Technical Due Diligence for Minihydro Power Plant Project in Indonesia

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Abstract. Technical due diligence as part of the bankability due diligence carried out by the bank for the minihydro power plant (MHPP) project which will be financed for its construction. This research is to determine important variables as the object of due diligence and to conduct technical due diligence based on the variables. The important variables as the object of due diligence were obtained from interviews with group of experts who have experience in the construction of MHPP. The results of the interviews were processed using the Relative Importance Index (RII) and the Analytical Hierarchy Process (AHP) method to determine the risk ranking/weight. The due diligence process is carried out on submitted project documents and onsite verification to three sample of MHPPs at West Sumatera Province, Indonesia. Based on the assessment to each variables to the sample MHPPs, we get result that one MHPP does not ready to be financed from a technical point of view.

Keywords. AHP, due diligence, minihydro, powerplant, RII

1. Introduction
The Business Plan for the Provision of Electricity of PT Perusahaan Listrik Negara (Persero) (RUPTL) for 2021 to 2031[1] states that there are still many additional needs for minihydro power plant (MHPP) in Indonesia, as the option as cheap renewable energy power. MHPP is a hydroelectric power plant with a capacity below 10 MW [2]. The report ASEAN Centre for Energy[3] also shows that the levelized cost of electricity of hydroelectric power in ASEAN countries is USD 0.044/kWh, lower than that of biomass power plants (USD 0.088/kWh).

One of the important things in the development of MHPP is the availability of funding to build the project. ICED-USAID states that funding for MHPP in general ranges from 65% to 75% of the total investment cost [4]. This means that the independent power producer (IPP) must be able to convince the banks that their MHPP project to be developed has mitigated the risks that may arise if it has received financing. One of the risks that must be mitigated is the risk related to technical aspects.

Many research discuss the technical feasibility study of MHPP in Indonesia, but they never mention what kind technical aspects need to be considered to make the project bankable (worthiness to be financed). There are many MHPP in have already signed power purchase agreement but have not obtained financial close yet [5].

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2. Method
Before the technical due diligence process is carried out, it is necessary to agree on what variables will be the object of the assessment. Therefore, a literature study and interviews from competent experts in the development of MHPPs were carried out. These variables are obtained using the Relative Importance Index (RII) and Analytical Hierarchy Process (AHP) method to get the ranking as well as the weighing of the frequency and the severity. The risk is multiplication between frequency and severity[6]. These variables include the stages of planning, construction, and operation. Figure 1 represents the research methodology.

![Research Methodology Diagram](image)

Figure 1: Research methodology

Based on the list of variables obtained through RII and AHP method, the technical due diligence process can be carried out. Data related to the MHPP Project is obtained from planning data (feasibility study, detailed engineering design and interconnection study), procurement and contracts (engineering contracts and machine purchase contracts), permit and licenses, PPA, and other data related to human resources.

3. Results and Discussions
3.1. Data Gathering and Processing
Interviews were conducted on 20 experts with technical backgrounds who have experience at least 2 MHPP projects. There are 11 important variables obtained from interviews and processed by RII and AHP Method.
Table 1: Important technical variables for technical due diligence

| Variable | Description | References |
|----------|-------------|------------|
| T1 | Quality of feasibility study | Feasibility studies made must include important things such as a description of geological conditions, hydrology, head, capacity factor. | [7],[8],[9],[10],[11],[12],[13],[14], Interviews |
| T2 | Detail engineering design (DED) for civil work | DED must be clear and detailed in providing information related to the type and specifications of the main building (dam/dam, intake, sand trap, waterway or tunnel, head pond or head tank, penstock, outlet) | [8],[15],[9],[10], Interviews |
| T3 | Mechanical and electrical design | The design of mechanical and electrical equipment must provide complete information about the specifications of the turbine and generator and transmission equipment. | [8],[9],[11],[14], Interviews |
| T4 | Local grid condition | The condition of the local electricity network must be able to absorb and distribute electricity production to the maximum and in safe conditions. | [7],[16],[17],[9],[15],[11],[18], [13], Interviews |
| T5 | Point of interconnection | The distance of the interconnection point should not be too far from the MHPP. | [19],[20], Interviews |
| T6 | Electricity load and its projections | The condition of the electricity load must be able to absorb the electricity generated by the MHPP to the maximum within the PPA period. | [13], Interviews |
| T7 | Experience of the IPP | The IPP must have experience in developing and operating MHPP. | [13],[21],[20], Interviews |
| T8 | Experience of the consultant | The Consultant must have experience in designing a MHPP, and the MHPP is already operating properly (at least 2 MHPPs) | [13], Interviews |
| T9 | Experience of the contractor | The Contractor must have experience in building a MHPP, and the MHPP is already operating properly (at least 2 MHPPs) | [7],[16],[8],[17],[9],[15],[10], Interviews |
| T10 | Operation & maintenance ability | The team appointed to carry out operation and maintenance activities must have been doing the same activity for at least 2 years. | [14],[21], Interviews |
| T11 | Supplier’s credibility | The supplier must have experience in supplying MHPP’s equipment in Indonesia, and the MHPP must have been operating properly (at least 2 MHPPs). | [7],[13], Interviews |

