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A Study on Productivity of Key Earth Moving Equipment (Based on Selected Road Projects of Gandaki Province, Nepal)

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Abstract
The efficient utilization of earth-moving heavy equipment is very important in the Nepalese Construction sector as the major construction works consist of heavy earthwork volumes. The importance of effective operation of key earth-moving heavy equipment such as Excavators, Bulldozers, Backhoe Loaders, Motor Graders, and Dump Trucks is vital for the project's successful completion. In-depth literature review on productivity and with experts' consultation the major factors (66 nos in 7 groups) are identified. Data are collected from the technical staff involved in Road projects in Gandaki Province, Nepal. A questionnaire is used to gather information from Clients/Employers, Consultants, & Contractors, ensuring that all three parties' views are represented. Strong internal consistency of test items is indicated by Cronbach alpha value 0.982. The top 3 most crucial groups of factors that affect in productivity of earthmovers have been identified as Equipment Related, Operator/Human Related, and Management Related . The opinions of the three parties are correlated, The Hypothesis is established and tested using t-statistics (p-value approach), which further strengthens the study outcome. Operator Skill, Operator Experience, Condition of Equipment, Skill Labor availability (Operator, Mechanics, etc.), and Insufficient number of Equipment are found as the most crucial factors from the Relative Importance Index (RII). Also, the most important precautionary strategies have been found as Mandatory Certification from an authorized body for operators, Reasonable wages and benefits to Operators & Helpers, Arrangement of the Weather monitoring system for early warning, and Conduction of Regular Training Programs for Operators. Similarly, as a part of project management measures, the top strategies have been found to Establish a reliable supply chain for equipment, fuel & accessories, Place the best economic brand available, Align Project Schedule with seasonal weather patterns, Make payments on time to operators & helpers and Identifying early warning signs related to project disturbances. Recommendations include operator training, regular maintenance, technology integration, effective management, and site clearance before word before construction.

Keywords
Earthmovers, Productivity, Equipment Management, Factors, Road Construction

1. Introduction

1.1 Background

Nepal is a developing economy therefore a lot of construction activities are ongoing throughout the nation executed from different levels. For instance: Midhill Highway, various Hydropowers, Roads, large Bridges, Multi-storey Buildings, etc. Such projects consist of huge earthwork and require efficient and optimized utilization of heavy earth-moving equipment for the economic, sustainable, & successful construction of the project and to improve the overall efficiency of the construction industry.

1.2 Problem Statement

The money invested in the construction sector in the province is a large part of the budget- a taxpayer's money and there are limited resources, hence the optimum utilization of key earthmovers is required for any project. In various mid-term and full-term review reports published by Gandaki province stated the time and cost overruns of projects. Therefore, there is a need to investigate if equipment productivity has a vital role in this. Authorities states that there are huge no of projects with delays and cost overruns. Addressing issues in the construction industry efficiency, safety, and quality needs a holistic strategy for equipment management to generate cost and time savings and better project outcomes[1]. Furthermore, for such bad performance, the project has to be analyzed from equipment productivity management. Factors influencing equipment management in construction projects, particularly maintenance timing, breakdowns, availability, efficiency, and outdated systems, are crucial to mitigate cost overruns and improve project outcomes [2].

1.3 Objective

The objectives set out for this study are:

1. To identify the major and most crucial factors that influence the productivity of key earth-moving equipment in Road Projects of Gandaki Province,
2. To categorize the identified factors, find their ranking and Relative Importance Index (RII). On this basis to find out the most influencing category of factor group and the most crucial sub-factors of each category, and
3. To suggest the possible mitigation and enhancing measures of productivity of key earth moving equipment as precautionary & project implementation phase.

1.4 Limitation

As per the scope and methodology of this study, it has the following distinctive limitations:

1. This research is limited to the selected key heavy earth moving equipment used in Road projects of Gandaki province, Nepal.
2. The study is based on the data/survey obtained from technical staff involved in 11 District's 22 road projects (2 projects from each district) of Gandaki province funded by GoN.
3. The primary focus of the project is to suggest on policy to avoid delays from poor management of key earth movers. Therefore, no mathematical figures are calculated on productivity.

