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A Multi-Methodology Approach to Creating a Causal Loop Diagram

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Abstract: Developing causal loop diagrams (CLDs) involves identifying stakeholders and endogenous variables and formulating variable causal relationships. Traditionally, the CLDs are developed mainly using a qualitative approach such as literature review, observations and interviews with stakeholders. However, modellers may question which stakeholders should be approached, whether the relevant variables are selected, and what to do when stakeholders perceive different variable relationships in the CLDs differently. Applying in a case study, this research proposes a multi-method approach by combining both quantitative and qualitative methods to select stakeholders, identify endogenous/exogenous variables, and develop the CLDs. The proposed quantitative method is expected to provide modellers with a justifiable stakeholder and variable selection process. The method also highlights possible hidden variables and relationships, which were further explored with a traditional qualitative approach.

Keywords: causal loop diagram; multi-methodology approach; structural analysis

1. Introduction

The systems thinking approach is a research lens that follows a holistic worldview and non-linear system behaviour over time [1]. Using this method, researchers can demonstrate system connectivity through modelling, and illustrate system behaviours of different scenarios [1–3]. The modelling process includes turning a qualitative conceptual model into a final quantitative simulation [4,5]. Experts and stakeholders are crucial to illuminating variable relationships in the system under investigation [6]. This research focuses on developing a qualitative conceptual model using causal loop diagrams (CLDs).

CLDs map the hypotheses of system structures by linking causal relationships between variables [2]. The easy-to-view CLDs help to engage stakeholders during the modelling process and facilitate their mind maps [7]. CLDs are not the final simulation and are not a mandatory part of the system dynamics modelling process [8]. However, the CLDs allow a smoother transition to the final quantitative stock-and-flow diagrams used in simulation [9].

Developing the CLDs involves identifying stakeholders and endogenous variables, and formulating variable causal relationships [2]. Modellers collect, refine and revalidate data multiple times using a mainly qualitative approach including literature reviews, observations, interviews, and consultations with stakeholders [6]. These traditional CLDs developed with stakeholders [8] limit researchers to the qualitative approach. This research contends that the paradigm is a world view [10] which, by default, can illuminate certain phenomena while concealing other paradigms [11]. Thus, combining the qualitative and quantitative approaches will complement different system aspects and deepen the modellers' understanding and interpretation [12]. This research adopts the

multimethodological approach for a systems modelling, which favours more than one methodology from different paradigms to examine an intervention more effectively [13–17].

We recommend integrating quantitative methods including stakeholder identification, a systematic quantitative literature review, and a structural-analysis MICMAC (Impact Matrix Cross-Reference Multiplication Applied to a Classification), with qualitative methods including the modeller's judgement or revalidation with stakeholders. This research contributes to the multi-methodology approach from different paradigms in complex settings [18]. The next section reviews the CLDs developing process and limitations. Section 3 presents the proposed multi-methodology. Section 4 applies the methods to a case study and compares the result with relationships obtained from the literature. Section 5 concludes and suggests further work.

2. CLDs Developing Process

Developing the CLDs incorporates two steps: Problem articulation and formulation of dynamic hypothesis [2].

2.1. Step 1: Problem Articulation

Step 1: In problem articulation, modellers identify research problems and key variables or concepts [2]. Problem articulation is also called 'conceptualisation' [19], and 'problem identification and definition' [20]. Common practices to articulate problems are client interview, stakeholder engagement and data collection [2,8]. This section focuses on traditional stakeholder and variable identification, and its limitations.

First, stakeholders are human entities, as individuals, groups or organisations; non-human entities include the environment; and mental constructs such as the respect for the past generation and the future generation's well-being [21–23]. In the system modelling process, stakeholders provide knowledge, develop the actual model, interpret the results, and/or create the alternate policies [24–26]. Modellers can involve a group of stakeholders to build a conceptual model [27], joint individual stakeholder's models [28], or record stakeholder interactions in a simulation [26]. The review of stakeholder participation in the modelling process can be found in [26,29,30].

This research argues that despite a vast literature on stakeholder and modelling processes, the fundamental questions of '*who's in*' and '*why*' are not explicit and remain a difficult issue in the systems' thinking literature [26]. Modellers often select stakeholders on an ad hoc basis, simply because they hold a 'stake' in research problems or ignore them all together [22,31,32]. Unclear and unjustifiable stakeholder lists may hinder result acceptance, model boundary, and system perception [33,34].

This research does not argue why stakeholders are important, because the reasons vary according to a modeller's stakeholder theories. Examples of stakeholder theories are: Perceiving stakeholders as an instrument to understand phenomenon versus as a 'right thing to include them' [35]; judging which stakeholders are more important versus avoiding this altogether; or focusing on the organisation's interests versus engaging stakeholders [36]. This research simply calls for articulating which stakeholders are omitted. Thus, this research suggests a structured stakeholder identification method to illuminate who's in and who's omitted at Step 1: Problem articulation.

Following creating a stakeholder list, modellers identify relevant variables to serve as a model boundary [2]. Compiling variables reflects a modeller's two epistemologies, both have their own limitations. Should modellers assume an objective epistemology that human knowledge reflects the reality, then the modellers' knowledge is sufficient and does not involve stakeholders [32]. However, modellers with the objective epistemology may sweep-in many variables and create a large model to reflect reality rather than the problem [34,37]. On the other hand, should modellers assume a subjective epistemology that humans construct the realities, then modellers would appreciate different perspectives and engage stakeholders [32].

Compiling a variable glossary with stakeholders depends on '*who's in*' because pushing out a stakeholder list impacts how the system is perceived and which variables should be included [34].

However, extracting variables from stakeholders depends on the success of the stakeholder engagement. A structured group model building (GBM) facilitator is instructed to ask stakeholders, "What are the key variables affecting the process and outcomes of the (project name) project?", and write on the whiteboard [38]. Yet two GBM case studies found that eliciting variables are subject to the stakeholder's organisation's culture, stakeholder personalities, and the problem dynamics [39]. This research suggests integrating a systematic quantitative literature review to quantify and justify a variable list. The list can be expanded when engaging stakeholders.

2.2. Step 2: Formulating a Dynamic Hypothesis

Step 2: Formulating a dynamic hypothesis aims to explain the problem dynamics [2]. Formulating a dynamic hypothesis is referred to as 'conceptualisation' in [19], and 'system conceptualisation' in [20]. Developing a dynamic hypothesis process includes: (1) Identifying endogenous variables, and (2) mapping system structures using CLD [2]. This section focuses on the limitations of variable classifications such as endogenous/exogenous, and the CLD developing process.

First, modellers and/or stakeholders must identify variables into endogenous (arising from within) and exogenous variables (beyond the system) [2]. Exogenous variables are important considerations to understanding a system, however, do not have important feedback compared to endogenous variables. Otherwise, they should be considered as endogenous variables and the model boundary must be expanded [2]. Incorrectly identified endogenous variables will result in narrow boundaries and a limited ability to propose solutions [40,41]. Despite the importance of variable classifications, how variables are classified as endogenous or exogenous is unclear and depends on the stakeholders' and modellers' interpretations. This leads us back to '*who*'-the-stakeholders-are argument. Furthermore, the endo/exogenous variable classifications are binomial and lead a modeller to focus on what lies within the model. The endo/exogenous classification does not discriminate the different degrees of variability that may arise within or beyond the model boundary. Such a classification could portray the importance or otherwise of variables in the decision-making process, and their opportunity to manipulate the system. However, our world is entangled with overlapped or embedded systems. Therefore, modellers must look inside, between and outside the system boundary [32].

After identifying endogenous variables, modellers map the system structure to communicate the model boundary and causal relationships between variables [2]. Mapping tools are model boundary diagrams, subsystem diagrams, CLDs, stock-and-flow maps, and policy structure diagrams, some of which have not been adopted in recent literature [2]. This research focuses on CLDs. The CLDs comprise variables connected with arrows representing causal relationships. Each arrow is assigned with '+' or '*s*' for a relationship that moves in the same direction (i.e., if A increases, then B increases and vice versa); with '-'or '*o*' for the opposite direction (i.e., if A increases, then B decreases and vice versa); and with '//' for the delay impact [2]. If the relationships can be traced back to the starting variable and form a feedback loop, then the loop is called either a reinforcing loop (for a loop that causes exponential growth/decay, denoted with 'R') or a balancing loop (for a loop that stabilises behaviour over time, denoted with 'B') [2]. The R and B denotations appear in a 1.pdf 1.pdf for loops that read anti-clockwise, and in 2.pdf 2.pdf for loops that read clockwise.

Modellers develop, refine, and revalidate CLDs several times through literature review, observation, interview, questionnaire and consultation [2]. This research argues that the CLDs development process and its visualisation has some limitations. For example, the CLDs' drawing process relies on existing literature or on qualitative stakeholders/experts knowledge [2], posing challenges on emerging research topics. Some literature may explore heavily using a linear approach, or lightly, if at all, on emerging topics. Thus, solely relying on the literature may not equip modellers with the knowledge to interview stakeholders [42]. Another example is that the CLDs' drawing process does not describe how to manage different stakeholders' perceived causal relationships [43]. As systems thinking contends that "everything is connected to everything else" [44], all variables in CLDs could be inter-related with arrows should all the stakeholders' opinions be considered. In addition, a consensus

among stakeholders about variable relationships may reflect invisible conflict and marginalisation [45]. Finally, CLDs lack an explicit decision-making process, because they portray the system structure as several connected feedback loops [46]. Upon viewing CLDs, one cannot simply identify where the decisions start or what information is important to decision makers [46]. The ability to capture such decision-making processes is crucial to understanding the operational policies and how internal information is used [47].

