Prioritization of Programs and Projects of the Department of Science and Technology for Endorsement to the Public Investment Program (PIP) of the National Economic and Development Authority (NEDA) using Analytic Hierarchy Process (AHP)

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Abstract

This study utilized the Analytic Hierarchy Process, one of the most inclusive systems which are considered to make decisions with multiple criteria. This paper analyzes the prioritization of DOST programs and projects for endorsement to the Public Investment Program (PIP) of the National Economic and Development Authority (NEDA).

Keywords

Analytic Hierarchy Process, Public Investment Program

1. Introduction

The NEDA is the authorized body to spearhead the necessary activities for the formulation or preparation of development planning and investment programming reports and other documents. This includes the Public Investment Program (PIP) reports which contain the proposed and ongoing priority programs and projects (PAPs) that are responsive to the outcomes and outputs reflected in the Results Matrices (RM) of the 2017-2022 Philippine Development Plan (PDP). NEDA then consolidates, processes, and endorses the PAPs to the Department of Budget and Management (DBM) to which will be utilized for the preparations of the annual National Government (NG) budget. Following the said responsibility of NEDA, every year, they release a timetable of activities and submissions needed for the budget preparation process. Each agency or office is required to submit a rolling list of priority PAPs which contributes to meeting the PDP targets and achieving RM outcomes.

The Department of Science and Technology (DOST) is the premier science and technology body in the country charged with the twin mandate through Executive Order No. 128 of providing central direction, leadership and coordination of all scientific and technological activities, and of formulating policies, programs and projects to support national development. It is composed of three (3) sectoral planning councils, seven (7) research, and development institutes, six (6) science and technology (S&T) service institutes, two (2) collegial bodies, and 16 regional offices.

Given this number of attached agencies and offices, it is expected that DOST will generate hundreds of PAPs in total. It is the job of the Central Office to consolidate, review, process, and submit to NEDA all the determined PAPs of DOST.

PAPs are being approved by NEDA based on the following criteria: responsiveness, readiness, and typology. It is the responsibility of the Central Office to filter all submitted DOST PAPs. The last update, prior to this study, which is in 2018, out of the 1,022 DOST system PAPs endorsed, 955 were able to pass through NEDA to DBM. This is in preparation for the Fiscal Year (FY) 2020 budget call.

For the preliminary part of the analysis, the researchers looked at various perspectives to analyze the demographic summary of the given data. Available data shows the priority programs and projects endorsed by DOST in the recent updating of the 2017-2022 public investment program and the formulation of the 2021-2023 three-year infrastructure program. This is in preparation for the FY 2021 budget call. The researchers will focus on the 1,203 PAPs submitted by the DOST system - DOST Office of the secretary (OSEC) and 18 attached DOST agencies in October 2019 (Table1).

Table 1. DOST Priority Programs and Projects Endorsed to NEDA in October 2019

AGENCY	Investment PAPs	Infrastructure PAPs	TOTAL
DOST-OSEC*	75	120	195
PCAARRD	354	9	363
PCHRD	17	1	18
PCIEERD	26	1	27
NAST	0	2	2
NRCP	14		14
ASTI	18	2	20
FNRI	5	2	7
FPRDI	3	10	13
ITDI	0	25	25
MIRDC	13	14	27
PNRI	0	14	14
PTRI	0	7	7
PAGASA	33	5	38
PHIVOLCS	11	0	11
PSHS	0	402	402
SEI	1	1	2

*DOST-OSEC comprises the Central Office and 16 Regional Offices

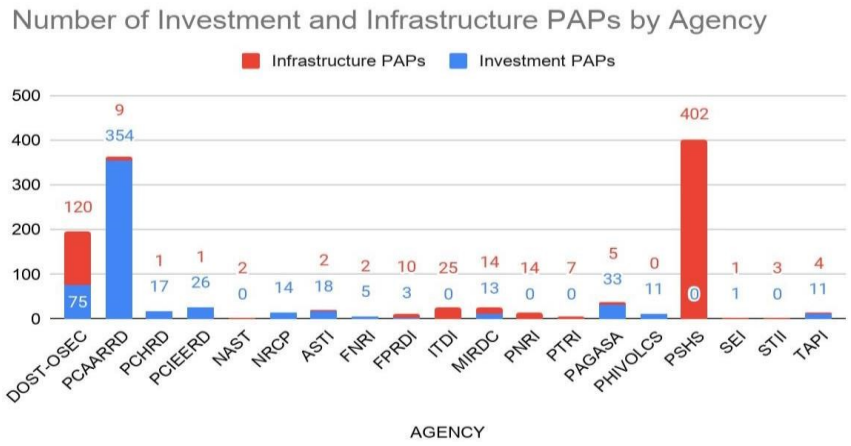


Figure 1. The number of investments and Infrastructure Programs and Projects by agency

Figure 1 shows the number of investments and infrastructure programs and projects by agency. The success of this study will have a significant implication on the evaluation of DOST programs and projects for endorsement to the Public Investment Program. The results of this study will provide insights into the policy and decision-makers on where to give attention to the endorsement of PAPs.