2. Literature Review

The construction industry is experiencing significant growth globally, and our neighbor India is also witnessing a surge in construction activities. At the beginning of any construction project, earthmoving operations are crucial. These operations involve the use of heavy construction equipment, especially excavators. The inclusion of excavating equipment in construction projects helps reduce the reliance on manual labor to a great extent and generally enhances construction productivity. However, if excavators are not selected or utilized properly, it may result in cost overrun, time extension, and even safety concerns for workers. The time required for earthwork depends on the output of the equipment involved. Various factors can affect the performance and productivity of excavators, as we have discovered through a review of existing literature. Understanding the fundamentals of these factors is an important responsibility of construction managers to improve excavating equipment performance [3].The identified factors affecting the performance of excavators, one of the key heavy construction equipment are presented in Table 1.

Table 1: Key Factors Identified for Excavator

1	Proper Equipment Selection
2	Site Condition
3	Cycle Time
4	Bucket Size
5	Angle of Swing
6	Repairs and Maintenance of Equipment

Hajare et al, (2020) [4] concluded that efficient utilization of construction equipment plays a crucial role in the success of heavy construction projects. Excavators, piling equipment, front loaders, pullers, dumpers, spreaders, dozers, engine graders, soil compactors, cranes, and other types of equipment are utilized in various construction applications such as highways, irrigation, housing, and power projects. These equipment types contribute significantly to the overall project cost, accounting for approximately 15-30 percent of the total expenses. They are essential for earthmoving operations but can incur high ownership and operating expenses.

Kishor Kulkarni Sushma S (2018) [5] concluded that Enhancing construction equipment productivity is crucial for ensuring timely and cost-effective project completion. To achieve improved productivity, it is necessary to make adjustments to methods, operation strategies, and systems. Proper planning of equipment operations is of utmost importance. The economic viability of equipment relies on its suitable utilization within its mechanical capabilities and in the intended environment.

I. Class of material
II. Height of Cut
III. Angle of Swing
IV. Operator Skill
V. Condition of Equipment
VI. Haul unit exchange
VII. Bucket size
VIII. Handling of oversize material
IX. Clean up loading area

Figure 1: Key factors identified by Kishor Kulkarni Sushma S (2018)

Sulochana, 2021 [6] illustrated that Construction equipment plays a critical role in the successful execution of construction projects. The effectiveness of construction machinery serves as a key differentiating factor between construction companies engaged in heavy construction and those involved in lightweight construction. Time and cost considerations are vital constraints for project success. The factors contributing to costs in construction projects were ranked based on the RII, and the top five significant factors were:

I. frequent equipment breakdowns,
II. maintenance of kit,
III. insufficient numbers of kit,
IV. performance and efficiency of kit, and
V. inadequate modern equipment systems.

Figure 2: Factors contributing to cost (Sulochana,2021)

Sachin Pindoria et al., 2017 [7] found that Examining equipment productivity is valuable in determining fair pricing or rental rates for the equipment. A study was conducted to assess the efficiency of construction equipment and identify the factors that influence its output. This study provides general information about the productivity of construction equipment and identifies the various factors that impact its productivity.

Methe et al., 2018 [1] concluded that addressing the challenges related to efficiency, safety, and quality in the construction industry requires a comprehensive approach to equipment management.This study also illustrated that by focusing on improving equipment productivity through effective management, construction companies can achieve cost and time savings, enhance project outcomes, and address industry challenges related to efficiency, safety, and quality.

Schabowicz & Hola, (2007)[8] found that Construction operations often involve the coordinated work of multiple

machines, which form complex technological systems. For instance, earthmoving machinery typically includes excavators and haulers (trucks) working together. The productivity of these system plays a crucial role in evaluating the effectiveness of process design.