First interview is in order to obtain frequency index uses 5- Likert’s scale frequency. The question is how important the variable on the success of the MHPP Project. The result of interview is presented in Table 3, and the data is processed using RII method.

Table 2: Likert scale for RII method

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very unimportant | Not important | Fairly Important | Important | Very Important |


Table 3: Result of interview (Likert’s scale)

| Resp. (R) | Variables (T) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|----------|---------------|---|---|---|---|---|---|---|---|---|----|----|
| R1       |               | 3 | 4 | 2 | 4 | 4 | 4 | 4 | 2 | 4 | 1  | 3  |
| R2       |               | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2  | 2  |
| R3       |               | 3 | 4 | 3 | 4 | 2 | 4 | 3 | 3 | 3 | 2  | 2  |
| R4       |               | 3 | 4 | 1 | 2 | 3 | 3 | 3 | 4 | 4 | 2  | 2  |
| R5       |               | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 2  | 3  |
| R6       |               | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 2 | 2 | 2  | 2  |
| R7       |               | 3 | 1 | 1 | 3 | 2 | 3 | 2 | 1 | 3 | 2  | 2  |
| R8       |               | 2 | 3 | 2 | 4 | 3 | 4 | 2 | 2 | 3 | 2  | 2  |
| R9       |               | 3 | 1 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 1  | 2  |
| R10      |               | 5 | 2 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 2  | 2  |
| R11      |               | 4 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 2  | 2  |
| R12      |               | 4 | 4 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 1  | 2  |
| R13      |               | 3 | 3 | 2 | 4 | 2 | 4 | 3 | 2 | 4 | 2  | 2  |
| R14      |               | 3 | 3 | 3 | 1 | 1 | 3 | 1 | 3 | 3 | 2  | 2  |
| R15      |               | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3  | 3  |
| R16      |               | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3  | 4  |
| R17      |               | 4 | 2 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 2  | 2  |
| R18      |               | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4  | 4  |
| R19      |               | 2 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 | 1  | 1  |
| R20      |               | 4 | 4 | 3 | 4 | 2 | 3 | 5 | 4 | 5 | 3  | 4  |

Second interview is in order to obtain severity index uses 9-scale of Saaty’s number [22]. The question is how important the variable if compared with other variable with regard the effect on the success of MHPP project. Table 5 presents the geometric mean of result of interview from 20 respondents. The data in Table 5 is processed using AHP method.

AHP method is used to assess the severity that will be faced by a MHPP project caused by errors in mitigating technical aspects as listed in Table 1. Eigen factor as the result of AHP method is converted to severity index based on a severity scale which described on PMBOK Guide [23].

Table 4: 9-scale of Saaty’s number

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Equal importance | Moderate importance | Strong importance | Very Strong importance | Extremly important |
Table 5: Result of interview (9-scale of Saaty’s number)

|         | Geomean |         | Geomean |
|---------|---------|---------|---------|
| T1 vs T2 | 2 1/4   | T4 vs T5 | 2 3/4   |
| T1 vs T3 | 2 3/7   | T4 vs T6 | 1 5/8   |
| T1 vs T4 | 2 2/7   | T4 vs T7 | 2 3/4   |
| T1 vs T5 | 3 5/9   | T4 vs T8 | 2 3/5   |
| T1 vs T6 | 2 1/8   | T4 vs T9 | 2 2/3   |
| T1 vs T7 | 2 1/6   | T4 vs T10| 2 3/5   |
| T1 vs T8 | 2       | T4 vs T11| 3 1/9   |
| T1 vs T9 | 1 4/7   | T5 vs T6 | 1 3/5   |
| T1 vs T10| 2       | T5 vs T7 | 1 2/7   |
| T1 vs T11| 2 2/5   | T5 vs T8 | 1 1/2   |
| T2 vs T3 | 4       | T5 vs T9 | 1 2/5   |
| T2 vs T4 | 3 2/3   | T5 vs T10| 1 1/2   |
| T2 vs T5 | 3 3/4   | T5 vs T11| 1 3/4   |
| T2 vs T6 | 2 5/7   | T6 vs T7 | 2 2/5   |
| T2 vs T7 | 2 1/7   | T6 vs T8 | 2 4/7   |
| T2 vs T8 | 2 1/3   | T6 vs T9 | 2 1/2   |
| T2 vs T9 | 1 1/2   | T6 vs T10| 2 5/9   |
| T2 vs T10| 3 3/7   | T6 vs T11| 3       |
| T2 vs T11| 3 1/3   | T7 vs T8 | 3 5/6   |
| T3 vs T4 | 2 2/3   | T7 vs T9 | 3 1/4   |
| T3 vs T5 | 3       | T7 vs T10| 3       |
| T3 vs T6 | 2       | T7 vs T11| 2 2/7   |
| T3 vs T7 | 2       | T8 vs T9 | 2       |
| T3 vs T8 | 2 1/5   | T8 vs T10| 2 1/2   |
| T3 vs T9 | 1 1/2   | T9 vs T10| 3 1/2   |
| T3 vs T10| 2       | T9 vs T11| 3 1/5   |
| T3 vs T11| 1 3/4   | T10 vs T11| 1 6/7   |

