Chapter 4

Barrier Analysis of Mini-grid Diffusion in Myanmar

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Chapter 4

Barrier Analysis of Mini-grid Diffusion in Myanmar

Energy access is still a challenge for many countries, as demonstrated by SDG 7, which '[e]nsure[s] access to affordable, reliable, sustainable, and modern energy for all' (United Nations, 2015). The government has set a target of 100% electrification by 2030. However, only 42% of households are connected to national grids, and only 22% are using off-grid solutions such as SHSs and mini-grids. To accelerate electrification, decentralised approaches should be considered in addition to the centralised option (national grid extension). Mini-grids can fill the gap between SHSs and national grids. In rural areas, where diesel fuel is considerably more expensive than in urban areas, mini-grids powered by renewable energy are more cost-competitive than diesel generators. However, diesel is still dominant as a source of power for mini-grids. In a previous study, we developed a typology of barriers to developing renewable energy–based mini-grids in Myanmar (Yoshikawa and Anbumozhi [eds.], 2018). This chapter analyses the barriers that are prioritised in each category. We conducted a questionnaire survey with stakeholders using a multi-criteria decision-making method called the analytic hierarchy process (AHP) to identify the prioritisation of each barrier factor based on stakeholders' evaluation, represented as a score of each factor by each respondent. The results of the prioritisation for each respondent were analysed with clustering by k-means to identify the tendency amongst respondents. Each cluster group includes a similar evaluation by the respondents. The mean value of the results in each cluster shows the evaluation of that group. The inconsistency amongst the clusters represents the disagreement amongst the clustered group of respondents. The results demonstrate that opinions were divided amongst stakeholders for some categories and that it was difficult to identify an indisputable main barrier, unlike in other countries. In the social and cultural barrier category, opinions were divided amongst clusters. One cluster prioritised the perception of inferior quality of renewable energy as the biggest barrier whilst the other cluster prioritised the gap in education of the local mini-grid developers and operators. There is no single 'silver bullet' for implementing mini-grids and overcoming the barriers needs steady work.

1. Introduction

1.1. Background

SDG 7 (affordable and clean energy) states that access to electricity is still a global issue (United Nations, 2015). The global population without access to electricity finally dropped to 840 million in 2017 (IEA, IRENA, UNSD, WB, and WHO, 2019). Access to power should be provided by expanding renewable energy instead of using fossil fuels. Sub-Saharan Africa attracts the most attention because of the large population that lives without access to electricity. In Asia, Myanmar has a similar electrification rate (Climatescope, 2019). The share of households connected to the national grid has grown from 34% in 2016 (Myanmar Energy Monitor, 2019) to 42% in 2018 (Billen and Bianchi, 2019), and 36 million people (70% of the population) live in rural areas (Myanmar Ministry of Immigration and Population Department of Population, 2014). The government has set a target of 100% electrification by 2030 (Ministry of Electricity and Energy Myanmar, 2018). The national grid accounts for over 80% of electrification in urban areas but for less than 13% in rural areas. Electrification by mini-grids represents approximately 13% (Ministry of Planning and Finance Myanmar and World Bank, 2017). The IRENA (2017) estimates that main grids and mini-grids need 37% and 44% more, respectively, to achieve universal energy access in developing Asian countries, suggesting that actions should not be focused on extending the national grids alone.

Mini-grids have recently begun to attract attention as a bridge between household electrification methods such as solar lanterns and home systems and large-scale national grids (Schnitzer et al., 2014; BNEF, 2017). In rural areas, which are not connected to the grid, roads are often not developed and fuel prices are higher because of transportation costs. In areas where diesel fuel is expensive, renewable energy is cost-competitive with diesel generators as a power source for mini-grids (Numata, Sugiyama, Mogi et al., 2018). In Myanmar, diesel is still used in most villages: 13,000 use diesel-powered mini-grids, 2,400 hydropower, 1,200 biomass, and 150 solar energy (Greacen, 2017). Various international aid agencies promote the introduction of mini-grids combining solar power and storage batteries (ADB, 2018; Frontier Myanmar Research Ltd., 2018) but mini-grids are still not expanding rapidly enough.

Myanmar has an abundance of renewable energy resources. The potential capacity of solar power is estimated as 27 GW, small and medium-sized hydropower 0.23 GW, and large-scale hydropower 100 GW (ADB, 2016; ADB, 2015). Myanmar's Intended Nationally Determined Contribution to the Paris Agreement establishes that the country will 'implement mitigation actions in line with sustainable development needs' (The Republic of the Union of Myanmar, 2015). Therefore, the country should use its abundant resources not only for large-scale power generation but also as a power source for mini-grids (del Barrio Álvarez and Sugiyama, 2018).

1.2. Previous Study

In a prior study (Yoshikawa and Anbumozhi [eds.], 2018), we conducted a bibliographic survey of the barriers to disseminating mini-grids associated with renewable energy sources in Myanmar (Table 4.1). Based on current conditions, we constructed a barrier typology through discussions with stakeholders (international organisations, private companies, NGOs, and field researchers). For the present study, we conducted a questionnaire survey of stakeholders based on an AHP and analysed the priority of each barrier.