Kulkarni, (2020) [2] concluded that various factors affecting equipment management in construction projects. The top five significant factors contributing to cost overruns were identified as maintenance timing, frequent equipment breakdowns, inadequate equipment availability, equipment efficiency, and performance, as well as the use of outdated equipment systems. Understanding and effectively managing these factors can help mitigate cost overruns and enhance project outcomes.

Salem, (2017) [9] illustrated that earthmoving operations and highway construction heavily rely on the effective use of heavy construction equipment. However, various factors can impact the efficient utilization of equipment in a direct or indirect way, leading to a decline in productivity.

Papadopoulos, (2003) [10] In his study utilizes computational methods to estimate the productivity of civil engineering equipment. The study identified various factors for excavation and moving machines like excavators, loader, and Dump trucks and average scores on productivity.

Balamurugan & Senthamilkumar, (2014) [11] The study emphasizes that the selection of equipment is influenced by the cost factor, which varies depending on the size of the projects, such as small, medium, or large-scale projects.

Dara, (2022) [12] The study emphasizes the significant influence of machine types on the construction industry and how equipment selection is determined by project size and cost considerations.The study's findings reveal that excavators are predominantly used in large-scale projects due to their cost-effectiveness.

R. Ranjithapriya & Dr. S. Arulselvan,(2020)[13] Identified the key factors are late inspection of equipment, type of soil at site, site conditon, operators efficiency and easily availability of sevicing parts.

Pg Student, (2019) [14] stated that Inefficient equipment management can result in production losses, delays, and reduced overall profitability for the company. It is crucial to utilize machines properly and match their capacities to meet specific project requirements.

After the vigorous literature and consultation with experts total 66 factors were identified. Most of them are from literature and some are added by experts. The identified factors and groups are shown in Tables 2 to 8.

Table 2: Group 1 Operators/Human related factors

Operator Skill
Skilled Labor Availability (Operator, Mechanics etc.)
Operator's Experience
Disloyalty
Lack of Training
Mental and Physical Health of Operator

Table 3: Group 2 Equipment related factors

Proper Equipment Selection-Equipment Specification
Cycle Time
Bucket Size
Angle of Swing
Repairs and Maintenance of Equipment
Condition of Equipment
Frequent Equipment Breakdown
Spare Parts not Available
Routine Checkup of equipment
Age of Equipment
Performance of Hydraulic system

Table 4: Group 3 Technology Related Factors

Inadequate Modern Equipment System or New Technology
GPS and Machine control systems
Fuel Efficiency
Advance Operation Instrumentation (Waki taki, Monitor disply on each equipment etc.)

Table 5: Group 4 Management Related Factors

Insufficient no of Equipment
Construction Facilities
Motivation and Planning
Lack of Supervision
Improbable planning or management and Expectation of Labour Execution
Communication between site administration & operator
Delay in placing the equipment
Interfacing Activites
Non-Payment of Charges/Delay in payment
Availability of Fuel/Lubricants in time
Effective Work Scheduling
Idle time and Downtime
Proper planning of Equipment Schedule throughout the project
Slow Decision Making
Low Payment to Operators and Helpers

Table 6: Group 5 Social, Environmental and Regulatory Factors

Temperature Effects
Snow,Rain and Wind & other weather conditions
Public Strike and intervention
Reallocation of Utilities
RoW clearance
Land Acquisition completion before construction begins
Coordination between Local, Provincial and Federal Government
Completion of Environmental Studies (EIA, IEE, BES etc.)
Effective Coordination Among Stakeholders
Not availability of Dumping/Mucking site nearby

Table 7: Group 6 Site Related Factors

Site Condition
Class of Material/Type of Soil
Height of Cut/Digging Depth
Obstacles on Site
Heavy Traffic
Altitude Effect on the performance of Engine
Site Congestion/working space availability
Condition of Haul Road
Geographical Conditions and Terrain Difficulties
Presence of Hazards at site
Difficulties in Transportation of Equipment, Fuel, and Accessories