Table 6 presents the risk level of each technical variable in Table 1. The risk level is the multiplication between frequency and severity [6].

Table 6: Frequency, severity, and risk rank for technical variable

| Frequency | Severity | Risk = Frequency x Severity |
|-----------|----------|-----------------------------|
| RII       | Rank     | Eigen          | Rank    | Risk level | Rank     | Weigh |
| T1        | 0.6300   | 1              | 0.1676  | 2          | 0.1056   | 1      | 21%   |
| T2        | 0.5600   | 2              | 0.1817  | 1          | 0.1018   | 2      | 20%   |
| T3        | 0.3800   | 9              | 0.1138  | 3          | 0.0432   | 5      | 8%    |
| T4        | 0.5500   | 3              | 0.1082  | 4          | 0.0595   | 3      | 12%   |
| T5        | 0.4400   | 8              | 0.0627  | 8          | 0.0276   | 8      | 5%    |
| T6        | 0.5500   | 3              | 0.0885  | 5          | 0.0487   | 4      | 10%   |
| T7        | 0.4900   | 6              | 0.0852  | 6          | 0.0418   | 6      | 8%    |
| T8        | 0.4700   | 7              | 0.0579  | 9          | 0.0272   | 9      | 5%    |
| T9        | 0.5500   | 3              | 0.0629  | 7          | 0.0346   | 7      | 7%    |
| T10       | 0.2900   | 11             | 0.0380  | 10         | 0.0110   | 11     | 2%    |
| T11       | 0.3300   | 10             | 0.0336  | 11         | 0.0111   | 10     | 2%    |

In this study, the quality of feasibility study (T1) is considered the most important variable to be considered for mitigation.
3.2. Sample MHPP for Technical Due Diligence
There are 3 MHPPs are involved in this technical due diligence. All MHPPs have a same capacity, same type of turbine and located in West Sumatera, Indonesia.

| Table 7: Sample MHPP for Technical Due Diligence |
|-----------------------------------------------|
| MHPP #1 | MHPP #2 | MHPP #3 |
| Capacity | 6 MW | 6 MW | 6 MW |
| Location | West Sumatera, Indonesia | West Sumatera, Indonesia | West Sumatera, Indonesia |
| Main structure | Weir, sand trap, waterway, syphon, headpond, penstock, powerhouse, tail race | Weir, sand trap, waterway, headpond, penstock, powerhouse, tail race | Weir, sand trap, waterway, headpond, penstock, powerhouse, tail race |
| Type of turbine | Francis horizontal | Francis horizontal | Francis horizontal |

3.3. Technical Due Diligence Process
The technical due diligence process is carried out on the related document of the MHPP (procurement, permits, PPA, contracts, company profiles, and key person’s profile). Basically, the due diligence will be assessed the availability and documents/data completeness, the data consistency, and actual condition at site.

| Table 8: Items to be assessed for technical due diligence |
|-----------------------------------------------|
| Feasibility study |
| Hydrology | Rainfall & climate | To determine the capacity of power plant, design of civil structure, design of mechanical & electrical equipment. |
| Catchment area | Discharge |  |
| Head | Type of rock | To ensure the strength and stability of the civil structure, calculation sedimentation rate & prevent erosion |
| Type of soil |  |
| DED |
| Civil structure | Weir | To ensure the reliability and durability of civil structure |
| Sand trap | Waterway |  |
| Head ponds | Penstock |  |
| Powerhouse | Tailrace |  |
| Mechanical & electrical | Turbine | To ensure the reliability and durability of mechanical and electrical equipment |
| Generator | Electrical cubicle |  |
| Transmission line |  |
| Interconnection study | Transmission line |  |
| Grid condition | Local grid condition (conductor, substation, relay & protection) | To ensure the absorption of electrical produced by MHPP |
| Load demand | Load demand |  |
| Human resources |
| Experience of the IPP |  |
Experience and capability
Experience of the consultant
Experience of the contractor
Operation and maintenance capability