Barrier Typology

Table 4.1: Barrier Typology

Category	Sub-categories	Description	Sources
Financial	Access to financing	Due to their lack of familiarity with project financing through a financial institution, developers find it difficult to obtain loans. Immature stock and debt markets limit financing options.	Gershenson et al. (2015); Greacen (2017b); Ahlborg and Hammar (2014); T. S. Schmidt, Blum, and Wakeling (2013); Luthra, Kumar, Garg, and Haleem (2015); UNCDF/UNDP (2012)
	High cost of capital	Even if funds are arranged, financing costs are high. Interest rates are high and loan fees costly.	Painuly (2001), Greacen (2017b), Gershenson et al. (2015), Comello et al. (2017), Luthra et al. (2015), UNCDF/UNDP (2012)
	Customers' insufficient capital	Customers' financing methods are limited. Microfinance is relatively new and unofficial money lenders are expensive.	Painuly (2001), Gershenson et al. (2015), Comello et al. (2017)
	Currency risk	If financing is based on a foreign currency, companies are exposed to exchange rate risks because their revenue and expenses are in different currencies.	Gershenson et al. (2015), BloombergNEF (2018)
Economic	Small market	The energy market in Myanmar is in its initial stage despite the rapid development of the international market.	Painuly (2001), Palit and Chaurey (2011), Bhattacharyya (2013), Luthra et al. (2015)
	Low demand	Creating demand in addition to basic use, such as for lighting, is still a challenge for operators.	Painuly (2001), Palit and Chaurey (2011), Bhattacharyya (2013), Ahlborg and Hammar (2014)
	Tariff structure: cost–revenue gap	Tariff revenue should cover costs but tariffs should be affordable, which is sometimes difficult to balance.	Bhattacharyya (2013); T. S. Schmidt et al. (2013); Comello et al. (2017); Ahlborg and Hammar (2014); Hasan (2018); Tenenbaum, Greacen, Siyambalapitiya, and Knuckles (2014)
	Uncertain fee collection	Operators must ensure that customers pay for the electricity, sometimes using new technology such as Pay As You Go.	Franz, Peterschmidt, Rohrer, and Kondev (2014); Bhattacharyya (2013); Ulsrud et al. (2011); Blum, Sryantoro Wakeling, and Schmidt (2013); Hasan (2018)
Social/ Cultural	Negative externalities caused by international organisations	Existing local mini-grid businesses were mostly for non-commercial and social welfare purposes, but the introduction of business models has changed the mindsets of operators and/or customers, breaking the trust between them.	Interviews with stakeholders

	Education	The educational gap hinders financing of local companies by international organisations, which provide lower capital costs. The language barrier (non-English speakers) is part of the reason.	Interview with stakeholders
	Ethnic or language differences	Residential areas with ethnic-minority groups overlap with off-grid areas. Language and cultural differences hinder project implementation.	Interview with stakeholders
	Perception of inferior quality	Especially in the early stages, it is difficult to offer 24/7 service.	Bhattacharyya (2014); Franz, Peterschmidt, Rohrer, and Kondev (2014); Comello et al. (2017)
Technical	Technology gap	Indigenous technology is different from international standards in many aspects but should not be flatly dismissed.	Interview with stakeholders
	Operation and maintenance	Operation and maintenance are often not appropriate or continued.	Gershenson et al. (2015); Comello et al. (2017); Ahlborg and Hammar (2014)
	Intermittency	The energy supply fluctuates over the day or season, which is typical for intermittent renewable energy sources.	T. S. Schmidt et al. (2013); Comello et al. (2017); Luthra et al. (2015)
	Lack of interoperability with national grid	Mini-grids might be designed without connections to the national grid due to the absence of technical rules.	Comello et al. (2017)
Regulatory	Lack of regulatory framework	There are no regulations for mini-grids.	Greacen (2017b); Painuly (2001); Luthra et al. (2015)
	Institutional capacity	Institutions are focused on their regular job, and it is difficult to coordinate between ministries beyond their current work.	Ahlborg and Hammar (2014); Bhattacharyya (2013); Comello et al. (2017); del Barrio Álvarez and Sugiyama (2018); Luthra et al. (2015)
	Lack of technical standards	Without technical standards or codes, it is difficult to maintain a certain level of quality for mini-grids. Rules for industrial waste, tar, and lead acid should be established.	Painuly (2001); T. S. Schmidt et al. (2013) ; Comello et al. (2017); UNCDF/UNDP (2012)
	Threat of grid extension	Mini-grid operators do not know what will happen to them after the national grid reaches their customers' villages.	Bhattacharyya (2013); Kobayakawa and Kandpal (2014); Comello et al. (2017); Hasan (2018); Tenenbaum, Greacen, Siyambalapitiya, and Knuckles (2014)

Source: Yoshikawa and Anbumozhi (eds.) (2018), modified by the authors.

2. Methodology

2.1. Analytic Hierarchy Process

The AHP is a decision-making method developed by T. L. Saaty in the 1970s and has been widely used since then (Saaty, 1987, 1990, 2003). A problem is hierarchically structured and a paired comparison for each factor is defined to rank their importance. The procedure is as follows (Saaty, 1994):

(i) Model the problem considering the hierarchy of the key factors.

(ii) Determine the importance of the elements by comparing pairs based on knowledge and emotion and score them (Table 4.2)

(iii) Calculate the priority of each factor based on the scores.

The result obtained is a square matrix (we chose 4 factors so here 4 × 4) with a diagonal component of 1. The obtained results are checked for consistency using the random index in Table 4.3 (0.89 for a matrix of n = 4) created by Saaty (2013). The consistency ratio is set to 0.1 as suggested in many papers (Saaty, 1994; Soma, 2003; Aras, Erdoğmuş, and Koç, 2004) and only answers whose consistency score is lower than 0.1 are used for the analysis.

Table 4.2: Fundamental Scale

1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

Source: Saaty (2013).

Table 4.3: Random Index

Matrix order	1	2	3	4	5	6	7	8	9	10
Random index	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: Saaty (2013).