2. Methodology

This study used the I-P-O framework as shown in Figure 2.

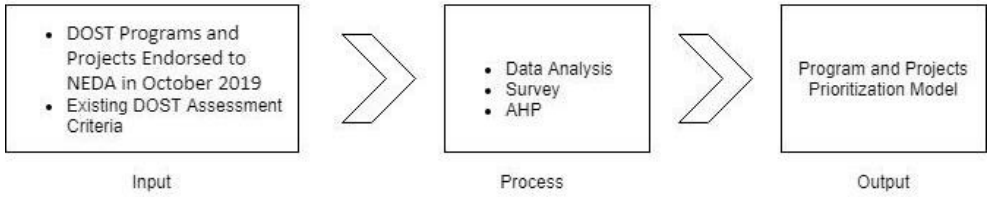


Figure 2. The framework of this study

The researchers conducted data analysis to identify the ranking of priority programs and projects submitted by the attached agencies and regional offices.

The AHP method is a robust and flexible tool for dealing with complex decision problems highlighted by (Mehdi Zandebasiri, 2016). This method divides a complicated system into a hierarchical system of elements, which usually includes objectives, evaluation criteria, and alternatives. The evaluation criterion level may be composed of various valuation criteria which can be also extended into a multi-layer structure. By weighting various evaluation criteria according to the objectives, as well as the alternatives from the viewpoint of each evaluation criterion, the final scores of the alternatives are determined. The pairwise comparisons are made of the elements of each hierarchy by means of a nominal scale. Then, comparisons are quantified to establish a comparison matrix, and the eigenvector of the matrix is derived, which signifies the comparative weight amongst various elements of a certain hierarchy. Finally, the eigenvalue is used to assess the strength of the consistency ratio of the comparative matrix and determine whether to accept the information. The conventional AHP method is a quantitative technique, that is, it does not directly allow the DMs to handle decision problems when they may be uncertain about their level of preference due to incomplete information or knowledge, complexity, and uncertainty inherent in the decision environment, or lack of an appropriate measure or scale. In these cases, it is easier to determine relative preferences by linguistic values such as “extreme priority", “very strongly priority”, “strong priority”, “moderate priority” or “equally priority” rather than by specific values of an agreed assessments scale.

As Sirous Yasseri (7th May 2016) cited, AHP is a qualitative method and very much dependent on the assessors' point of view. In an unbiased experience, you will find that the consistency index is far from ideal. Those who have the method and have time, they will tinker with numbers until they get a good consistency index.

Hence the researchers used the AHP and modeled how DOST-CO prioritize projects and programs as shown in figure 3.