To ensure the quality of planning documents (feasibility study and detail engineering design), the quality of MHPP and the best practise of operation & maintenance works

Supplier credibility
Supply and after sales record
To ensure the quality of equipment (s) to be supplied and after sales warranty

3.4. Scoring
The scoring for the technical due diligence will be in 1-5 (1 = very poor, 2 = poor, 3 = fair, 4 = good, 5 = excellent). The MHPP have to obtain minimum score “3 or fair” to pass the technical due diligence process. The minimum score is concluded refer to the discussions with the experts and experience involved in technical due diligence process for MHPPs during 2013-2019.

Table 9: Scoring & Parameters

| No | 1 | 2 | 3 | 4 | 5 | References |
|----|---|---|---|---|---|------------|
| T1 | 1 | Incomplete data | 1500 - <2000 mm/year | 2000 - <2500 mm/year | 2500 - <3000 mm/year | >= 3000 mm/year | [24] Interviews |
| 2 | Incomplete data | <100,000 ha | 100,000-500,000 ha | 500,000 – 1,500,000 ha | >1,500,000 ha | [24] Interviews |
| 3 | Incomplete data | Ephemeral river | Episodic/intermittent river | Periodically river | Permanent river | [25] Interviews |
| 4 | Incomplete data | H net <=2 m | 2m < H net <=30 m | 30 m < H net <=100 m | H net > 100 m | [26] Interviews |
| 5 | Incomplete data | Tipically CL,CH, SW,SM,SC,SP | The relatively stable ground and not find indication of ground movement evidence, typically GW-GC-SC | The relatively stable ground and not find indication of ground movement, typically shale (argillaceous) or RQD<25 | The relatively stable ground and not find indication of ground movement, typically sediment, slate, granite, diorite, basal | [27] Interviews |
| 6 | Incomplete data | High risk for erosion (example: andosol, laterit, grumosol, podsol, podsolik, regosol litosol, organosol, renzina) | There is the slightly potential for erosion (example: brown forest soil, noncalcic brown, Mediterranean) | There is no potential for erosion (example: latosol) | There is no potential for erosion (example: alluvial, planosol, literite) | [28][29] Interviews |
| T2 | 7 | Incomplete data | Complete data, but the data is inconsistent with other | The data is complete and consistent | The data is complete and consistent with other | Complete data, there is consistent with other | [30][29] Interviews |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| T3 | 11   | document, ex. Deviate with Basic Design in the Feasibility Study | data/document, construction drawing is available | data, 3D simulation available |
| T3 | 12   |  |  |  |
| T3 | 13   |  |  |  |

| T3 | 14   | Incomplete data | Complete data, but the data is inconsistent with other document, ex. Deviate with Basic Design in the Feasibility Study | Complete data, there consistent with other data, 3D simulation available |
| T3 | 15   |  |  |  |
| T3 | 16   |  |  |  |
| T3 | 17   |  |  |  |

| T4 | 18   | Incomplete data | Complete data, but there is a limitation for power distribution and there are limitations to power delivery and a significant additional investment is required for capacity upgrades | Complete data, there is no limitation for power distribution |
| T4 | 19   |  |  |  |
| T4 | 20   |  |  |  |

| T5 | 19   | Incomplete data | Complete data, distance of point of connection >30 km | Complete data, distance of point of connection 20 < PoC <=30 km |
| T5 | 20   |  |  |  |

| T6 | 20   | Incomplete data | Complete data, load absorption < 70% | Complete data, load absorption 100% |
| T6 | 21   |  |  |  |

| T7 | 21   | Incomplete data | Involving in 1 project, and already in operation phase in a good condition | Involving in 3 projects, and already in operation phase in a good condition |
| T7 | 22   |  |  |  |

| T8 | 22   | Incomplete data | Involving in 1 project, and already in operation phase in a good condition | Involving in 3 projects, and already in operation phase in a good condition |
| T9 | 23   | Incomplete data | Involving in 2 projects, and already in operation phase in a good condition |  |
| T10| 24   | Incomplete data | Involving in 3 projects, and already in operation phase in a good condition |  |
| T11| 25   | Incomplete data | Involving in 3 projects, and already in operation phase in a good condition |  |

[30][29] Interviews
3.5. Result and discussion

The result of the technical due diligence is presented in Table 10. The MHPP # 2 does not pass the minimum score. Based on the documents submitted, there are several weakness and potential risk to be mitigated for MHPP#2.