Various multi-criteria decision-making methods can be applied to energy planning (Bhattacharyya and Palit [eds.], 2014; Kumara, 2015), but we chose AHP because it is widely used and easy to understand. AHP has been applied to prioritise decentralised power in Iran (Zangeneh, Jadid, and Rahimi-Kian, 2009) and Jordan (Kablan, 1997); develop energy in rural China (Xiaohua and Zhenmin, 2002); and select suitable locations for wind power generation (Aras et al., 2004) and research long-term energy resources as well as development planning in the Republic of Korea (Lee, Yoon, and Kim, 2007).

Barrier analysis has been applied to small-scale power sources in Sri Lanka (P. D. C. Wijayatunga, Siriwardena, Fernando, Shrestha, and Attalage, 2006), the adaptation of renewable energy in India (Luthra et al., 2015), cooking stoves and biogas fermenters in rural Thailand (Limmeechokchai and Chawana, 2007), energy efficiency in small-scale industries in India (Nagesha and Balachandra, 2006), and cleaner production by small and medium-sized enterprises in China (Shi, Peng, Liu, and Zhong, 2008). In this study, we applied AHP to analyse the barrier to dissemination of mini-grids powered by renewable energy in Myanmar. A questionnaire survey was conducted from September 2018 to February 2019. Table 4.4 lists the respondents. Energy-related stakeholders were selected from amongst various occupations. We sent out about 50 questionnaires and received 42 answers.

Table 4.4: Details of Questionnaire Survey

No. of respondents (individuals)	Sent	Answered
NGO (international, local)	8	8
Government	8	7
Private company	25	15
Media	2	2
Academia	6	6
International organisation	4	4
Total	53	42

2.2. K-means

K-means is a non-hierarchical clustering algorithm. The values are partitioned to the nearest cluster that has the nearest mean value within the cluster. The number of clusters k is given. The classification is based on the following process:

(i) Allocate each unit of data to a cluster at random. Set the number of clusters.

(ii) Calculate the centroid (arithmetic mean) of each cluster.

(iii) Calculate the square of the distance (difference) between each unit of data and the centroid of the cluster.

(iv) Reassign each unit of data to the centroid cluster with the closest distance (for which the difference square is minimum).

(v) Recalculate until the allocation of each unit of data in the cluster does not change.

The elbow method was used to investigate the number of clusters (Raschka, 2017): the sum of squared errors for each cluster number is calculated and a line graph is plotted. The number of clusters in the elbow-like bend is the reference with which to determine the lack of effect in increasing the number of clusters. This happens when the number of clusters increases and is subdivided but the decrease in the sum of the squared errors is not significant. Nevertheless, it is rare for a dataset to have a clear elbow-like bend.

3. Results

In AHP, a problem is hierarchised. Figure 4.1 shows the hierarchised barriers. The number of factors in each category was arranged in order based on a prior study (Yoshikawa and Anbumozhi [eds.], 2018). There are four factors in a category for which a pair comparison is performed. Whilst conducting the questionnaire survey based on the AHP, the subjects answered 30 questions with 6 sets of paired comparisons × 5 barrier categories. Four factors were to be compared in each category. If the number of factors was 5, there would be 10 × 5 = 50 questions, and 15 × 5 = 75 questions for 6 factors. It was assumed that an excessive number of questions would impact the response rate. The questionnaire is in Appendix 3.

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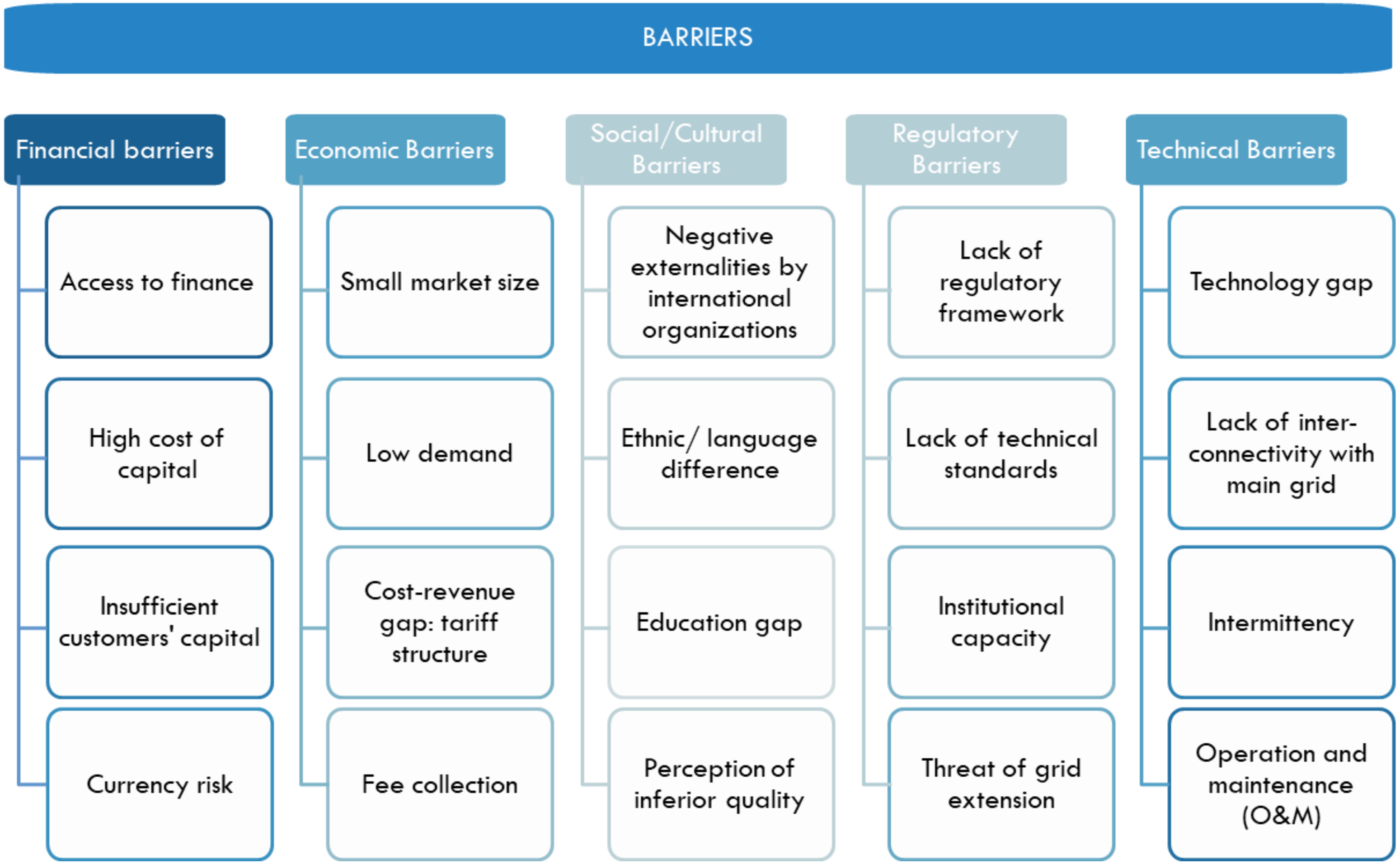
Figure 4.1: Hierarchy of Barriers Based on Previous Study