Table 8: Group 7 Other Factors

Delay in obtaining permits (Forest , conservation area permits etc.)
Accidents (Labour Injuries etc.)
Safety and security
Defective design and Rework
Low Financial capability of contractor
Uncertainty of project fund
Insufficient feasibility, inadequate and inaccurate investigations
Drawings, line and Level not provided
Force Majeure (Act of God) and Natural Calamities

3. Methodology

This study uses data from the Gandaki provincial Road projects. The first step was to undertake a thorough examination of the literature to determine the various elements and how they can be categorized as contributing to the productivity of the important pieces of earth moving machinery, such as the excavator, bulldozer, backhoe loader, motor grader, and dump truck. Then, in order to fit with the particular context of Nepal's Gandaki Province, these elements were examined, adjusted, and categorized.Three experts with vast experience in Nepalese construction projects, particularly in road projects, were asked for their expert opinions in order to validate the elements that had been discovered. They represented the Client, Consultant, and Contractor viewpoints.A questionnaire survey was carried out using a 5-point Likert scale to establish the main factors influencing productivity, and the resulting data was analyzed in SPSS and MS Excel software.

For the mitigating measures the in depth interview, field observations were conducted and finally Key Informant's Interview-KII and expert opinion were taken for finalization.

3.1 Questionnaire Design

Data were gathered through a questionnaire. The questionnaires were distributed to a) Employer/Client b) Contractor c) Consultants of study projects. For each cause/group, the participants were asked about the importance degree in causing equipment productivity on a five-point scale importance index ranging from 5 to 1-point scale: Very Major=5, Major=4, Moderate=3, Minor=2, Very Minor=1.

An initial questionnaire was created on the basis of a thorough analysis of the literature that already existed. A pretest was carried out with 10 percent of the sample group,with than ten years of relevant experience, to gauge the usefulness of the questionnaire. The suggested questionnaire was modified in response to the experts' insightful comments. The final questionnaire was then improved, with unnecessary questions being eliminated and required added.

3.2 Method of Data Collection

Participants in this study included Client, Consultants & Contractors of cause study road projects. The survey was administered through an online platform, specifically KoboToolbox, and all respondents received a comprehensive explanation of the study's purpose and methodology. To enhance responders' comprehension, clear instructions were provided. It's important to note that the information collected was treated with utmost confidentiality. The key data for the study were gathered through surveying those involved in project construction.Secondary sources of information included Department of Roads (DoR) reports, project office completion reports, and articles publishe in national daily newspapers and online publications.

For mitigating measures KII, Field observations, interviews and Expert opinion was taken and the obtained data is analysed for priority and reliability.

3.3 Population and Sample size

Since the study is based on 22 road projects (2 projects form 11 Districts of Gandaki province) suffering from time and cost overrun. The study population of this research is based on the no of technical staff directly involved in the construction of above mentioned 22 road projects funded by GoN as shown in Table 9.

Table 9: Total number of Technical staffs involved

Catagory	Owner	Consultant	Contractor
PM	11	11	22
R.E.	11	11	22
S.I/S.E	22	22	22

PM = Project Manager R.E. = Road Engineer
S.I/S.E = Site Incharge /Sub Engineer

4. Data Analysis,Results and discussion

4.1 Responses to Questionnaire

Total of 154 questionnaire were distributed via KoboToolbox forms. Total of 109 responses received which is 70.78%. From Clients/Employers there were 42 respondents in this category, comprising approximately 38.53% of the total. From Consultants 39 respondents, making up about 35.78% of the total. Contractors responses were 28 , accounting for approximately 25.69% of the total. This data shows significant number of participation from all three parties, therefore we

can say that data obtained will be equally representative from all parties.