- The river has only small catchment area. In the other hand, there is high rainfall in the area. Based on our experience and discussion with the experts, the data is contradictory. The wider a watershed, the greater the possibility of rainwater being captured.
- There is significant difference between the FS and the DED of MHPP#2. The generating capacity of MHPP#2 according to the FS is 6 MW, while in the DED is 8 MW.
- The other risk is local grid capability. The local grid conditions can only absorb 3.9 MW.
- The distance of point of interconnection is far from the power house (24 kms). It will requires larger investment costs and the possibility of significant losses.
- There is no information regarding operation and maintenance strategy. The IPP has no exeperience to operate and maintenance power plant.

Table 10 : Technical due diligence result

|                                | MHPP#1 | MHPP#2 | MHPP#3 |
|--------------------------------|--------|--------|--------|
| **Feasibility study**          |        |        |        |
| Weight                         | [1]    | [2]    | [1]x   |
| Score                          | [3]    | [4]    | [1]x   |
| Final score                    | [3]    | [4]    | [1]x   |
| T1: Hidrology                  |        |        |        |
| Rainfall                       | 21%    | 3      | 0.74   |
| Catchment Area                 | 2      | 3      | 2      |
| Discharge                      | 4      | 3      | 4      |
| Capacity factor                | Head   | 4      | 4      |
| Type of rock                   | 4      | 4      | 4      |
| Type of soil                   | 3      | 3      | 3      |
| **DED**                        |        |        |        |
| T2: Civil structure            |        |        |        |
| Weir                           | 20%    | 4      | 0.80   |
| Sandtrap                       | 4      | 4      | 4      |
| Waterway                       | 4      | 2      | 4      |
| Headponds                      | 4      | 2      | 4      |
| Penstock                       | 4      | 2      | 3      |
| Power house                    | 4      | 2      | 3      |
| Tailrace                       | 4      | 4      | 3      |
| T3: Mechanical & Electrical    |        |        |        |
| Turbine                        | 8%     | 4      | 1      |
| Generator                      | 4      | 2      | 3      |
| Electrical Cubicle             | 4      | 2      | 3      |
| Transmission Line              | 4      | 2      | 3      |
| **Interconnection study**      |        |        |        |
| T4: Grid condition             |        |        |        |
| Local grid condition           | 12%    | 3      | 0.24   |
| Transmission line              |        |        |        |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T5** | 19 | Point of connection | Point of connection | 5% | 4 | 0.48 | 3 | 0.36 | 5 | 0.60 |   |   |
| **T6** | 20 | Load demand | Load demand | 10% | 3 | 0.15 | 2 | 0.10 | 4 | 0.20 |   |   |
| **Human resources** |   |   |   |   |   |   |   |   |   |   |   |   |
| **T7** | 21 | Experience and capability | Experience of the IPP | 8% | 2 | 0.16 | 1 | 0.08 | 1 | 0.08 |   |   |
| **T8** | 22 | Experience and capability | Experience of the consultant | 5% | 5 | 0.25 | 5 | 0.25 | 5 | 0.25 |   |   |
| **T9** | 23 | Experience and capability | Experience of the contractor | 7% | 5 | 0.35 | 5 | 0.35 | 5 | 0.35 |   |   |
| **T10** | 24 | Experience and capability | Operation and maintenence capability | 2% | 2 | 0.04 | 1 | 0.02 | 1 | 0.02 |   |   |
| **Supplier** |   |   |   |   |   |   |   |   |   |   |   |   |
| **T11** | 25 | Supplier credibility | Supply and after sales record | 2% | 5 | 0.10 | 5 | 0.10 | 5 | 0.10 |   |   |

|   | 100% | 3.31 | 2.65 | 3.28 |
|---|---|---|---|---|
|   | PASS | N-PASS | PASS |   |

**4. Conclusions**

The technical due diligence which conducted on 3 MHPPs shows that MHPP #2 has not technically feasible to obtain financing yet. There are several potential risk which need to be mitigated. Improvements to the DED by concerning to the actual conditions in the field (availability of discharge, installed capacity, and electricity absorption) absolutely necessary to determine the investment cost and how mitigate the risk might be occured in the construction and operating phase. The appointment of experience consultant, contractor and operator (for operation and maintenance work) needs to be considered, since the IPP have no experience in MHPP development.
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