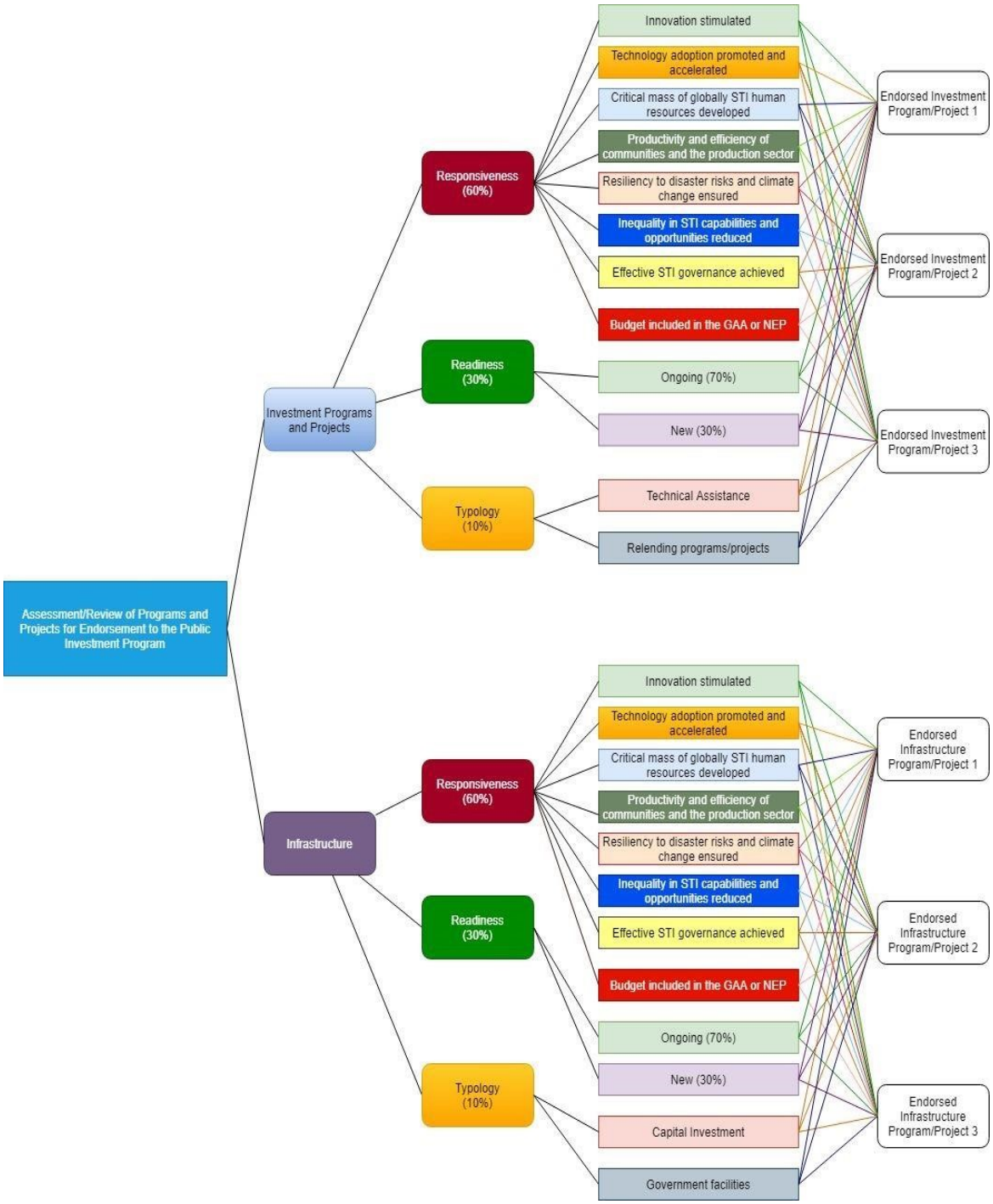


Figure 3. AHP Model and Framework of Assessment/Review of Priority Programs and Projects

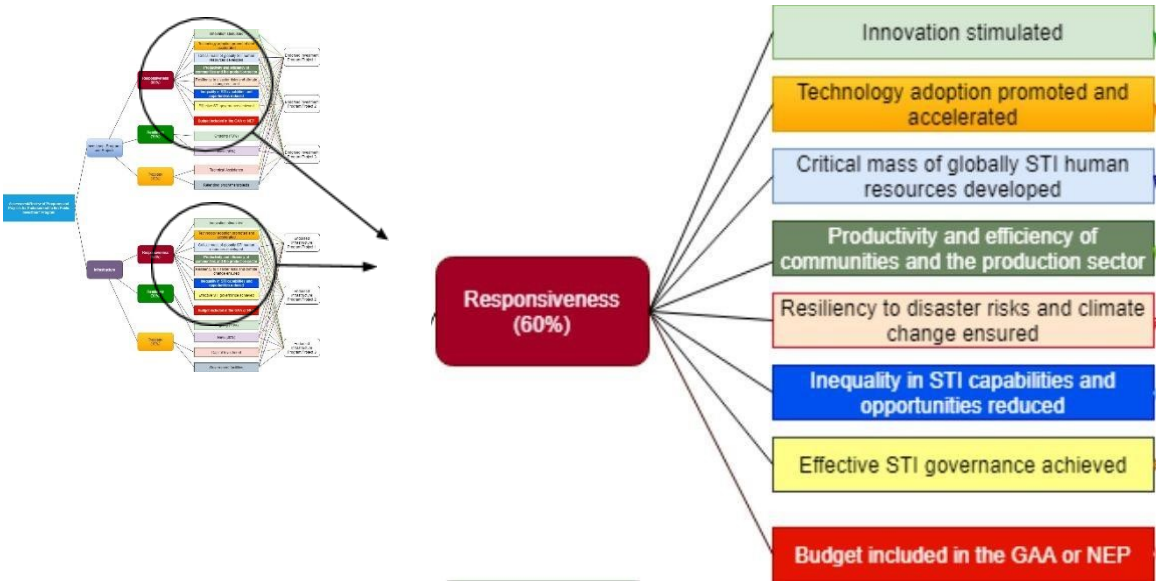


Figure 4. AHP Model and Framework of Responsiveness for Investment and Infrastructure Priority Programs/Projects

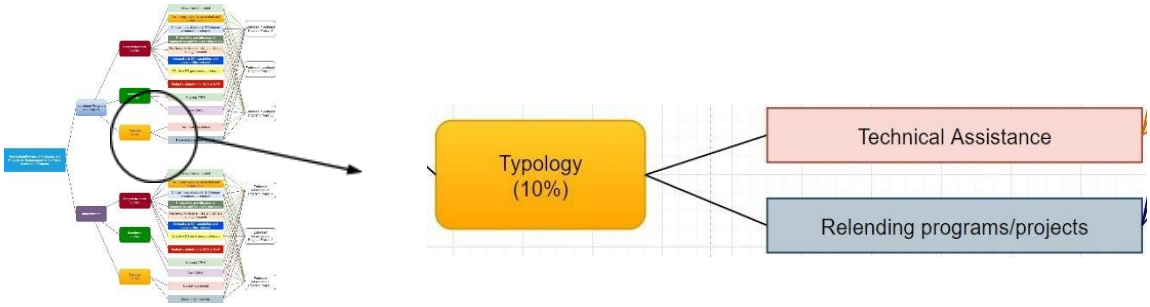


Figure 5. AHP Model and Framework of Typology for Investment Priority Programs and Projects