Source: Yoshikawa and Anbumozhi (eds.), (2018).

Table 4.5 shows an example of the answers obtained using the questionnaire. The score for each factor (financial barrier 1, financial barrier 2,..., technical barrier 4) is calculated from the score that the subject provided. The total score is 1. The consistency ratio of each category was calculated, and only those with a consistency ratio lower than 0.1 were considered valid answers. The results obtained were analysed by category.

Table 4.5: Example of Answers

Financial	Barrier 1	Barrier 2	Barrier 3	Barrier 4	Consistency Ratio
Respondent 1	0.059	0.191	0.647	0.103	0.084
Respondent 2	0.433	0.085	0.048	0.433	0.057
...					

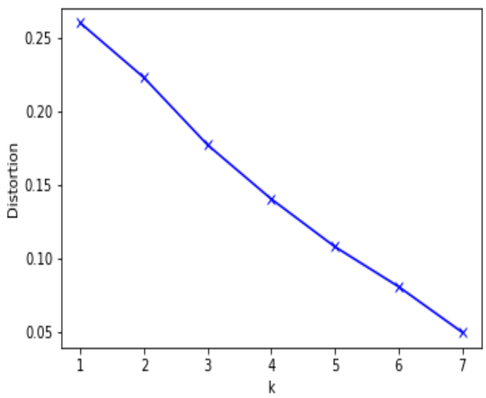
Economic	Barrier 1	Barrier 2	Barrier 3	Barrier 4	Consistency Ratio
Respondent 1	0.059	0.191	0.647	0.103	0.084
Respondent 2	0.25	0.25	0.25	0.25	0
...					

The number of clusters was examined using the elbow method (Figure 4.2). However, since most of the barrier categories did not display a clear elbow shape, the number of clusters was set to three based on the balance with the number of valid answers. For all barrier categories, the number of clusters was set as the same in a way that was easy to understand. Within each category, the scoring results obtained from the respondents were clustered into three groups and analysed. The numbers of valid answers for each category are in Table 4.6. The consistency ratio was set to 0.1, which led to less than half of the answers being classified as valid.

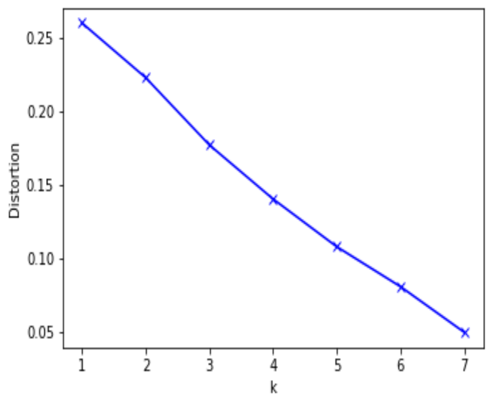
Table 4.6: Number of Valid Answers

	Number of Valid Answers / Total Number of Answers
Regulatory barriers	17/42
Social or cultural barriers	13/42
Economic barriers	12/42
Technical barriers	12/42
Financial barriers	8/42

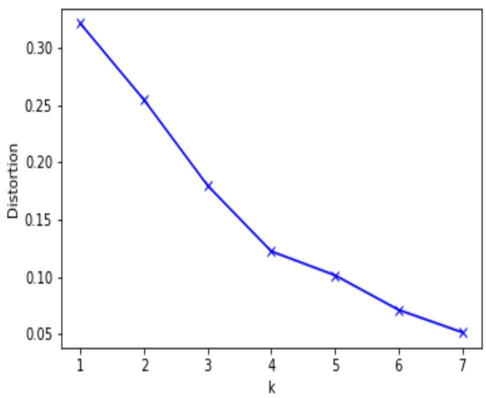
Figure 4.2: Elbow Plot of Each Barrier Category