4.2 Reliability Checking of Data

The internal consistency indicator Cronbach's alpha measures how well replies from Clients, Consultants, and Contractors correlate with one another as a set of items. Higher values of the coefficient, which has a range from 0 to 1, indicate stronger internal consistency. The value 0.982 is significantly higher than the threshold, indicating that the information gathered from this study is very reliable for analysis as well as drawing conclusions.

4.3 Justification of Productivity effect on Project Performance Parameter

To move forward on this study, it was required to justify the productivity has effect or significantly contributes to the projects key performance parameter-Time, Cost and Quality. It was done through the first confirmatory question for the study and 100% responses indicated productivity has significant role.

Value	Frequency	Percentage
Yes	108	99.08
Manually-Very significantly	1	0.92

Figure 3: Responses whether the productivity of key earth mover's has significant role in project's performance

4.4 Correlation between the views of Three parties & Hypothesis testing

As shown in Table 10 the correlation between the parties about their views is found to be significant.

Table 10: Spearman's Rank Correlation Coefficient

Value of (k)	87
Between Client & Consultant	0.792
Between Consultant & Contractor	0.704
Between Client & Contractor	0.696

It can be conclude that there are positive monotonic relationships between all three pairs of variables. The strength of the relationships varies, with the Client-Consultant relationship being the strongest, followed by the Consultant-Contractor and Client-Contractor relationships. Hypothesis was established to further validation of views of three parties using T-statistics (p-value approach). the p-value is significantly lower than 0.05, level of significance in all cases as shown below. The result confirmed rejection of null hypothesis of no relationship to accept alternative hypothesis of strong relationship between Client, Consultant and Contractor's view.

Table 11: p-value (less than 0.05) between parties view

Parties	p-value
Client & Consultant	1.593×10-15
Consultant & Contractor	1.563×10-10
Client & Contractor	1.090×10-9

4.5 Most important 25 factors from RII

After obtaining data , Relative Importance Index (RII) of each group was calculated and overall ranking was done based on RII data. This RII subsequently gives idea for mitigation measures to the most crucial factor.Operator Skill is found to be most crucial factor followed by Operator's Experience. Similarly Condition of equipmnet, skilled labour availability, Proper Equipment Selection and Equipment Specification are among crucial factors.The top most 25 factors found are shown in Table 12.

Table 12: Top 25 crucial factors effecting productivity of Key Earthmovers

FACTOR	RANK
Operator Skill	1
Operator's Experience	2
Condition of Equipment	3
Skilled Labor Availability (Operator, Mechanics etc.)	4
Proper Equipment Selection Equipment Specification	5
Insufficient no of Equipment	6
Mental and Physical Health of Operator	7
Frequent Equipment Breakdown	8
Site Condition	9
Repairs and Maintenance of Equipment	10
Proper planning of Equipment Schedule throghout the project	11
Routine Checkup of equipment	12
Effective Work Scheduling	13
Improbable planning/management and Expectation of Labour Execution	14
Drawings , line and Level not provided	15
Land Acquisition completion before construction begins	16
Slow Decision Making	17
Lack of Supervision	18
Spare Parts not Available	19
Insufficient feasibility, inadequate and inaccurate investigations	19
Lack of Training	21
Class of Material/Type of Soil	22
Delay in obtaining permits (Forest , conservation area permits etc.)	23
Age of Equipment	24
Defective design and Rework	25

4.6 Overall Group factor effect on Time, Cost and Quality

The study also examined overall group factors effect on the key performance parameters of project, i.e. it was to be known

that which group is more considerable for productivity enhancement and mitigation measures findings. The results is shown in Figure 4.