Given the limitation of binomial variable classifications and the CLDs' developing process, this research suggests the integration of a structural-analysis MICMAC method to expand the variable categories, illuminate causal relationships, and deal with causal relationship discrepancies. CLDs produced using this method are expected to assist modellers for further discussion with stakeholders.

3. Multi-Methodology Approach for CLDs' Development

This research acknowledges a current debate on paradigm incommensurability and the multi-methodology approach. On the one hand, different paradigms cannot be merged because the underlying assumption about objective/subjective ontologies and epistemologies are irreconcilable [18]. On the other hand, the separation of paradigms is questioned altogether and the pluralist view is recommended to elucidate phenomena [48]. This research follows the latter school of thought. See [49,50] for discussion on paradigms for systems' thinking.

This research combines the quantitative and qualitative approaches sequentially. Quantitative results provide modellers with pre-conceptual knowledge. Such knowledge will assist modellers to guide the dialogue during the qualitative approach [51]. Table 1 summarises the multi-methodology approach for the CLDs' development proposed by this research.

Table 1. The multi-methodology approach for causal loop diagrams (CLDs) development proposed by this research.

Step (1) Problem Articulation					
1.1 Identifying stakeholders	Clients/modellers gather stakeholder lists (QL*).	→	Use the stakeholder identification method (SI) to organise stakeholders based on their roles (affect, being affected, or both) and the degree of their roles (most, moderate, least) (QL*).	→	Clients/modellers select stakeholders (QL*).
1.2 Identifying relevant variables	Modellers gather variables using the systematic quantitative literature review (SQLR) (QT*).	→	Clients/stakeholders review/amend variable list (QL*).		
Step (2) Formulating Dynamic Hypothesis					
2.1 Identifying endo/exogenous variables	Stakeholders complete a structural-analysis MICMAC matrix (MICMAC) (QT*).	→	Use the direct influence and dependence chart to identify endo/exogenous variables (QT*).	→	Clients/stakeholders review/amend variables and their relationships in the CLDs (QL*).
2.2 Mapping the system structure using CLD		→	Use the displacement map and the direct and indirect influence graphs to understand the possible hidden variables and relationships; and use them as a reference for drawing CLDs (QT*).		

* QL = Qualitative approach, QT = Quantitative approach.

3.1. Step 1: Problem Articulation

3.1.1. A Stakeholder Identification (SI)

This research proposes SI to show *'who's in'* and who is omitted. SI [52] allows modellers to identify stakeholders through experts, other stakeholders, announcements, population records or census, oral or written accounts of major events, or using [52]'s suggested stakeholders. Modellers can group stakeholders if the list is too long. Then, modellers sort stakeholders on a rainbow diagram by whether stakeholders can (1) 'affect', (2) 'are affected by', or (3) 'affect and are affected by' the phenomenon; by their role degrees of 'most', 'moderate' or 'least' (Figure 1).

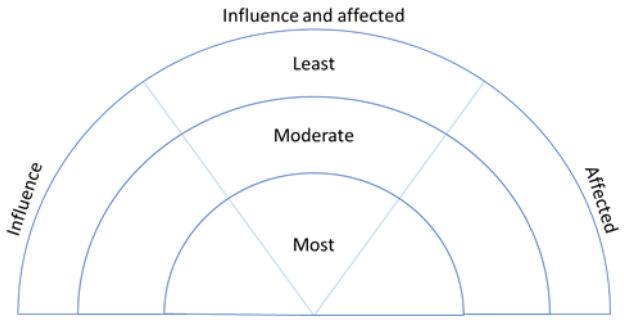

Figure 1. Stakeholder identification method's rainbow diagram. Source [52].

The clear stakeholder division based on their roles and role degree are flexible according to the stakeholder theories modellers may hold. For example, working on an environmental pollution, modellers may adopt an inclusive perspective and include all stakeholders in the diagram based on moral ground. If the research objective concerns the effectiveness of a given project, then stakeholders who 'most' and 'moderately' affect the project function should be included [53]. In both cases, SI illuminates which stakeholders are in/excluded with justifications. SI is limited to the subjective stakeholder selection of experts and modellers. Using several experts or multiple sources can minimise, but not completely eliminate such biases.

Other stakeholder identification methods in systems thinking exist. Vennix [54] recommends including stakeholders who can implement the decisions. Yet the process for identifying those stakeholders is rather superficial and lacks detail [55]. Müller, et al. [55] propose the four-phase stakeholder identification with a distinction between actors, experts and agents. However, their method is based on the inclusive perspective stakeholder theory and is not suitable for research adopting other stakeholder theories [55].

3.1.2. Systematic Quantitative Literature Review (SQLR)

This research proposes SQLR to create a quantifiable variable list. SQLR [56] allows modellers to assess and select literature systematically based on preset-inclusion criteria such as search keywords, databases, publication years, manuscript types, etc.

SQLR is flexible with a modeller's epistemology. Should stakeholders be excluded, the variable list is a quantifiable and justifiable literature scope [57]. Should stakeholders be included, they can review and amend the variable list. SQLR is useful for the novice researcher and on an emerging topic [58]. However, SQLR limits the inclusion criteria leading modellers to search only relevant literature. This bias can be minimised by expanding the inclusion criteria and engaging stakeholders for they too have a mental database [59].

Other literature review methods are the narrative method and Cochrane review's meta-analysis. With the narrative method, modellers read relevant literature as much as possible. However, selecting 'relevant' literature is highly subjective and relies on a modeller's expertise [60]. The Cochrane review's meta-analysis requires an expert team to weight the literature based on the methodology, sample size

and effect size [61]. However, meta-analysis is inadequate for the sole modeller or small research team, and for an emerging topic with limited data [58]. Thus, because Step 1 evaluates the breadth rather than the depth of the research, SQLR has an advantage over a meta-analysis.

3.2. Step 2: Formulating a Dynamic Hypothesis

Structural-Analysis MICMAC

This research integrates a structural-analysis MICMAC to identify endogenous variables and develop the CLDs quantitatively. MICMAC determines variable roles and their *direct* and *indirect* influence/dependence specified by stakeholders [62]. The MICMAC process [62] includes: (1) Identifying relevant variables recommended under 80 variables for the presentation purpose; (2) arranging variables into a matrix in a horizon and vertical lines; (3) asking experts to rate a *direct* relationship between variables from zero (no influence), one (weak influence), two (moderate influence), and three (strong influence) line by line. Arcade et al. [63] recommends that stakeholders fill in the matrix together in seminars spread over three to six months. See the algorithm behind MICMAC in [64].

The MICMAC variable role analysis helps modellers quantify their endo/exogenous variable selection. MICMAC produces the *direct* influence and dependence chart and positions each variable in a quadrant based on its *direct* relationship. MICMAC sorts variables into four main and five sub-categories. These categories are: (1) *Determinant variable*, which is very influential with little dependence and can act on the system. Included in determinant variables are (1.1) *environmental variable*, which conditions the system and cannot be controlled; (2) *relay variable*, which is very influential and very dependent. Included in relay variables are: (2.1) *Stake variable*, that is the 'potential breakpoint of the system' or has a strong influence on the system; (2.2) *target variable*, that is more dependent than influent but influences the system if conducted in a desirable way; (3) *depending variable*, that is the system result, little influent, very dependent, and sensitive to the determinant and relay variable changes; (4) *autonomous variable*, that is incapable of changing the system or benefits from such change. Among the autonomous variables are: (4.1) *Secondary lever* that is more influent than dependent and is the possible secondary system actor; and (4.2) *Disconnected variable* whose origin is excluded from the studied system [63]. This research contends that the autonomous category, particularly the disconnected variable, is equivalent to the traditional exogenous variable. Thus, MICMAC quantifies the exogenous variable justification. This research recommends triangulating decisions to exclude any variables with stakeholders. In addition, different variable roles may illuminate where the decision starts in the system, hence, enhance the CLDs' visualisation.

MICMAC also produces a displacement map displaying changes in variable roles under *indirect* relationships. Changes in variable roles may indicate possible hidden influential variables through the feedback loop. This displacement map is based on MICMAC's principle that if A directly influences B, and B directly influences C then changes in A would influence C. Thus, A and C have an indirect relationship which is hidden in the direct influence and dependence chart above [65]. Research shows that 20% of variables would change their categories under indirect relationships, a result considered to be important [66]. Modellers should explore the hidden variables with stakeholders.

The MICMAC *direct* and *indirect* relationship analysis helps modellers develop the CLDs. MICMAC produces the *direct* and *indirect* influence graph, illustrating weak, moderate, or strong variable relationships indicated by stakeholders. Modellers may refer to these relationships when drawing the CLDs. Relationships indicated by MICMAC are provisional, unclear whether they are negative or positive relationships, and need validation with stakeholders. Yet, this research contends that variable relationships could be numerous and missed without the help of computers.