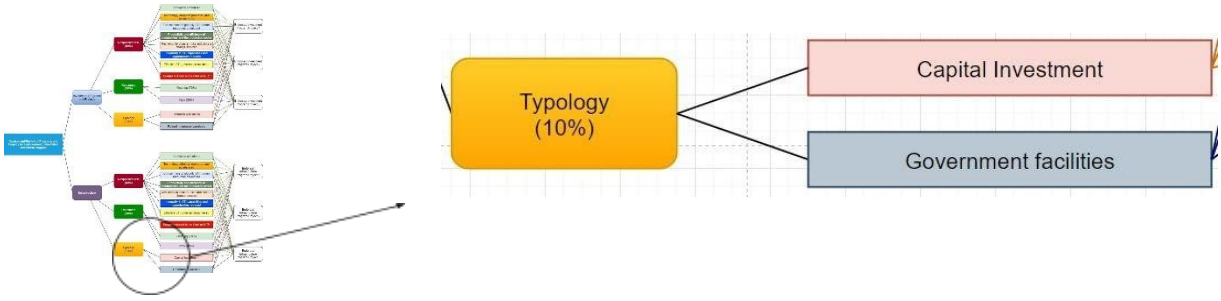


Figure 6. AHP Model and Framework of Typology for Infrastructure Priority Programs and Projects

The researchers identified the following main and sub-criteria

1. Responsiveness for both Investment and Infrastructure (Figure 4)
    a. **Innovation stimulated** - stimulate innovation, strengthen and utilize Research and Development (R&D) capabilities, R&D programs under the Harmonized National Research and Development

Agenda (HNRDA) are implemented. Priority R&D areas implemented and funded primarily focused on integrated basic research, health, agriculture, aquatic and natural resources, industry, energy, and emerging technology and disaster risk reduction and climate change adaptation.

b. **Technology adoption promoted and accelerated** - Technology adoption allows the country's firms and people to benefit from the results of innovation. In particular, the results of R&D will be further developed until they are transformed into products, processes, and services for the benefit of the people. Technology transfer and commercialization activities and support services will be strengthened.
c. **Critical mass of globally STI human resources developed** - provides scholarship and training programs to entice more students to pursue S&T careers as well as develop S&T leaders and professionals that will drive innovation and contribute to national progress.
d. **Productivity and efficiency of communities and the production sector** - addressed through programs, projects, and activities related to the provision of STI services and setting-up, upgrading, and maintaining STI facilities for MSMEs, startups, and spinoffs.
e. **Resiliency to disaster risks and climate change ensured -** enhancing monitoring and warning systems; intensifying provision of products, information, and services; and leveling up of knowledge and capacities on DRR-CCAM and reducing the effects of disaster risks and climate change in the country.
f. **Inequality in STI capabilities and opportunities reduced** - reduce the inequality in STI capacities and opportunities by setting up and upgrading R&D facilities and equipment in different Higher Education Institutions (HEIs) in the regions and implementing STI programs in these areas to spur R&D activities and innovation.
g. **Effective STI governance achieved -** programs, projects, and activities, internal processes, and capacities are improved. It also necessitates the development, review, and updating of policies that govern the STI ecosystem.
h. **Budget included in the GAA or NEP** - projects that are included and funded through the General Appropriations Act (GAA) or already in the actual implementation/construction stage of the project.

2. Typology to Investment Programs and Projects (Figure 5)
    a. **Technical Assistance** - PAPs such as research and development, institutional development, human resource capacity building or system/process improvement
    b. **Re-lending programs/projects** - re-lending PAPs to local government units (LGUs) or other target beneficiaries

3. Typology to Infrastructure (Figure 6)
    a. **Capital Investment** - projects to deliver public goods and services that contribute specifically to the country's productive capacity (e.g. infrastructure)
    b. **Government Facilities** - part of the agencies' development strategies and contributing to the outcome and output targets

The next step involves carefully defining the hierarchy structure. It consists of a set of ethics and sub-standards that outline the elements that should influence the goal. In the last level, we define different alternatives. Following the purpose of identifying and establishing the hierarchy, the AHP rated each criterion according to a review and comparison of each pair of criteria using the Saaty Scale.

With respect to AHP priorities, which criterion is more important, and how much more on a scale of 1 to 9 defined in Table 2.