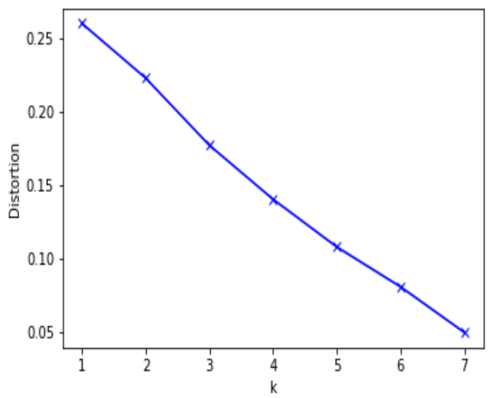
(a) Social and cultural barriers



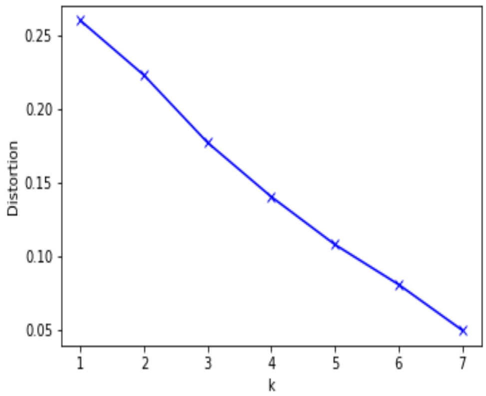
(b) Regulatory barriers



(c) Technical barriers



(d) Economic barriers



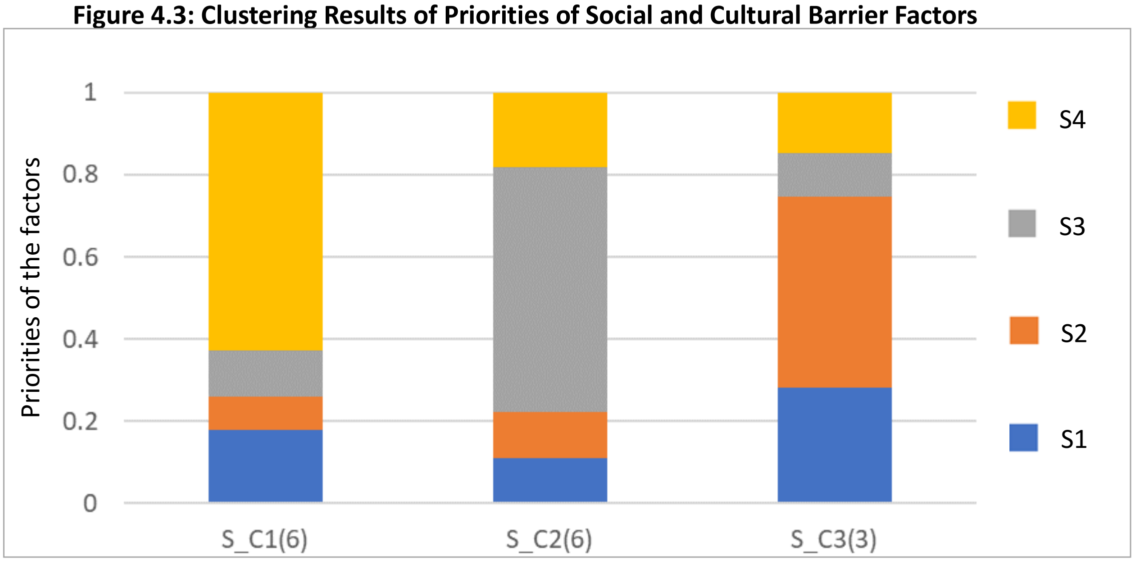
(e) Financial barriers

3.1. Social and Cultural Barriers

Figure 4.3 shows the results of the social and cultural barriers. The valid responses were divided into three clusters, and the weight of each barrier factor was averaged considering the responses in the cluster. Results are shown in the graphs, where the vertical axes show the weight value.

In the social and cultural category, clusters 1 and 2 have six valid responses each. 'S4: Perception of inferior quality' was considered the most important factor in cluster 1, and 'S3: Education gap' the most important in cluster 2. These factors are the most important by far in their clusters (S4 has a weight of 0.63 in cluster 1 and S3 has a weight of 0.60 in cluster 2).

Figure 4.3: Clustering Results of Priorities of Social and Cultural Barrier Factors



Note: S_C1 (6) indicates that cluster 1 of the social category contains six valid responses. The legend indicates each barrier factor (S1 to S4) in Table 4.7.

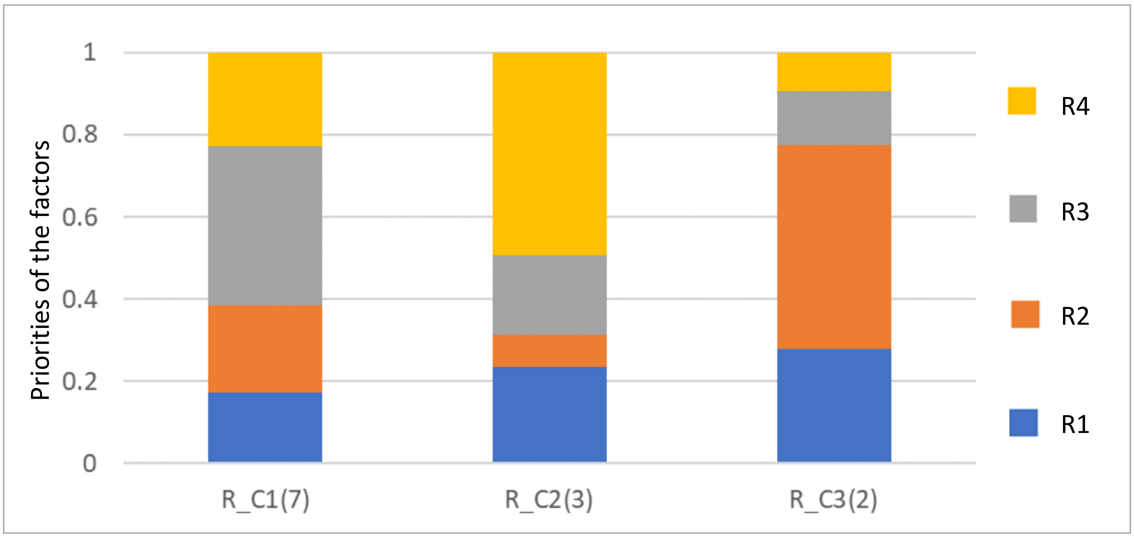
Table 4.7: Numbering of Social and Cultural Barrier Factors