The MICMAC results limit the subject choice of stakeholders. This bias can be minimised by using a diverse stakeholder group [63]. However, stakeholder consensus could represent a mistake

as a group or the silence of the minority [63]. Time consumption to complete the matrix is another limitation. Arcade et al. [63] recommends organising a two to three-day seminar for 70 variables.

Other structural-analysis approaches exist that could conceptualise the CLDs. Among these, the interactive cross impact simulation (INTERAX) and trend impact analysis (TIA) are more well-known [67]. INTERAX requires numerous experts to analyse and develop alternative future scenario databases and strategies, sometimes up to 100 events with 50 trend forecasts [68,69]. Thus, INTERAX is expensive and difficult to use [67]. TIA times future events and their impacts by combining historical data and expert identified probabilities [70]. However, TIA is inappropriate when historical data are unavailable or unreliable [67]. The previous effort to combine MICMAC and CLD can be found in [71–74]. This present research provides the justification for combining MICMAC and CLD.

4. Application in a Case Study

We demonstrate the multi-methodology approach on renewable energy technology (RET) adoption as a case study in the hotel sector in Queensland, Australia. We focus on the application of the multi-methodology approach and its contribution to the CLDs' development. The explanations and interpretation of the social, economic and environmental impact of RET are beyond the scope of this paper. Other research that has applied the multi-methodology approach to develop a final quantitative model on renewable energy exist such as [75–77]. However, discussing them is beyond the scope of this paper.

Australia is the world's 15th largest greenhouse gases (GHG) emitter mainly from burning fossil fuel for electricity [78]. As per the Paris Agreement, Australia is committed to reducing its emissions by 26–28% below the 2005 level by 2030 [79]. Promoting the RET adoption is one of Australia's strategies to mitigate GHG emission [80]. The Australian government requires its electricity sector to source 20% of the power from renewable energy resources by 2020 [81]. Aided by some incentive policies such as Feed-in Tariff and large-scale RET investment funds [82], the national renewable energy production level has increased by 12% in 2016–2017, accounting for 16% of the total electricity production Australia-wide [83,84]. However, at the state level, Queensland has the lowest share of electricity generated by RET at 7% when compared with other states (Tasmania (87%), Southern Australia (43%), Victoria (14%), Western Australia (8%), and New South Wales (13%)) [84]. Queensland remains the largest emitter of the states/territories produced mainly by the coal-fired electricity sector [85]. Queensland needs to do more to assist Australia to meet the nation's emissions target.

This research proposes that the hotel sector in Queensland has the potential to reduce emissions by adopting RET. This is because the hotel sector is one of the biggest electricity consumers among commercial buildings, spending approximately 10% of their budget on energy to provide 24-h services such as air-conditioning, space and water heating, lighting, lifts, and kitchen equipment [86,87]. In 2016, Queensland had 1235 establishments including hotels, motels, guesthouses, and serviced apartments with more than 15 rooms [88]. The number of hotel establishments and their energy consumption are expected to rise as the tourist visitor nights in Queensland increased by 5.7% in 2017–2018 [89]. The electrical grid distribution is not available Queensland-wide [90]. It is assumed that some hotels still rely on diesel generators, which further emit GHG through combustion. No significant findings of how many hotels are adopting RET currently worldwide, except for [91] who found that the RET adoption in the hotel sector globally is low with the exception of the thermal solar. Thus, research about the variables contributing to the RET adoption in the hotel sector in Queensland is required to promote the RET adoption.

A systems approach helps to understand different perspectives of the hotel RET adoption because the approach captures variables' non-linear and feedback relationships. Taking a hotelier perspective, factors influencing the hotels' RET adoption decision are: The hotelier's perceived RET financial benefits, hotel's organisational values, hotel size, hotelier's beliefs of the RET usefulness [92–95]. Taking a government perspective, the policies that protect the monopoly of centralised electricity generation

can hinder the RET breakthrough [96]. The RET adoption is also influenced by the energy storage price, and grid distribution and skilled workforce availability [96–98].

Different perspectives on the RET adoption highlight interactive components which affect an RET adoption decision, and their inherent non-linear relationships. In addition, different perspectives indicate possible multiple stakeholders and an interdisciplinary topic; warranting a systematic approach to identify stakeholders and measure the literature breadth. The given RET adoption in the hotel sector is an emerging topic, integrating that a structural-analysis would provide modellers with a system preunderstanding. Thus, this research adopts a multi-methodology approach to develop the CLDs.

4.1. Step 1: Problem Articulation

4.1.1. Stakeholder Identification

Experts identified stakeholders related to the hotel RET adoption in Queensland in this research. Experts can represent different stakeholder perspectives [55] suitable for this multi-disciplinary topic. In this research, one tourism industry and one engineering expert have identified 19 stakeholders (see Table 2), classified into seven categories: The hotel sector, tourists, the government, RET companies, the community, the financial sector and electricity providers. Both experts agree that: The RET industry can influence RET adoption the most, the hotel sector can influence and is affected by RET adoption the most, and the local community and the environment are affected by such decision the most. No stakeholder is identified in the 'least' category. This research aims to understand the variables contributing to the hotel RET adoption from different perspectives, thus we avoid any trade-off and include all identified stakeholders. Modellers reserve the right to represent the environment. This research does not seek expert consensus about stakeholder identification.

Table 2. Expert identified stakeholders influencing, both influencing and affected by, and affected by the hotel RET adoption in Queensland, Australia.

Expert	Influencing		Influencing and Affected		Affected	
	Most	**Moderate**	**Most**	**Moderate**	**Most**	**Moderate**
Tourism	RET consulting company	-Federal Gov. * -Guest -Hotel chain head office	-Hotel engineer -Hotel manager -Hotel owner	-Bank -State Gov. -Electricity company	Atmosphere	Community
Engineering	RET industry		-Hotel owner -State Gov. -Financial institution	-Tourists		-Local Gov. -Local community -Koalas

* Gov. = Government.

4.1.2. Variable Inventory

The next step is to identify variables related to the hotel RET adoption, first using the SQLR quantitative approach followed by the qualitative approach. For SQLR, original research papers published in English language academic journals were obtained by searching electronic databases including Science Direct, Scopus, ProQuest, Sage, and Web of Science. These searches were carried out between 1–28 November 2016. The keywords used in these searches were: 'hotel', 'motel', 'caravan park', 'tourist accommodation', 'resort', 'guest service*', 'camping ground', 'tent', 'camp', 'lodge', 'inn', 'RV park', 'apartment', 'caravan park', 'bungalow' and a combination of 'renewable energy', 'solar power', 'wind power', 'hydro power', 'geothermal', 'microgrid'. Excluding criteria are: (1) Review papers, book chapters, literature review, news, bulletins, datasets and research notes. However, reference lists of these papers were used to find additional academic papers; (2) papers addressing RET and related technologies that do not result in electricity; (3) fuel cells which are hydrogen fuelled by non-renewable energy; and (4) water pumps, desalination units, and electric cars

even if they are used in tourist accommodation and fuelled by renewable energy resources. Papers must collect data from existing or modelled tourist accommodation. Research on a hybrid system with RET was included. The review includes electricity generation from renewable energy resources and multi-purpose functions such as cooling and heating. Electricity produced from RET must be used to support the tourist accommodation. A total of 52 research journal papers and 81 variables related to tourist accommodation and RET were identified. Discussing the SQLR result is beyond this paper's scope.

One tourism and two engineering experts revised the 81 variables, their names and interpretations. Experts can represent stakeholder perspectives and are appropriate for a validating task [55]. Experts merged and split some variables for clarity, resulting in 38 variables (see Appendix A). Thirty-eight variables serve as a starting point for CLDs' development but not a final list.

4.2. Step 2: Formulating a Dynamic Hypothesis

4.2.1. Identifying Endogenous Variables

Next, we identified endo/exogenous variables by using a quantitative MICMAC method, followed by a qualitative stakeholder review. For the MICMAC method, the 38 variables identified in the previous process were arranged into a matrix, equivalent to 1444 questions (38×38). Two governmental departments related to energy and innovation, two RET companies, two hotel accountants, two hotel engineers, two hotel managers, and one financial institution were approached. However, we were unable to organise a workshop for the MICMAC completion due to the stakeholders' other commitments. Therefore, we sent the matrix and variable definitions to stakeholders to be filled in individually. Space was given at the end of the matrix should stakeholders wish to add their own variables. None has taken this option. Stakeholders had 14 days to complete the matrix, with an email reminder sent on the seventh day. Two hotel accountants, two hotel engineers, and two hotel managers completed the matrix. The low response rate could be due to the length of time needed to complete the matrix. The small sample size is acceptable because the MICMAC process is based on the experts' opinions rather than a statistical mean [63]. The stakeholders' responses were summarised using the geometric mean and analysed in the MICMAC software version 6.1.2. The geometric mean is selected over the mean and median because it is insensitive to the skewed data and works well with the small sample size [99].

We identified endo/exogenous variables through MICMAC's *direct* influence and dependence chart. Based on the stakeholders' ranking, MICMAC classified 38 variables into nine roles (Figure 2). The MICMAC categories suggest that 'availability of the workforce' and 'public engagement in RET policy' are disconnected variables. Decisions to exclude disconnected variables were discussed during stakeholder interviews.

