures.

This paper recommends some of the significant ingredients that help in achieving a good design based on the responses. Of these ingredients, the prominent ones include engineering judgment, consistency and aesthetics. Furthermore, additional ingredients were also suggested to be taken into account to produce quality design, which need
close follow up both pre and during-design stages by the concerned parties. The dynamic nature of geometric designs can be influenced by human, smart technology, consistency, flexibility and reliability analysis factors. At last but not least, an automated data collection has a vital contribution towards achieving a quality design in most parts of the disciplines for road projects and further studies have to be carried out to customize the outdated data being used based on the actual conditions of the country.

In general, quality management system of road projects’ design has to be comprehended prior to the issuance of approval and further physical work commencement. Among the major quality management system, the following factors were found to be so important to be practiced:

- Standardizing design approval documents and formats,
- Control of nonconforming products/services, and
- Guidance on the use of competency management system.

B. Recommendation

Based on the findings of the study and conclusion made, the following recommendations were drawn:

- Professionals experience and competency requires to be assessed and evaluated regularly so that the assessment can determine whether the designers involvement on the upcoming design service.
- Automated and advanced data collection system like traffic counting, planning inputs, geotechnical investigations, site conditions assessment, etc have to be made and utilized during detail design preparation so as to get a reliable information about road projects before the works procurement process.
- In accordance with ERA standards of both 2002 and/or 2013 manuals and reasonable judgement of designers for design exceptions, some parameters shall be entertained for amendments provided that the changing conditions shall conform to the prevailing topographical, function and safety concerns of the project.
- Nonconforming outputs of design deliverables have to be managed by taking corrective measures against such practices in consultation with the design institutions.

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VIII. REFERENCES