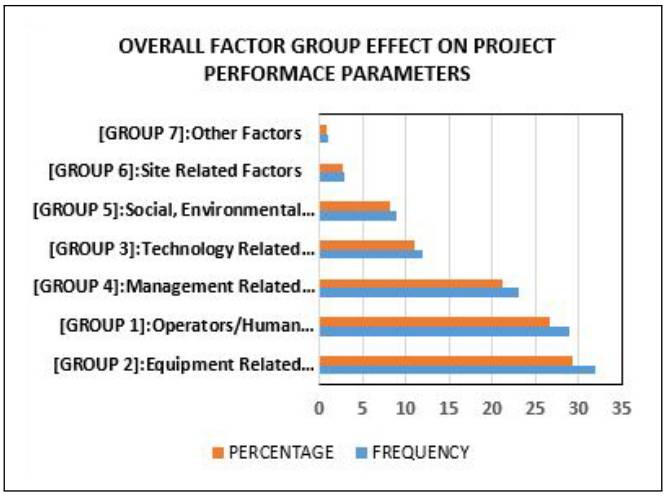

Figure 4: Group of Factor with key effect on productivity

Equipment Related Factors: This is the most frequently mentioned group, with 32 respondents (29.36%) identifying factors related to equipment as significant.The highest ranked sub factor is "Condition of Equipment".

Operators/Human Related Factors: The second most common group is operators and human-related factors, with 29 respondents (26.61%) highlighting their importance..The highest ranked sub factor is "Operator Skill".

Management Related Factors: Management-related factors are also noteworthy, with 23 respondents (21.1%) recognizing their significance. .The highest ranked sub factor is "Insufficient no of Equipment".

Technology Related Factors: Technology-related factors are mentioned by 12 respondents (11.01%).The highest ranked sub factor is "Inadequate Modern Equipment System/New Technology"indicating that a smaller but still substantial group recognizes the importance of technology in n the productivity of key earth movers.

Social, Environmental, and Regulatory Factors: This group garnered 9 respondents (8.26%). It suggests that a modest proportion of participants consider factors related to social, environmental, and regulatory aspects.The highest ranked sub factor is "Land Acquisition completion before construction begins"

Site Related Factors: Site-related factors are identified by only 3 respondents (2.75%). . The highest ranked sub factor is "Site Condition"

Other Factors: Only 1 respondent (0.92%) mentioned other factors.The highest ranked sub factor is "Drawing, line and level not provided in time."

4.7 Mitigation Measures

A total of 37 mitigation measures were identified thorough KII and expert opinion. Seventeen of them are categorised as A. Precautionary Strategies and twenty are categorised as B. Project Management Strategies. For the reliability of the outcome, once again the reliability and internal consistency was checked by calculating Cronbach's alpha, of which the value was found to be 0.895 , this means obtained data is reliable to draw results. The RII was calculated for both categories and presented in Table 13 (A. Precautionary Strategies) and Table 14 (B. Project Management Strategies).

Table 13: A. Precautionary Strategies

PRECAUTIONARY STRATEGIES	RANK
Mandatory Certification from a authorized body for operators	1
Reasonable wages and benefits to Operators and Helpers	2
Arrangement of weather monitoring system for early warning	3
Conduction of Regular Training Programs to Operators	4
Manage the fuel in advance to avoid shortage	5
Formulation of robust maintenance and inspection program	6
Right equipment selection for the targeted job	6
Use of Excellent Quality hydraulic oils and parts	6
Conduct safety audits and drills	6
Implement Fuel Monitoring system	10
Develop achievable work schedule for all parties	10
Ensure the sufficient fund/Budget is available to the project	10
Update and follow regulatory requirement from GoN	10
Prepare and clear the site before work starts	10
Provision of Safety,Healthcare and Wellness to staffs	15
Detail project study works	15
Stock inventory for critical spare parts that are frequently needed	17

Table 14: B. Project Management Strategies

STRATEGIES	RANK
Establish a reliable supply chain for equipment, fuel, and accessories	1
Placing best economic brand available	2
Align project schedules with seasonal weather patterns	2
Make payments in time to operators and helpers	4
Identifying early warning signs related to project disturbances	5
Establish inventory of parts and pre-deal with vendors	5
Maintain daily log books project diaries	7
Establish regular communication with government agencies and local stakeholders	7
Establish a good communication measure	7
Regular safety monitoring	7
Regular update in schedule along with the change in logic and sequences	11
Good parking and laying space at site	11
Deal realistically with site conditions	13
Managing interfacing activities	13
Process, approve and execute changes in timely manner	15
Have a comprehensive baseline schedule	15
Avoid Defective design and Rework	15
Providing adequate authority at the job site so that quick decisions for changes could be made	15
Develop fuel-efficient operating procedures	19
Implement surveillance and monitoring system	19