4.2.2. Structural-Analysis MICMAC Results

MICMAC produces a displacement map and direct/indirect influence graph, which can be used to illustrate the complex system of the RET adoption in the hotel sector. First, MICMAC's displacement map shows that seven variables changed their categories when comparing their *direct* and *indirect* influence and dependence. These changes include: (1) 'hotel availability of finance' from relay to determinant variable; (2) 'eco-friendly hotel design' from stake to target variable; (3) 'tourist willing to stay in RET hotel' and 'tourists' electricity consumption in room' from autonomous to depending variables; (4) 'travel season' from secondary to disconnected variable; and (5) 'tourist willing to pay for RET' from determinant to disconnected variable. These changes indicate possible hidden variables that connect between them and the hotel RET adoption. Modellers referred to this information during stakeholder interviews.

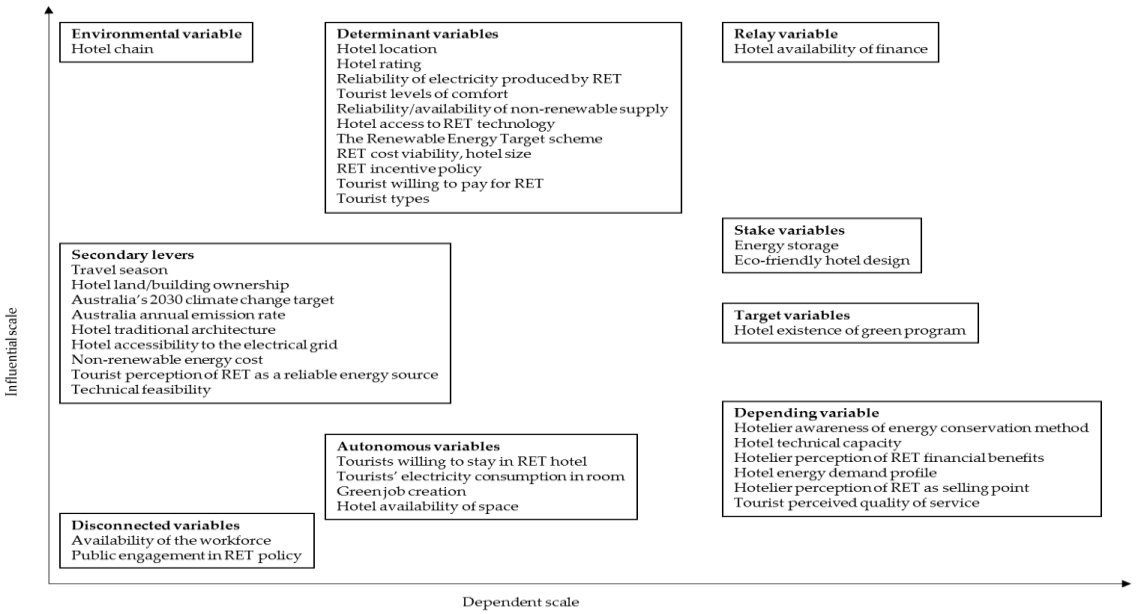

Figure 2. Roles of variables related to the renewable energy technology adoption in the hotel sector in Queensland, based on Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC)'s direct influence and dependence map.

Second, MICMAC maps weak, moderate and strong *direct* influence relationships between variables. For clarity, Figure 3 displays only strong *direct* influence relationships. Figure 3 shows 24 variables are strongly related in the Queensland context. Arrows concentrate particularly on energy storage, hotel technical capacity, and non-renewable energy cost. However, MICMAC does not indicate whether the relationships are positive or negative. We used these arrows to draw the CLDs. The CLDs and direct relationships were later discussed with stakeholders.

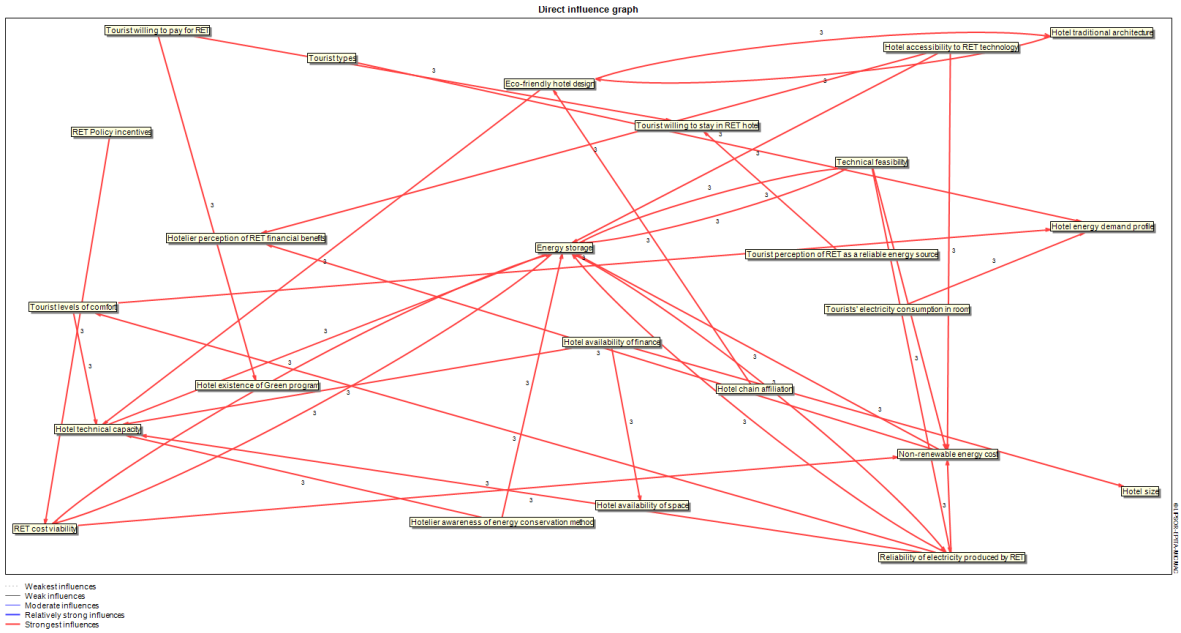

Figure 3. Direct influence graph representing the strongest influence of variables of the RET adoption in the hotel sector in Queensland.

MICMAC also indicates three strong *indirect* influence relationships from: (1) 'hotel availability of finance' to 'existence of Green program in hotel'; (2) 'hotel rating' to 'hotel energy demand profile';

(3) 'hotel chain affiliation' to 'hotel energy demand profile', indicating hidden variables between the pair. We discussed these relationships with stakeholders during interviews.

4.2.3. Mapping System Structure Using CLD

Developing the CLDs of the hotel RET adoption went through five main stages, using the VENSIM software version DSSx32 6.3E (Ventana Systems, Inc., Harvard, MA, USA.). In the first stage, we developed a preliminary CLD based on variables and relationships found in the SQLR. In the second stage, we added MICMAC's *direct* strong variable relationships and marked the role of each variable, resulting in the CLD_1. In the third stage, we asked individual stakeholders face-to-face to review CLD_1. In these meetings, we explained the concept of systems thinking and the research problem and asked stakeholders if the CLD_1 coincided with their opinions. Changes to CLD_1 from one interview were incorporated to the next. Any disagreements between interviews were clarified in the stakeholder engagement workshop. Interviews results in CLD_2. In the fourth stage, we organised a stakeholder engagement workshop to review CLD_2. Stakeholders received an information package about systems thinking, CLD_2 copied, and variable definitions one week prior to the workshop. At the workshop, CLD_2 was presented and stakeholders were asked to amend variables and relationships with justifications. The stakeholder engagement workshop resulted in CLD_3. At the final stage, CLD_3 was presented at the 2017 International Congress on Modelling and Simulation Conference, held in Tasmania, Australia [100] and again at the 2018 Council of Australasian Tourism and Hospitality Education Conference, held in Newcastle, Australia [101]. Conference attendees were invited to amend variables and their relationship. These revisions resulted in the final CLD. No changes to CLD_3 were made at either conference. Stakeholders present at each research stage are summarised in Table 3.

Table 3. Involving stakeholders at each stage of the CLD's development (MM = MICMAC, I = one-on-one interview, WS = stakeholder engagement workshop).

Stakeholder Category	Stakeholder Group	Data Collection Method
Hotel sector	Hotel managers	MM, I
	Hotel owners	MM, I
	Hotel engineers	MM, I
	Hotel accountants	MM, I
	Hotel sustainable accreditation companies	I, WS
Tourists	Academic experts in tourist behaviours	I, WS
Government	State government	WS
	Local government	WS
	Tourism organisation	WS
Electricity provider		I

1. Preliminary CLD

Figure 4 shows the preliminary CLD developed from the SQLR. Figure 4 contains 38 variables, grouped in five sectors including the hotel, technology, tourist, policy, and other sectors, each highlighted with different colours. The preliminary CLD shows most arrows pointed to the 'hotel RET adoption' without feedback loops, indicating a linear approach by the previous research.