Table 2. Rating Scale for Pairwise Comparison

PRIORITY	SCALE DEFINITION OF PRIORITY SCALE	EXPLANATION
1	Equal Priority	Two qualifications contribute equally to the program cluster
2	Equal to Moderate Priority	Appraisal slightly favor one qualification over the other
3	Moderate Priority	
4	Moderate to Strong Priority	Appraisal strongly favor one qualification over the o
5	Strong Priority	
6	Strong to Very Strong Priority	One qualification is very strongly favored over the other
7	Very Strong Priority	
8	Very Strong to Extreme Priority	The appraisal favoring one qualification over the other is of the highest possible order of affirmation
9	Extreme Priority	

As part of this, the pairwise comparison matrix will be established through the calculation of Eigenvalue and Eigenvector. The Eigenvalue and Eigenvector formula can be seen below:

$$\text{Eigenvalue: } \lambda_{max} = \sum_{j=1}^{n} a_{ij} \frac{w_j}{w} \quad (1)$$

$$\text{Eigenvector: } (A\lambda \text{ max } I)\ X = 0 \quad (2)$$

In addition to the above, as this study will be utilizing the pairwise comparison, it is important to assess the consistency of the comparison matrix, hence, it requires the utilization of consistency ratio (CR) (Saaty,1990). The formula for CR can be seen below:

$$\text{Consistency Ratio: } CR = CI / RI \quad (3)$$

The following AHP Identification of the decision or the objective processes has been made by the researchers as shown in figure 7.

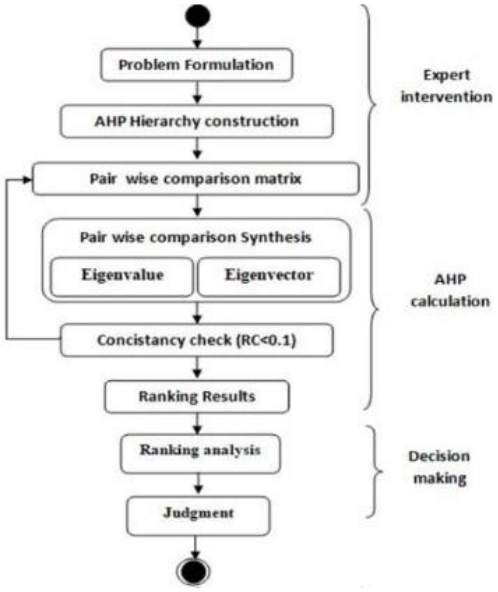


Figure 7. The AHP Process

Using a geometric means to "normalize" the sequences was reached so that no range was exceeded, and a given percentage change in any property explained the same geometric effect. Geometric importance relates to the transformation of logarithmic data.

Compared to the arithmetic mean, the geometric mean is said to be 'not overly influenced by the very large values in a skewed distribution'. The choice of measure of location may not always be so straightforward. Alfonso J. RodriguezMorales (13th Jan 2015) quoted

The researchers calculated the AHP Geo Mean of the survey submitted by the respondents and calculated to create the AHP model. Lastly, they compared the developed AHP model and results from data analysis.

3. Results and Discussion

Table 3. Resulting weights for the responsiveness criteria based on the geomean pairwise comparisons

Investment Programs and Projects	Infrastructure
See table below	See table below
# of comparisons = 28 Consistency Ratio CR = 5.5%	= 28 = 9.1%

Cat		Priority	Rank	(+)	(-)
1	Innovation stimulated	28.5%	1	11.6%	11.6%
2	Technology adoption	4.4%	6	2.0%	2.0%
3	STI human resource development	18.0%	3	7.4%	7.4%
4	Productivity and efficiency of communities	4.9%	5	1.9%	1.9%
5	Disaster risk and climate change resiliency	13.4%	4	4.6%	4.6%
6	STI capabilities and opportunities	2.9%	7	0.7%	0.7%
7	Effective STI governance	2.2%	8	0.9%	0.9%
8	Budget included in the GAA or NEP	25.7%	2	11.0%	11.0%

Priority	Rank	(+)	(-)
11.4%	4	6.1%	6.1%
6.0%	5	3.6%	3.6%
32.0%	1	19.4%	19.4%
4.3%	6	2.0%	2.0%
22.3%	2	8.7%	8.7%
2.8%	7	1.3%	1.3%
1.8%	8	0.9%	0.9%
19.3%	3	6.2%	6.2%

Table 3 presents the pairwise comparison results of the alternatives and the criteria with the respective consistency ratio (CR). Twenty-eight (28) comparisons were generated to produce this result. Results from the computation show that both the CRs for the responsiveness for investment programs and projects and for infrastructure are less than 10%. This is a good sign that the measurement of the assessment for endorsed programs and projects from the DOST agencies and regional offices using the AHP model is trustworthy or reliable.

Table 4. Resulting weights based on the principal eigenvector of the mean decision matrix