S1	Negative externalities caused by international organisations	Existing local mini-grid businesses were almost all non-commercial, but the introduction of business models has changed the mindsets of operators and/or customers.
S2	Ethnic or language difference	Residential areas with ethnic-minority groups overlap with off-grid areas. Language and cultural differences hinder project implementation.
S3	Education gap	The educational gap hinders financing of local companies by international organisations, which provide lower capital costs. The language barrier (non-English speakers) is part of the reason.
S4	Perception of inferior quality	Especially in the early stages, it is difficult to offer 24/7 service.

3.2. Regulatory Barriers

Figure 4.4 shows the results of the regulatory barriers. Cluster 1 has 7 valid responses (out of 12), and the tendency of the respondents was consistent with the other categories. In cluster 1, ‘R3: Institutional capacity’ was the most important factor. In Myanmar, the extension of the national grid and the mini-grids connected to it are under MOEE jurisdiction, but off-grid electrification is under DRD jurisdiction. However, if mini-grids are constructed in areas where there is no national grid, the involvement of the MOEE, which is the governing authority in the electric power sector, is essential to develop legal systems and technical standards. However, the respondents believe that the ministries do not cooperate.

Figure 4.4: Clustering Results of Priorities of Regulatory Barrier Factors



Note: R_C1 (7) indicates that cluster 1 of the regulatory category contains seven valid responses regarding regulatory barriers. The legend indicates each barrier factor (R1 to R4) in Table 4.8.

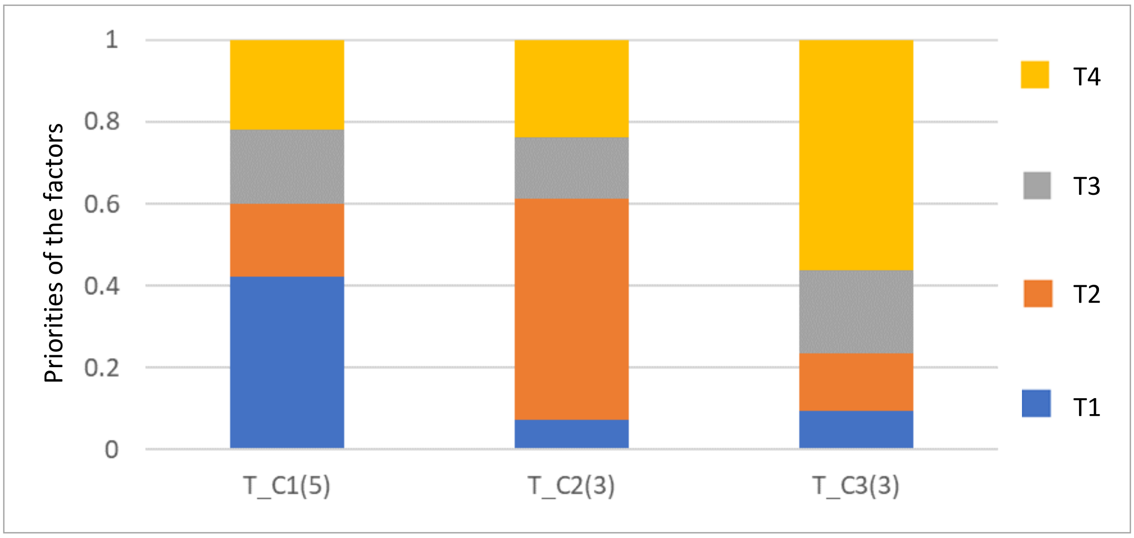
Table 4.8: Numbering of Regulatory Barrier Factors

R1	Lack of regulatory framework	There are no regulations for mini-grids.
R2	Lack of technical standards	Without technical standards or codes, it is difficult to maintain a certain level of quality for mini-grids. Rules for industrial waste, tar, and lead acid should be established.
R3	Institutional capacity	Institutions are attached to their current work, and it is difficult to coordinate priorities between ministries and/or other institutions.
R4	Threat of grid extension	Mini-grid operators do not know what will happen to them after the national grid reaches their customers' villages.

3.3. Technical Barriers

Figure 4.5 shows the results of the technical barriers. Cluster 1 has five valid answers, slightly more than other clusters. For Cluster 1, 'T1: Technology gap' is the most important factor. Local technology is often deemed inferior by international experts, but domestic technology has developed alongside local needs and often is affordable.

Figure 4.5: Clustering Results of Priorities of Technical Barrier Factors



Note: T_C1 (5) indicates that cluster 1 of the technical category contains five valid responses. The legend indicates each barrier factor (T1 to T4) in Table 4.9.