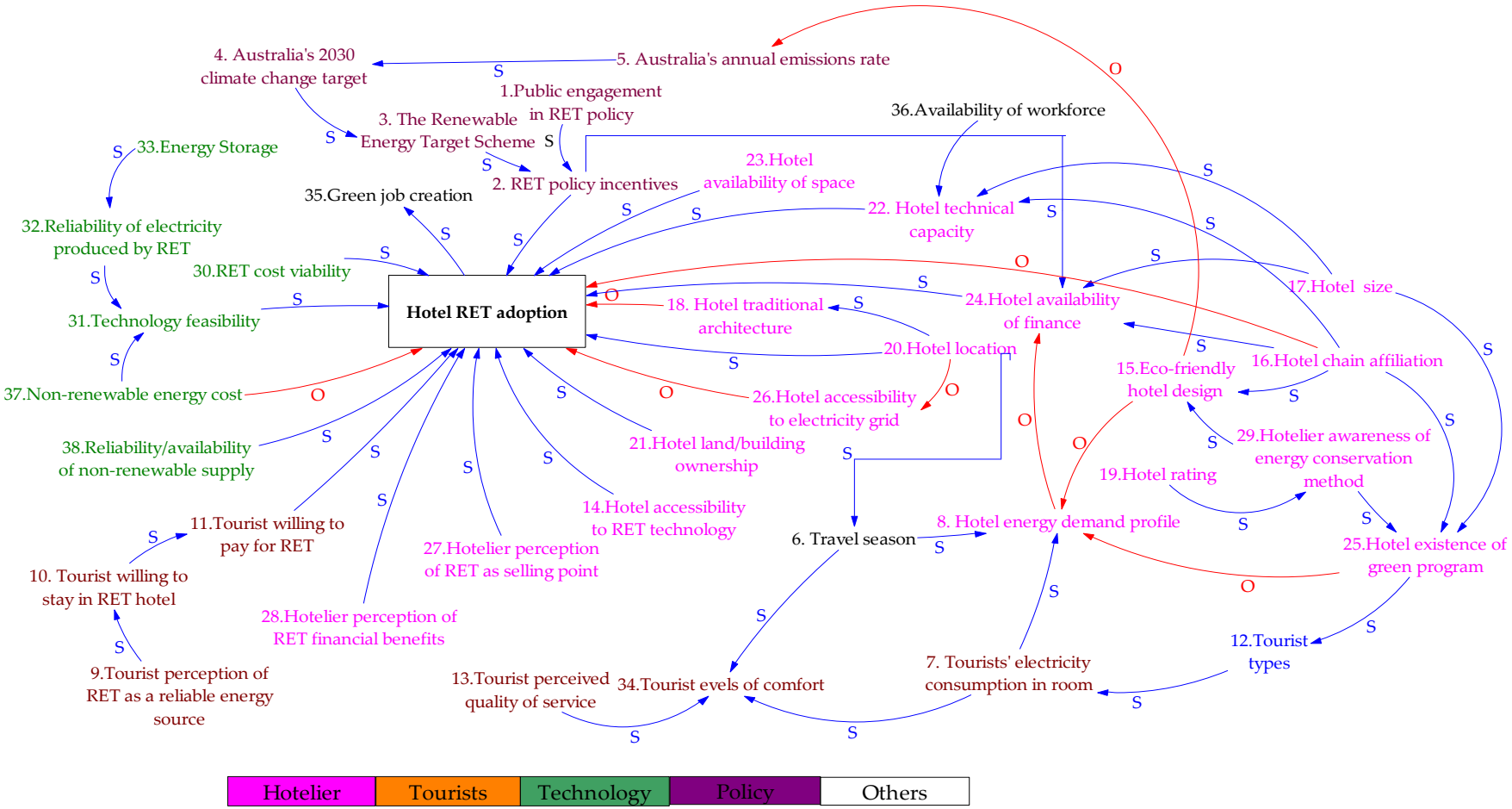

Figure 4. The preliminary CLDs of RET adoption in the hotel sector based on the systematic quantitative literature reviews.

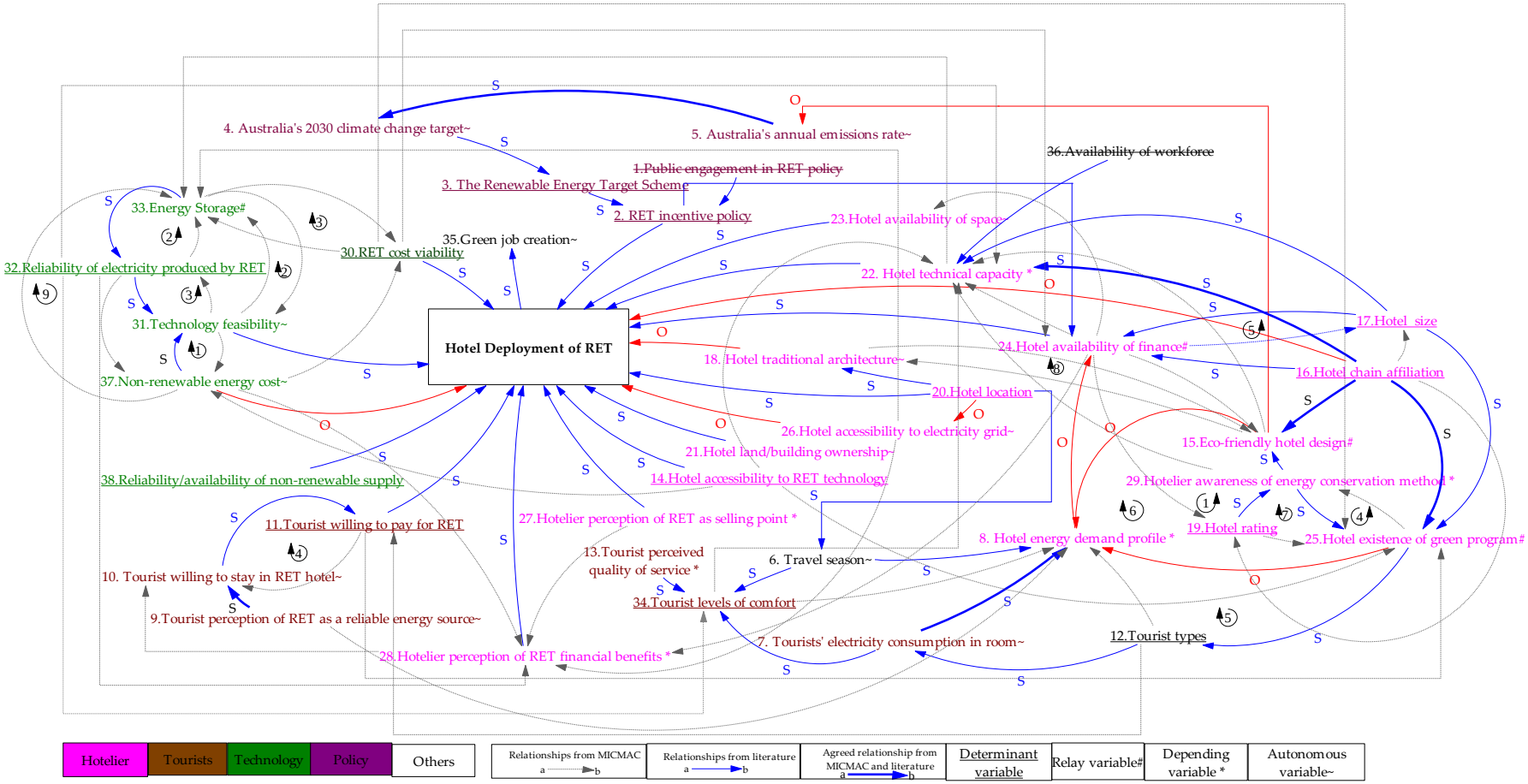

Figure 5. CLD_1 of RET adoption in the hotel sector within Queensland, based on the systematic quantitative literature review and MICMAC.

2. CLD_1

Figure 5 shows CLD_1 produced by integrating MICMAC's and SQLR's variable relationships. The integration reveals three system complexities. First, CLD_1 exposes additional relationships unexplored in the previous research (see dotted arrows), indicating limited research about the hotel RET adoption. Only six stakeholder-identified relationships have been researched previously (see thick arrows), including: Australia's annual emission rate—Australia's 2030 climate change target, tourists' perception of RET as a reliable energy source—tourists willing to stay in the RET hotel, tourists' electricity consumption in room-hotel energy demand profile, hotel chain affiliation—eco-friendly hotel design, hotel affiliation—hotel implementing a green program, and hotel chain affiliation—hotel technological capacity.

Second, CLD_1 has 14 feedback loops, including five counter clockwise and nine clockwise loops (Table 4). The next stakeholder interview can illuminate whether these loops are reinforcing (creating exponential growth/decline over time) or balancing (stabilising the system overtime) loops. Third, CLD_1 illuminates each variable's role to the hotel RET adoption, enhancing the modellers' understanding of the system.

Table 4. Descriptions of the feedback loops within Figure 5.