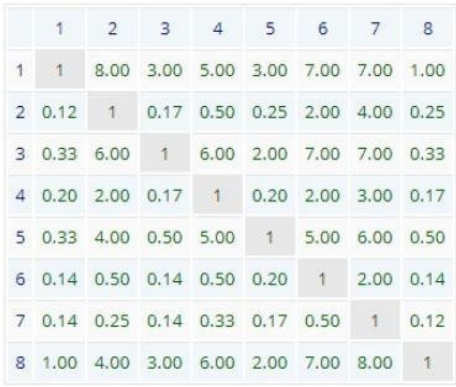
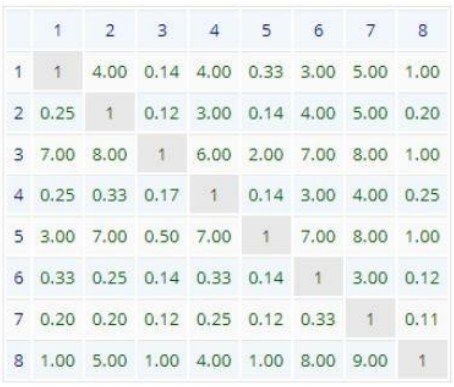
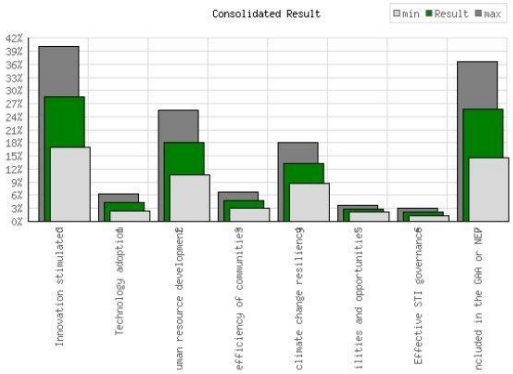
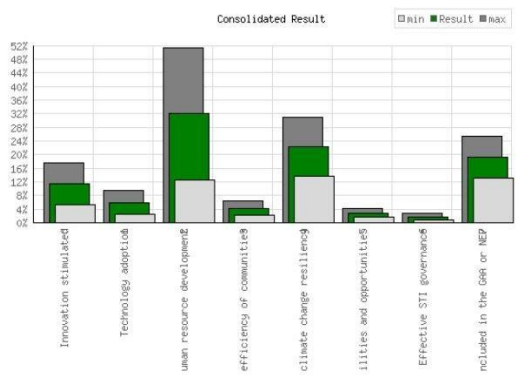
Investment Programs and Projects	Infrastructure
	
Principal eigenvalue = 8.542	= 8.892
Eigenvector solution 6 iterations, delta 1.3E-8	= 7 iterations, delta 1.8E-8
	

Table 4 shows the resulting weights based on the principal eigenvector of the mean decision matrix with respective consistency ratio (CR). All values show consistency with CR ranging from 0.14% to 8%. This shows that responsiveness for investment and infrastructure PAPs are below 10% and that measurement of the assessment for endorsed programs and projects from the DOST agencies and regional offices is trustworthy or reliable using the AHP model is trustworthy and reliable across all criteria.

Table 5. Resulting weights for the typology criteria based on the geomean pairwise comparisons

Investment Programs and Projects	Infrastructure
	

Number of comparisons = 1 Consistency Ratio (CR) = 0.0% Principal eigenvalue 2.000 Eigenvector solution 1 iterations, delta = 0.0E+0	Number of comparisons = 1 Consistency Ratio (CR) = 0.0% Principal eigenvalue 2.000 Eigenvector solution 1 iterations, delta = 0.0E+0

Table 5 presents the pairwise comparison results of the alternatives and the resulting weights based on the principal eigenvector of the mean decision matrix with respective consistency ratio (CR). Only one comparison was generated to produce this result. Results from the computation show that both the CRs for the responsiveness for investment programs and projects and for infrastructure are both 0%. This shows that both This also holds true that the AHP Model is a trustworthy and reliable measurement of the assessment for endorsed programs and projects from the DOST agencies and regional offices.

After generating results with the preliminary tests and showing that performing AHP is appropriate for this study, the succeeding results show the actual data from endorsed DOST investment and infrastructure PAPs and the recommended prioritization based on the AHP Model.

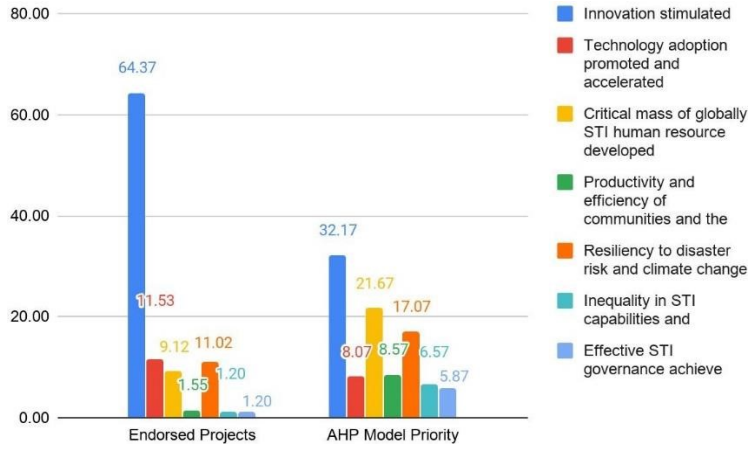


Figure 8. Actual Data vs AHP in percent - Responsiveness for Investment

Figure 8 shows the actual data for responsiveness for investment and the result of the AHP in percentage. Innovation stimulated investments as the top priority for both results. However, it is halved in the AHP Model, giving more opportunities to other investments such as investments focusing on developing a critical mass of globally competitive STI human resources, which went up from 9.12% in the actual data to 21.67% in the AHP Model. Similar cases are also true with investments that focus on the improvement of the productivity and efficiency of communities and the production sector, particularly MSMEs, ensuring resilience to disaster risk and climate change, reducing inequality in STI capacities and opportunities, and achieving an effective STI governance. Only investments that focus on the promotion and acceleration of technology adoption revealed a lower percentage from the actual data as compared to the AHP Model data.