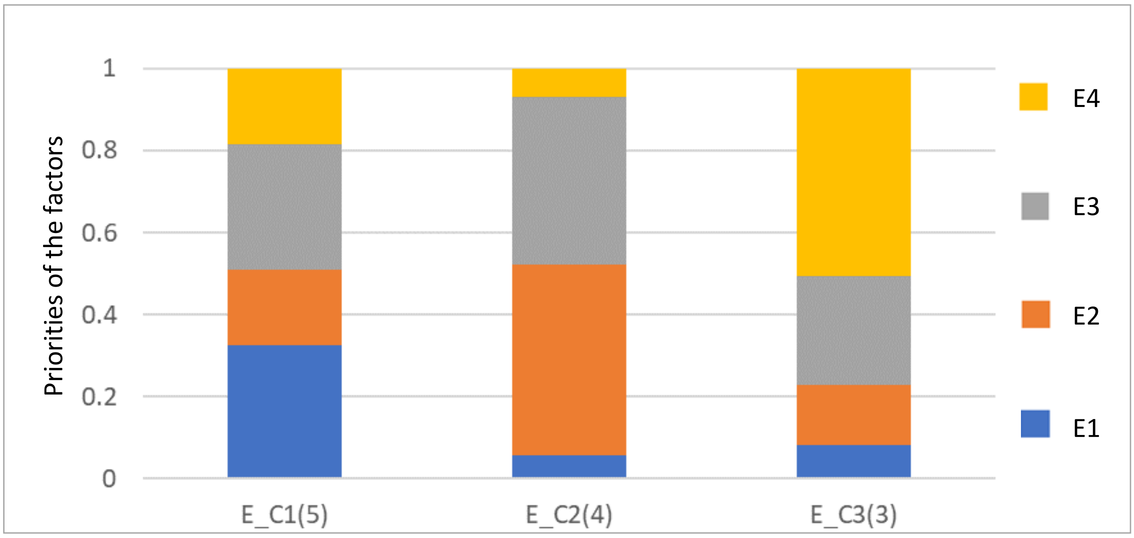
Table 4.9: Numbering of Technical Barrier Factors

T1	Technology gap	Indigenous technology is different from international standards in
T2	Lack of	Mini-grids might be designed without connections to the national
T3	Intermittency	The energy supply fluctuates over the day or season, which is
T4	Operation and	Operation and maintenance are often not appropriate or

3.4. Economic Barriers

Figure 4.6 shows the results of the economic barriers. 'E1: Small market size' (weight of 0.33) and 'E3: Cost-revenue gap' (weight of 0.31) are important in cluster 1, with the highest number of valid responses. 'E2: Low demand' (weight of 0.46) and 'E3: Cost-revenue gap' (weight of 0.41) are important in cluster 2, with the highest number of valid responses. E3 was evaluated as relatively important considering the top two clusters. In this context, solar power generation is particularly capital-intensive and has a business model that recovers the initial costs through electricity charges. However, if a high tariff is set for recovery, the costs might exceed the consumers' ability to pay for electricity, and consumers will likely refrain from using it. Therefore, the consumers' ability to pay should be balanced against recovery of cost.

Figure 4.6: Clustering Results of Priorities of Economic Barrier Factors



Note: E_C1 (5) indicates that cluster 1 of the economic category contains five valid responses. The legend indicates each barrier factor (E1 to E4) in Table 4.10.

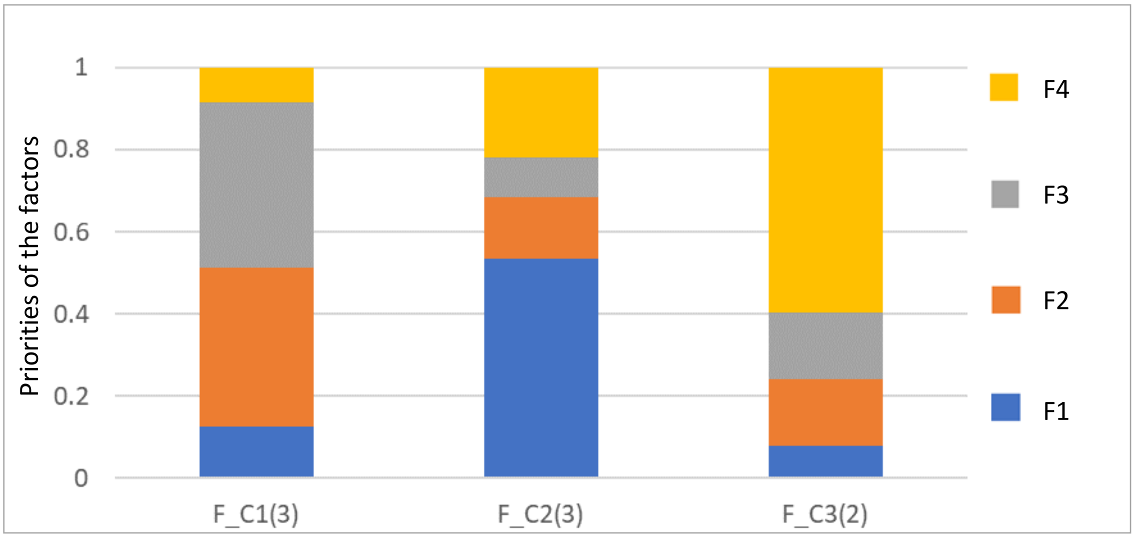
Table 4.10: Numbering of Economic Barrier Factors

E1	Small market	The Myanmar market is in its initial stage, despite the rapid development of the international market.
E2	Low demand	Creating demand in addition to basic use, such as for lighting, is still a challenge for operators.
E3	Cost–revenue gap	The design of the tariff structure affects the business model.
E4	Fee collection	Operators must ensure that customers pay for the electricity, sometimes using new technologies such as Pay As You Go.