Loop Name	Reinforce/Balancing	Variables Involved
Counter clockwise 1	Unknown	19, 29, 15, 8, 24
Counter clockwise 2	Unknown	32, 33
Counter clockwise 3	Unknown	31, 32
Counter clockwise 4	Unknown	25, 29
Counter clockwise 5	Unknown	17, 24
Clockwise 1	Unknown	37, 31
Clockwise 2	Unknown	33, 31
Clockwise 3	Unknown	33, 30
Clockwise 4	Unknown	11, 10
Clockwise 5	Unknown	25, 12, 7, 8, 24,19
Clockwise 6	Unknown	25, 8, 24, 19
Clockwise 7	Unknown	25, 19, 29
Clockwise 8	Unknown	15, 18
Clockwise 9	Unknown	37, 33, 32, 31

The modellers prepared stakeholder interviews based on these insights. Careful interview preparation can actively engage and interest stakeholders [102].

3. CLD_2, CLD_3, and Final CLD

During the interviews and workshop, each stakeholder group had its own concerns. For example, the hotel sector prioritised customer satisfaction, and identified RET adoption drivers as 'tourist's levels of comfort' and tourist's perceived value for money, 'the reliability of electricity produced by RET', and 'the hotel owner's perceptions of RET financial benefits'. The government representatives were interested in variable contributing RET policy incentives; the electrical provider in future demand for grid electricity and RET incentive policy; and the hotel's sustainable accreditation in reducing the hotel's impact on the environment.

The final CLD produced from the stakeholders' engagement workshop and conference discussion is shown in Figure 6. Many variable names changed after interviews and workshop. Only 14 out of 36 variables identified by the SQLR remained, while seven were deleted, 12 were evolved, three dissolved, and 13 newly added, resulting in a total of 42 variables in the final CLD (see list of variables in Appendix A).

The final CLD contains 22 feedback loops, including three balancing and 19 reinforcing loops (see Table 5). Several final CLD feedback loops were built on the SQLR and MICMAC's result. These

loops include: (1) The influence of energy storage on the RET electricity reliability, and the RET benefit; (2) the influence of a hotel owner/manager's perception of the RET financial benefits on the RET adoption, and the perception's reliance on the RET incentive policy, the RET benefits on marking and expense savings, and grid price; (3) the impact of the hotel's electricity expense on the hotel's revenue and the RET adoption decision; and (4) the importance of a hotel engineer's efficiency to lead hotels to adopt RET.

Table 5. The feedback loop descriptions within Figure 6.

Loop Name		Variables Involved (Number)
Balancing	B1	19, 35
	B2	1, 2, 3, 4, 5, 6, 7, 8, 9
	B3	1, 2, 3, 4, 10, 11, 12, 13, 6, 7, 8, 9
Reinforcing	R1	1, 2, 12, 13, 6, 7, 8, 9
	R2	14, 15
	R3	14, 15, 16, 17, 18
	R4	14, 7
	R5	1, 2, 3, 4, 19, 17, 18, 14, 7, 8, 9
	R6	19, 20, 2, 3, 4
	R7	4, 10, 11, 3
	R8	21, 22, 23, 24
	R9	21, 22, 24
	R10	21, 25, 24
	R11	21, 6
	R12	1, 2, 21, 6, 7, 8, 9
	R13	1, 2, 21, 22, 23, 26, 27, 7, 8, 9
	R14	1, 2, 21, 25, 28, 7, 8, 9
	R15	1, 2, 21, 25, 29, 30, 7, 8, 9
	R16	1, 31, 32, 26, 6, 7, 8, 9
	R17	1, 31, 32, 33, 16, 17, 18, 14, 7, 8, 9
	R18	1, 2, 12, 34, 33, 16, 17, 18, 14, 7, 8, 9
	R19	1, 31, 32, 26, 27, 7, 8, 9

Interviews and workshop revealed several hidden variables. These variables were: (1) Hotel will set aside funds for energy conservation methods only if and when the hotel is aware of its financial benefits; (2) hotel rating has an influence on hotel energy demand profile, but through tourists' attitude towards the environment and their behaviour; (3) being part of a hotel chain affiliation has an influence on the hotel energy demand profile, but through bargaining power with electricity retailer; (4) even if the engineer is very skillful, the hotel will not be able to adopt the RET if it does not have money, and vice versa; (5) tourists would be willing to stay at the hotel with RET if its electricity is reliable; and (6) the amount of electricity consumption in a room depends on the tourists' attitude towards the environment and their green behaviour. This indicates that some hidden variables would have been overlooked had such a systematic and exhaustive reflection not taken place.

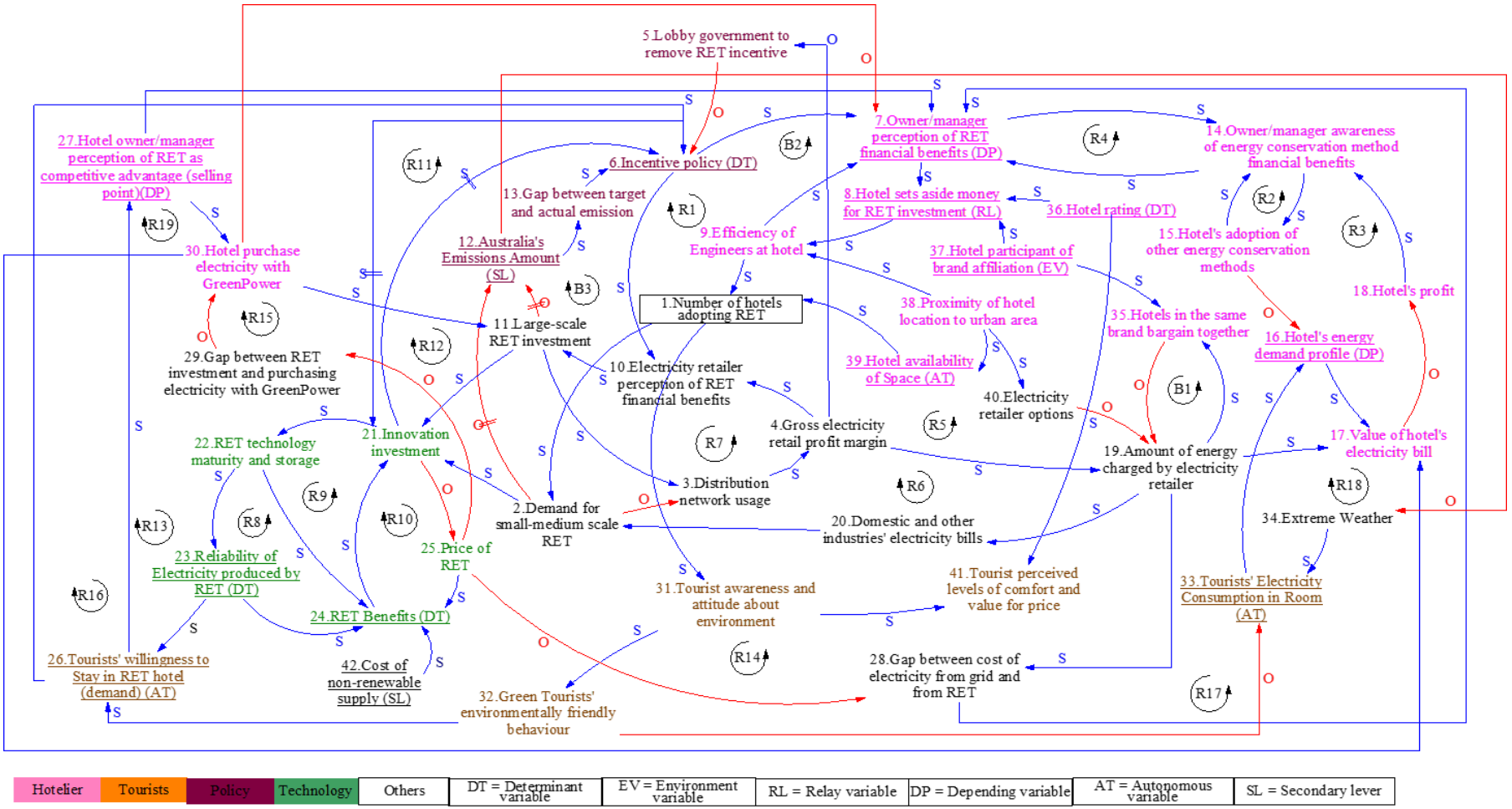

Figure 6. The final CLD for the RET adoption in the hotel sector in Queensland, Australia, developed from the systematic literature review, MICMAC, stakeholder interviews and workshop.

5. Conclusions and Further Work

This research presents a multi-methodology approach to develop the causal loop diagrams (CLDs). We integrate the quantitative approach including stakeholder identification method (SI), a systematic quantitative literature review (SQLR), and a structural-analysis MICMAC, with the traditional qualitative approach including stakeholder interviews and an engagement workshop. Our proposed multimethod maintains the essence of the original CLD process but adds new stages to define stakeholders, variables, their roles and relationships in a quantitative and logical way. The key findings and main contributions to developing the CLD process are:

- Allowing detailed stakeholder identification based on their roles and the role degrees.
- Providing a quantifiable literature scope to identify relevant variables.
- Identifying endogenous and exogenous variables quantitatively.
- Illuminating possible direct and indirect relationships between variables quantitatively.
- Indicating possible hidden variables quantitatively.

The multi-methodology approach was applied to develop the CLDs in a case study. In our opinion, the case complexity illustrates the multi-methodology application advantages and may be useful for other studies.