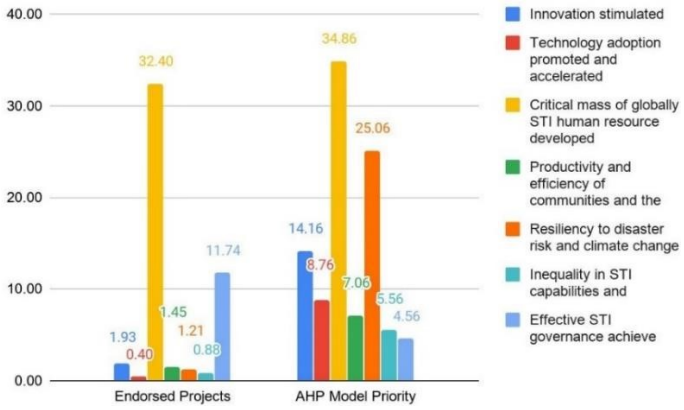


Figure 9. Actual Data vs AHP in percent - Responsiveness for Infrastructure

Figure 9 shows the actual data for responsiveness for infrastructure and the result of the AHP in percentage. Infrastructures for developing a critical mass of globally competitive STI human resources reveal as the top priority for both results and have about the same percentage for both datasets. Infrastructures for stimulating innovation, the improvement of the productivity and efficiency of communities, and the production sector, particularly MSMEs, and reducing inequality in STI capacities and opportunities increased its priority percentage by about five to seven times in the AHP Priority Model. Priority percentage for infrastructures for ensuring resilience to disaster risk and climate change and promotion and acceleration of technology adoption increased by more than 20 times in the AHP Model. Priority percentage for Infrastructure for achieving an effective STI governance was decreased to about half of the actual data.

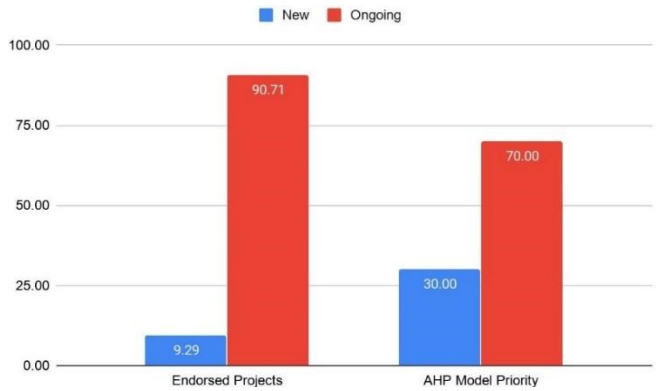


Figure 10. Actual Data vs AHP in percent - Readiness for Investment

Figure 10 shows the readiness for the investment of new and ongoing projects based on actual data from endorsed projects and results from the AHP Model. It shows that ongoing projects are more prioritized in both the actual data and the AHP Model. However, more new projects are given priority in the AHP Model.

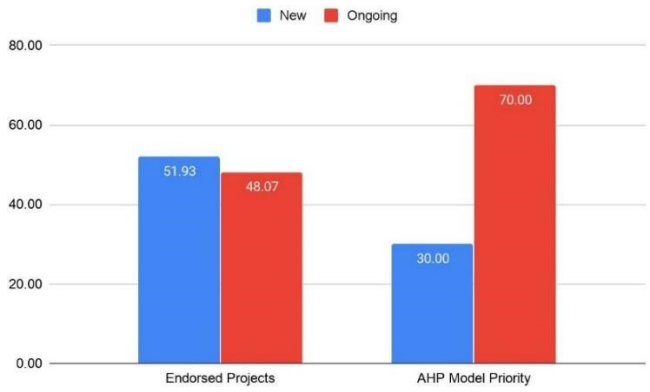


Figure 11. Actual Data vs AHP in percent - Readiness for Infra

Figure 11 shows the readiness for the infrastructure of new and ongoing projects based on actual data from endorsed projects and results from the AHP Model. Actual data from endorsed projects shows that both new and ongoing projects are prioritized for about the same percentage. However, according to the AHP Model, more priority should be given to ongoing projects as compared to new projects.

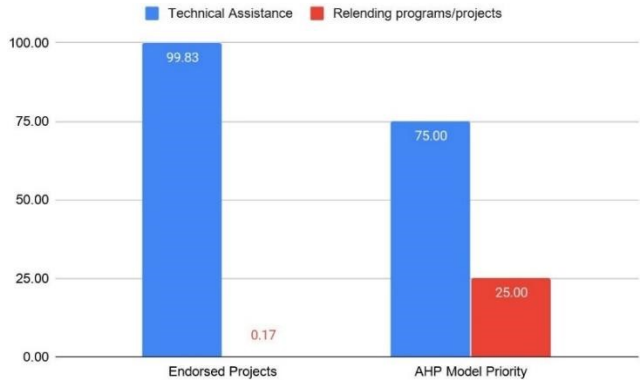


Figure 12. Actual Data vs AHP in percent - Typology for Investment

Figure 12 shows the priority given to DOST PAPs in terms of their typology for investment as based on actual data from endorsed projects and results from the AHP Model. Actual data from endorsed projects shows that there is a minute priority given to programs and projects that are based on re-lending.
However, according to the AHP Model, a quarter of the re-lending PAPs should be given priority.