3.5. Financial Barriers

Figure 4.7 shows the results of the financial barriers. As a result of the consistency analysis, the financial category presented many inconsistent answers with the smallest number of valid answers. The weighting tendency also varied according to each cluster. It was concluded that the evaluation of each factor varied according to personal perspectives.

Figure 4.7: Clustering Results of Priorities of Financial Barrier Factors



Note: F_C1 (3) indicates that cluster 1 of the financial category contains three valid responses. The legend indicates each barrier factor (F1 to F4) in Table 4.11.

Table 4.11: Numbering of Financial Barrier Factors

F1	Access to financing	Due to local banks' lack of familiarity with project financing through a financial institution, obtaining loans is difficult. Immature stock and debt markets limit the options for financing arrangements.
F2	High cost of capital	Even if funds are arranged, financing costs are high. Interest rates are high and loan fees are costly.
F3	Customers' insufficient capital	Customers' financing methods are limited. Microfinance is relatively new and unofficial money lenders are expensive.
F4	Currency risk	If financing is based on a foreign currency, companies are exposed to exchange rate risks because their revenue and expenses are in different currencies.

4. Discussion and Conclusions

In some categories, high agreement amongst respondents was observed. In other categories, opinions were divided. Clear findings, such as the greatest barrier for mini-grid development being the threat of national grid extension in India (Comello et al., 2017), were not observed. We investigated whether the respondent's occupation had an impact but did not observe any particular trends related to occupation in any category. The results indicate that there are various barriers to disseminating mini-grids based on renewable energy in Myanmar, and there is no consensus yet on what the greatest barriers are.

In the social and cultural category, respondents' opinions were divided. In the top two clusters, 'S4: Perception of inferior quality' and 'S3: Education gap' were evaluated as important. The output of mini-grids that use solar, hydropower, and other renewable energy may be affected by weather conditions, which hinders securing quality. Securing enough power generation and transmission requires an increase in installation capacity and in the capacity of backup power supply. However, the extra facilities would lead to increasing costs. System capacity is normally set according to the village's demand, and power generation may not be available because of the weather. It should be noted that explaining appropriate measures to the residents would facilitate business.

The gap in education is significant for businesses developing mini-grids in rural areas. Mini-grid developers from overseas entering the market can speak English and operate tools such as computers and Microsoft Office. However, existing operators are often based in rural areas where the net high school enrolment was 39% in 2017 (Central Statistical Organization et al., 2018). It is challenging for them to prepare the required documentation for low-interest financing from international donor organisations, such as the Excel-based finance model required for '60/20/20' under the NEP. This limits their access to favourable finance.

In the regulatory category, there is a considerable degree of agreement that institutional capacity is important. The Electricity Law 2014 (Pyidaungsu Hluttaw, 2014) established that sources generating 30 MW or more and any power generation connected to the national grid come under MOEE jurisdiction. Power generation under 30 MW that is not connected to the national grid is under the jurisdiction of the state and region governments. However, under the NEP, which is funded by the World Bank, electrification of off-grid areas is being promoted by the DRD. The off-grid mini-grid legal system has been developed under the DRD and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and submitted to the MOEE (Du Pont, 2019). By accelerating the development of legislation, business risks surrounding mini-grids will be reduced (e.g. handling of the mini-grid when the national grid reaches the mini-grid business area) and investments are likely to accelerate.

The technology gap was considered relatively important under the technical category. Despite the differences between native Myanmar technology and foreign standards, domestic technology has not been entirely rejected. Indigenous technology refers to technology independently developed in Myanmar before the country became democratic and the market was opened. Stakeholders identified technologies for small hydropower and biomass power generation, which allow operation and maintenance to be performed easily in off-grid rural areas. Practical issues occur often, such as the difficulty of obtaining repair parts in rural areas, too-high technology installed by international organisations, and the lack of engineers who can conduct repairs. In the future, it will be important to select affordable technologies and introduce power plants using more advanced technology, which will lead to improving engineers' skills.

In the economic category, the cost–revenue gap was relatively important in the top two clusters. The cost–revenue gap can be considered a problem of tariff setting. Solar power generation is particularly capital-intensive, and it is a business model that recovers the initial costs incurred through electricity charges. However, consumers' ability to pay is limited and a high tariff to recover costs will cause consumers to refrain from using electricity. Consumers’ ability to pay should be balanced against recovery of cost. The acceptance of the tariff by residents depends largely on the reference price. Myanmar has subsidised its residential prices for the national grid and set them very low. The price of mini-grids will likely seem high if the residents reference the price of the national grid. Therefore, implementing mini-grids depends on the economic equilibrium of price and convenience of electricity. In villages that originally relied on diesel power, electricity from solar-powered mini-grids is cheaper than electricity generated from diesel, which is more expensive in rural than in urban areas. Villagers in those areas are more willing to pay tariffs for mini-grids, which shows that the reference price is important and can deeply affect customer behaviour.

This study has some limitations. For the AHP, prioritisation was first performed between factors of the lowest hierarchy. Subsequently, prioritisation was performed at a hierarchy that was one level higher. However, since the paper-based questionnaire survey was conducted, immediate prioritisation results could not be presented and superior prioritisation based on the results could not be investigated further. For future research, we would like to use a survey method that allows for ease in obtaining answers, which can then lead to a deeper analysis. We also had inconsistent answers. We used the consistency ratio of 0.1 as suggested in most of the extant literature, but some studies have a consistency ratio of 0.2 (Cox, Alwang, and Johnson, 2000). The consistency ratio should be examined in more detail.