However, the multi-methodology approach to develop the CLDs has some limitations. First, SI obscures how to deal with different identified stakeholders. In this research, both stakeholders have identified similar results. However, other research may encounter different stakeholder identification. We recommend future research to use more than two experts and seek consensus when identifying stakeholders. Second, the MICMAC matrix is time-consuming, and took more than three hours for stakeholders. Future research is recommended to reduce the variable numbers. We conclude that managing the vagueness in the stakeholder and modeller judgement will improve the CLDs developing process. Hence, the multimethod approach can be helpful.

We acknowledge that translating the CLDs to the quantitative model is a non-trivial process. Our motivation underlying this work is that modelling the quantitative model through the CLDs would benefit from engaging early with the stakeholders, understanding their mental models, and formulating the dynamic hypotheses [2]. We focus on improving the CLDs developing process before translating into the quantitative model. This research is limited to a qualitative conceptualization. Developing a quantitative model of the hotel RET adoption in Queensland is ongoing and will be published in a subsequent paper. The literature on converting the CLDs to a quantitative model can be found in [2,103].

We also acknowledge a low agreement about whether to use the CLDs or quantitative model to conceptualize the studied phenomenon. Engaging in such a debate is beyond the scope of this paper, but can be found in [8,104].

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Appendix A.

Table A1. List of Variables Related to the RET Adoption in the Hotel Sector, Queensland

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Public Engagement in RET policy	Public perception is considered when designing renewable energy policy.	[105,106]	Disconnected	Delete by researchers.
M *	RET incentive policy	Feed-in-tariff and investment funding through the Australia Renewable Energy Agency (ARENA).	[107,108]	Determinant	Keep. Name change to 'Incentive policy' as per stakeholders.
M *	The Renewable Energy Target scheme	The RET scheme operates in two parts: Large Renewable Energy Target (LRET) and Small-Scale Renewable Energy Scheme (SRES) The LRET creates a financial incentive for the expansion of renewable energy power stations. The new target for LRET is 33,000 GWh in 2020 or equivalent to 23.5% of Australia's electricity generation. The SRES creates financial incentives for households, small businesses and community groups to install small-scale renewable energy system.	[109]	Determinant	Dissolve into 'Incentive policy', 'Large-scale RET investment', and 'Demand for small-medium scale RET' as per stakeholders.
M *	Australia's 2030 climate change target	Australia will reduce emissions to 26–28% on 2005 levels by 2030. This target represents a 50–52% reduction in emissions per capita and a 64–65% reduction in the emissions intensity of the economy between 2005 and 2030.	[110]	Secondary lever	Evolve to 'Gap between the target and actual emission' as per modelling experts.
M *	Australia's annual emissions rate	The amount of Australia's annual emissions. For example, in 2014–2015 Australia emitted 549.3 Mt CO_2-e. This figure is the second lowest emissions level since, and 1.9 per cent below, 2000 levels (560.2 Mt CO_2-e) and 10.2 per cent below 2005 levels (611.4 Mt CO_2-e). The level of atmospheric gases including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) which are responsible for the greenhouse effect and climate change.	[111,112]	Secondary lever	Keep. Name change to 'Australia's emission amount' as per stakeholders.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Travel season	Certain seasons (i.e., winter, summer) are perceived by tourists to be favourable to visit a certain destination. For example, a favourable season for a coastal hotel is summer, and winter for a ski resort. Electrical load of a hotel varies according to a variable tourist presence during travel season.	[113]	Secondary lever	Evolve to 'Extreme weather' as per stakeholder.
M *	Tourists' electricity consumption in the room	The amount of electricity consumed by tourists during their stay at the hotel. Tourists consume higher rate of energy during their stay in the hotel when compared with when they are at home. This irrational behaviour results from tourists paying a flat rate for their room irrespective of amount of energy consumed. Tourists also wish to enjoy the hotel's available service to the maximum during their stay.	[114]	Autonomous	Keep
M *	Hotel energy demand profile	The amount of electricity used by the hotel on heating, cooling and food processing. Types of hotel and star rate determine the availability of guest facilities such as a swimming pool, spa, air conditioner, heater, etc. In addition, the hotel operates 24 h per day.	[115,116]	Depending	Keep
M *	Tourist's perception of RET as a reliable energy source	Tourist's perception of RET as a reliable source of energy for the hotel.	[117]	Secondary lever	Evolve to 'Tourists' perceived levels of comfort and value for price' as per stakeholders.
M *	Tourist willing to stay in RET hotel	Tourists willing to stay in hotels that invest in RET.	[117–119]	Autonomous	Keep. Name change to 'Tourists' willingness to stay in RET hotel (demand)' as per stakeholders.
M *	Tourist willing to pay for RET	Tourists willing to pay extra for hotels that invest in RET.	[117–119]	Determinant	Delete as per stakeholders as it is covered in 'Tourist willing to stay in RET hotel'.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Tourist types	Tourists are classified as either eco-conscious or others. Eco-conscious tourists are more concerned about the environment and demand more environmentally friendly services during their vacation than other types of tourists. Targeting these eco-conscious tourists can differentiate a hotel from its competitors. The hotel can imbue this message through marketing materials, stay packages, and advertising. Eco-conscious tourists, however, are highly suspicious of a hotel's commitment to the environment and can accuse such hotel of 'greenwashing'.	[120,121]	Determinant	Change to 'Tourists' awareness and attitude about the environment' and 'Green tourists' environmentally friendly behaviour' as per stakeholders.
M *	Tourist's perceived quality of service	Tourists' cognitive perception of the hotel's ambience including lighting, heating and cooling. This perception is influenced by the value of time travelling to and spending at the hotel, and money spent at the hotel to determine a hotel's quality of service. Quality of service influences the tourists' level of pleasure and perceived image of the hotel.	[114,122–125]	Depending	Evolve to 'Tourists' perceived levels of comfort and value for price' as per stakeholders.
M *	Hotel accessibility to RET technology	RET is available and accessible to a hotel that wishes to adopt it.	[95]	Determinant	Evolve to 'Number of hotels adopting RET' by researchers.
M *	Eco-friendly hotel design	Hotel designs can conserve energy and reduce GHG emission. Examples of these hotel designs are installing thermal insulation on the external wall; improving fabric, lighting, appliances; changing heat, ventilation and air-conditioning systems.	[126–128]	Stake	Delete by stakeholders.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Hotel chain affiliation	Whether a hotel is a part of a group operated by the same company or owner or not. Being part of a hotel chain influences hotel's environmental practices, availability of financial and technical resources that influence successful environmental management such as RET adoption. Being part of hotel chain can also prevent RET adoption due to bureaucracy problems associated with chain hotels.	[95,129,130]	Environment	Keep. Name change to 'Hotel participation of brand affiliation' as per stakeholders.
M *	Hotel size	Size of a hotel influences its environmental practices, availability of financial and technical resources which further determine the success of environmental management. A smaller hotel usually has unclear green policies such as RET adaptation and has less borrowing ability than a larger hotel.	[95,129,130]	Determinant	Delete by stakeholders.
M *	Hotel traditional architecture	The traditional architecture of a hotel, particularly on the island, plays a dominant role in its beauty. This design becomes a challenge when integrating RET such as solar collectors.	[91,131]	Secondary lever	Delete by stakeholders.
M *	Hotel rating	Hotel-star rating influences its business's environmental concern and willingness to use energy-efficient appliances. A hotel with a higher star rating has greater environmental concern and willingness to use energy-efficient appliances than a hotel with a lower star rating.	[94]	Determinant	Keep
M *	Hotel location	Where the hotel is situated influences the type of RET it adopts. For example, wind energy is technologically feasible and economically viable for coastal hotels, while solar energy suits a desert safari camp. Hotel location also influences accessibility to the grid.	[132–136]	Determinant	Evolve to 'Proximity of hotel location to urban area' as per stakeholders.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Hotel land/building ownership	Hotels that do not operate on their own land or in their own building are restricted in physical development such as RET adoption.	[95]	Secondary lever	Delete by stakeholders.
M *	Hotel technical capacity	The hotel has engineers who support and promote energy projects.	[91,131]	Depending	Evolve to 'Efficiency of engineers at a hotel' as per stakeholders.
M *	Hotel availability of space	Available area for RET installation in a hotel.	[95,137]	Autonomous	Keep
M *	Hotel availability of finance	Whether or not a hotel has a fund available for RET investment in the hotel.	[91,95,131]	Relay	Keep. Name change to 'Hotel sets aside money for RET investment' as per stakeholders.
M *	Existence of a Green program at the hotel.	Whether or not a hotel has a social and environmental responsibility program. This green program can act as an environment advertising campaign and create an environmental image among tourists. This campaign is effective to target eco-conscious tourists.	[93,95]	Target	Evolve to 'Hotel's adoption of other energy conservation methods' as per stakeholders.
M *	Hotel accessibility to the electrical grid	The electrical grid such as a transmission line is within reach of a hotel. Hotel's location that is in a remote area or island may limit access to the grid, causing them to generate their own electricity through diesel generator or RET.	[113]	Secondary lever	Evolve to 'Gap between the cost of electricity from the grid and from RET' as per modelling experts.
M *	Hotelier perception of RET as a selling point	Hotelier perceives that adopting RET may improve their hotel image as being green and has a marketing effect.	[92]	Depending	Keep. Name change to 'Hotel owner/manager perception of RET as a competitive advantage (selling point)' as per stakeholders.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Hotelier perception of RET financial benefits	Hotelier perceives that adopting RET may save hotel energy expenditure.	[95]	Depending	Keep. Name change to 'Owner/manager perception of RET financial benefit' as per stakeholders.
M *	Hotelier awareness of energy conservation methods	The hotelier is aware of methods that can be adopted in a hotel to reduce energy consumption. RET is rarely considered to reduce energy consumption. Other practices including recycling and not changing guest towels daily are perceived to reduce energy consumption.	[94,116,127]	Depending	Evolve to 'Owner/manager awareness of financial benefits of energy conservation as per stakeholders.
M *	RET cost viability	The cost of making electricity from RET is less than its net present costs including capital, replacement and maintenance costs. This can be measured by, for example, money saved from using RET, revenue from selling electricity back to the grid, and simple payback period. Interest rates and inflation rates also moderate the cost of RET.	[138–142]	Determinant	Keep. Name change to 'RET benefits' as per stakeholders.
M *	Technical feasibility	RET adoption in a hotel is possible when measured against: (a) Environmental inputs, i.e., solar radiation, wind speed and air temperature; (b) The length of working life of RET; (c) Payback period; (d) Size of RET measured by kW it produces and a physical area size required; (e) Options of the electrical delivery system to a hotel including on grid, off-grid, or hybrid systems; (f) The availability of mature and reliable core RET technology; (g) The availability of mature and reliable RET; (h) The adoption of SmartGrid.	[132,135,143–148]	Secondary lever	Dissolve into 'Innovation investment', 'RET technology maturity and storage', and 'RET benefits' as per stakeholders and modelling experts.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Reliability of electricity produced by RET	The ability of RET to produce power consistently.	[149,150]	Determinant	Keep
M *	Energy storage	Storage such as battery increases the energy flow between the grid and intermittent renewable power in a hotel.	[151]	Stake	Evolve to 'RET technology maturity and storage' as per stakeholders.
M *	Tourist levels of comfort	Tourist levels of comfort and perceived value that are influenced by the hotel's physical environment in the form of ambience particularly lighting, heating and cooling. Tourists' perceived levels of pleasure influence their revisit intention.	[114,152,153]	Determinant	Evolve to 'Tourists' perceived levels of comfort and value for price' as per stakeholders.
M *	Green job creation	Employment in an industry that is considered to produce environmental benefits such as renewable energy. Examples are jobs in RET manufacturing, installation and maintenance. Jobs in renewable energy can be found in the annual publication of the renewable energy status report such as REN21.	[106,154,155]	Autonomous	Delete by stakeholders.
M *	Availability of workforce	Appropriate trained workforce for the generation and distribution of the targeted RET.	[106,156–158]	Disconnected	Delete by researchers.
M *	Non-renewable energy cost	Price of non-renewable energy sources such as diesel and gas, and price of electricity purchased from centralised grid influences the feasibility of RET in a hotel and an RET adoption decision. If the price of diesel is low, hotels found that a diesel generator is more economical than RET, and the opposite when the price of diesel is high. Changes in non-renewable energy costs also determine the pace of RET development. The comparison between non-renewable and renewable energy costs determines when price subsidy and tax incentives for renewable energy electricity will be put in place.	[107,138,159–162]	Secondary lever	Keep. Name change to 'Cost of non-renewable supply' as per stakeholder.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
M *	Reliability/availability of non-renewable supply	Whether a hotel has access to a reliable and continuous supply of non-renewable energy or not influences a hotel's decision to adopt RET.	As per expert revision	Determinant	Delete by stakeholders.
CLD_{final} **	Number of hotels adopting RET	The number of hotels that acquire renewable energy technology to produce electricity for its own use.	Adjusted by researchers		Evolve from 'Hotel accessibility to RET technology'.
CLD_{final} **	Demand for small-medium scale RET	The quantity of a small to medium scale RET (that is not solar or wind farm) that the public and industries, including the hotel sector, are willing and able to buy.	Adjusted by stakeholders during I/WS		Dissolve from 'The Renewable Energy Target scheme'.
CLD_{final} **	Distribution network usage	The consumption of grid-based electricity between the public and industries including the hotel sector.	Added by stakeholders during I/WS		
CLD_{final} **	Gross electricity retail profit margin	The financial gain for electricity retailers after deducting expenses such as operating costs.	Added by stakeholders during I/WS		
CLD_{final} **	Lobby government to remove RET incentive	Industries that lose their profit to RET influence the legislator to withdraw RET incentives.	Added by stakeholders during I/WS		
CLD_{final} **	Electricity retailer perception of RET financial benefits	Electricity retailer perceives that switching to RET-sourced electricity will generate them an income through government incentive policy.	Added by stakeholders during I/WS		
CLD_{final} **	Large-scale RET investment	The amount of money used to establish or expand renewable energy power stations, such as wind and solar farms.	Adjusted by stakeholders during I/WS		Dissolve from 'The Renewable Energy Target scheme'.
CLD_{final} **	The gap between the target and actual emission	The difference between the amount of Australia's target and actual emissions. Calculate by Australia's target minus actual emissions.	Adjusted by modelling experts during I/WS		Evolve from 'Australia's 2030 climate change target'.
CLD_{final} **	Competency of engineers at hotel	A skillful and knowledgeable engineer who works at the hotel.	Adjusted by stakeholders during I/WS	Depending	Evolve from 'Hotel technical capacity'.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
CLD_{final} **	Owner/manager awareness of financial benefits through energy conservation methods	Hotelier perceives that adopting energy conservation methods (other than using RET) will save the hotel energy expenditure. These methods are, for example, recycling and not changing guest towels daily.	Adjusted by stakeholders during I/WS		Evolve from 'Hotelier awareness of energy conservation methods'.
CLD_{final} **	Hotel's adoption of other energy conservation methods	Hotel adopts energy conservation methods (other than using RET) to save the hotel's energy expenditure. These methods are, for example, recycling and not changing guest towels daily.	Adjusted by stakeholders during I/WS		Evolve from 'Existence of Green program in hotel'.
CLD_{final} **	Value of the hotel's electricity bill	Actual dollar value of the hotel's electricity bill.	Added by stakeholders during I/WS		
CLD_{final} **	Hotel's profit	The differences between hotel's earnings and expenses (including energy bills).	Added by stakeholders during I/WS		
CLD_{final} **	Amount of energy charged by the electricity retailer	The amount electricity retailers charge in an energy plan for a hotel business.	Added by stakeholders during I/WS		
CLD_{final} **	Domestic and other industries' electricity bills	Actual dollar value of electricity bill for domestic and industries other than the hotel sector.	Added by stakeholders during I/WS		
CLD_{final} **	Innovation investment	The monetary assistance from the public and private sectors for RET-related and development processes up until the product is commercially available.	Adjusted by stakeholders and modelling experts during I/WS		Dissolve from 'Technical feasibility'.
CLD_{final} **	RET technology maturity and storage	The availability of matured RET core technology and energy storage (i.e., battery).	Adjusted by stakeholders and modelling experts during I/WS		Evolve from 'Technical feasibility' and 'Energy storage'.