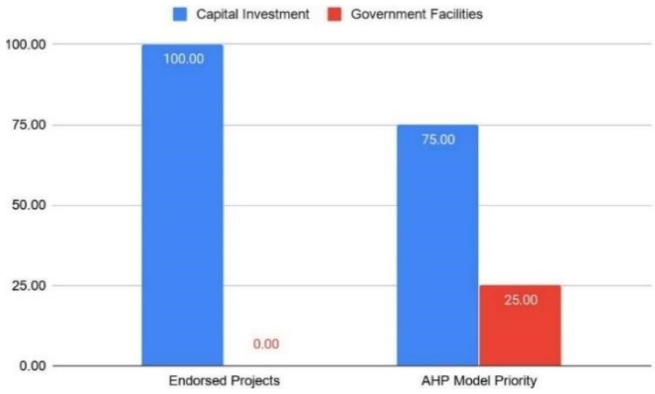


Figure 13. Actual Data vs AHP in percent - Typology for Infrastructure

Figure 13 shows the priority given to DOST PAPs in terms of their typology for infrastructure as based on actual data from endorsed projects and results from the AHP Model. Like the results shown in Figure 12, actual data from endorsed projects shows that all infrastructures dedicated to capital investments. Similar results as in Figure 12 are also generated, in which according to the AHP Model, a quarter of the PAPs that are for government facilities should be given priority.

3.1. Discussion

Respondents of this survey are from the three divisions of the Planning and Evaluation Service (PES). Out of ten involved personnel of PES, eight answered the survey. PES provides services relating to policy development and planning, program coordination and monitoring, and S&T resource assessment and evaluation matters.

As of this study, the DOST Central Office endorses all proposals submitted by the DOST system as long each PAP contains all requirements/documents needed by NEDA-PIP.

In this study, the researchers focused on the 1,203 PAPs submitted by the DOST system - DOST-OSEC (central office and 16 regional offices) and 18 attached DOST agencies in October 2019. Its findings may have been seen in the light of limitations on the control of data. The researchers were not able to get data on the approved prioritized PAPs from NEDA, this may be due to the current situation nationwide, the pandemic CoViD-19.

The AHP allows the researchers to classify the most important factors influencing the project or program priorities. Based on these findings, the three main factors for Investment are Innovation Stimulated, technology adoption, and STI Human Resource Development respectively. For Infrastructure programs or projects, STI Human Resource Development, disaster risk and climate change resilience, and Innovation stimulated respectively. The weights of each sub-criteria shown in Tables 3 and 5

Because of the use of AHP in the analysis of the project and program prioritization, this type of study is strongly related to its context and the results vary from one country to another and even from one institution to another.

The designed AHP model has good consistency ratios but the Actual Data is very far from the ideal AHP model as seen in the results of the conducted data analysis.

The reason amid the gap between the actual data and ideal AHP model shown in Figures 8 to 13 is because most DOST attached agencies are very focused on Innovation and they have no priority weighing tool resulting in neglection of the other priority areas.

4. Conclusion

The researchers utilized the Analytic Hierarchy Process, one of the most inclusive systems and considered to make decisions with multiple criteria. This paper analyzes the prioritization of DOST programs and projects for endorsement to the Public Investment Program (PIP) of the National Economic and Development Authority (NEDA). Innovation stimulated investments as the top priority for both results. However, it is halved in the AHP Model, giving more opportunity to other investments such as investments focusing on developing a critical mass of globally competitive STI human resources

Priority percentage for infrastructures for ensuring resilience to disaster risk and climate change and promotion and acceleration of technology adoption increased.

The developed AHP model was created to have fair, balanced and efficient prioritization of projects and programs

Innovation Stimulated, STI human resource development, and Disaster Risks and Climate Change Resiliency respectively should be considered as top priorities by the DOST

Thus, the researchers recommend DOST to test the effectiveness of the developed AHP model and possibly create a better policy on the assessment of new program and project proposals

References

Rodriguez-Morales, A. When to use Geometric Mean and Harmonic Mean Instead of Arithmetic Mean in Data Analysis, ResearchGate.Net, 13th, Jan 2015

Saaty, T. L. The Analytic Hierarchy Process, New York: McGraw-Hill, Inc., 1980.

Yasseri, S. Subsea Technologies Selection Using Analytic Hierarchy process, ResearchGate.Net, 7th May 2016.

Zandebasiri, M. Better decision-making processes AHP or FAHP, ResearchGate.Net, 4th May 2016

Biographies

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