5. Conclusion and Recommendations

5.1 Conclusion

The study's major conclusions are summed up as follows:

1. The 66 factors have been identified from various literatures, interviews with experts finalized in consultation with the supervisor and grouped into 7 categories. The survey's data

showed strong internal consistency, as shown by the Cronbach's alpha value of 0.982.

2. The top 3 most crucial groups of factors that affect in productivity of earthmovers have been identified as **Equipment Related Factors** (29.36%), **Operator/Human Related Factors** (26.61%), and **Management Related Factors** (21.1%). Also, the majority of respondents stated that if a group factor occurs there is a significant effect on project performance parameters i.e. Time, Cost & Quality.
3. In further analysis of only factor crucial on productivity, the top 10 important factors as per their RII found to be **Operator Skill** (0.91), **Operator's Experience** (0.88), **Condition of Equipment** (0.86), **Skill labor availability (Operator, Mechanics etc.)** (0.84), **Proper Equipment Selection-Equipment specification** (0.84), **Insufficient no of Equipment** (0.83), **Mental and Physical Health of Operator** (0.83), **Frequent Equipment Breakdown** (0.83) **Site condition** (0.82), and **Repairs and Maintenance of Equipment** (0.82).
4. The analysis showed a notable correlation between the opinions of the Clients/Employers, Consultants, and Contractors, showing the agreement on the factors affecting productivity. Also hypothesis testing using t-statistics (p-value approach) further strengthens the result.
5. Thirty Seven (37) mitigating methods were found by the study through Key Informant Interviews (KII) and professional expertise. As a part of possible mitigation and enhancing measures of the factors the most important **precautionary strategie**s have been found as Mandatory Certification from an authorized body for operators (0.94), Reasonable wages and benefits to Operators and Helpers (0.88), Arrangement of Weather monitoring system for early warning (0.86), and Conduction of Regular Training Program to Operators (0.84). Similarly, as a part of **project management measures**, top strategies have been found to Establish a reliable supply chain for equipment (0.92), fuel, and accessories, placing the best economic brand available (0.88), Align Project Schedule with seasonal weather patterns (0.88), make payments in time to operators and helpers (0.84) and identifying early warning signs related to project disturbances (0.82).

5.2 Recommendations

The following recommendations have been made based on the study:

1. The key earthmoving equipment mobilized in the construction site should be in good condition with routine and proper maintenance to avoid frequent equipment breakdown. The selection and mobilization (number) of equipment must be done properly considering planned progress, site condition, and equipment capacity.
2. Equipment operators must be skilled and experienced in the required working environment. Regular Training & certification programs for skill enhancement and human resource development are strongly recommended. The payment and logistics have to be properly managed.
3. The management should formulate realistic, effective, and achievable work progress, and accordingly, the resource plan has to be done. Cash flow arrangements, proper site facilities, smooth supply of fuel/lubricants, and replacement parts are key recommendations.
4. Technology like GPS and Machine Control Systems shall be integrated to track the work progress for productivity improvement.
5. Clearance of site for work like Land acquisition, Environmental approvals, Reallocation of utilities & RoW has to be finalized prior to the beginning of construction & as per contract.

6. Further Research

The limitations of this study area as recommendations for further work.

1. Further study based on the actual calculation of loss to the project due to productivity decrease of key earthmovers in terms of time and cost can be done.
2. Further analysis using ANN and mathematical modeling for optimized productivity can be done considering the constraints.
3. Taking all regions, weather & condition, a real-time productivity effecting factors and evaluation may be done.

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