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
CLD_{final} **	Price of RET	The initial cost in dollar values of RET.	Added by stakeholders during I/WS		
CLD_{final} **	The gap between the cost of electricity from the grid and from RET	The difference between the cost of electricity purchased from the grid and produced by hotel-owned RET. Calculate by grid price minus the hotel's own.	Adjusted by modelling experts during I/WS		Evolve from 'Hotel accessibility to the electrical grid'.
CLD_{final} **	The gap between RET investment and purchasing electricity with GreenPower	The difference between the cost of electricity produced by the hotel-owned RET and purchased from the GreenPower providers. Calculate by RET investment minus purchasing electricity with GreenPower.	Added by modelling experts during I/WS		
CLD_{final} **	Hotel purchases electricity with GreenPower	Hotel purchases electricity from GreenPower providers.	Added by stakeholders during I/WS		
CLD_{final} **	Tourist awareness and attitude about the environment	Tourists being conscious of the environmental issues.	Adjusted by stakeholders during I/WS		Dissolve from 'Tourist types'.
CLD_{final} **	Tourists' perceived levels of comfort and value for the price	Tourist perceives value pricing. The value indicates what tourists think they derive from consuming a service.	Adjusted by stakeholders during I/WS		Evolve from 'Tourist levels of comfort' and 'Tourists' perceived quality of service'.
CLD_{final} **	Green tourists' environmentally friendly behaviour	Environmentally-conscious tourists engage in environmentally friendly behaviours such as demanding eco-friendly accommodation and reducing their energy consumption during their stay.	Adjusted by stakeholders during I/WS		Dissolve from 'Tourist types'.
CLD_{final} **	Extreme weather	Unusual weather conditions such as heat wave or blizzard.	Added by stakeholders during I/WS		Evolve from 'Travel season'.
CLD_{final} **	Hotels in the same brand bargain together	A company or owner that operates multiple hotels negotiates with electricity providers for a cheap electricity plan.	Added by stakeholders during I/WS		

Table A1. *Cont.*

Stage Used	Variable Name	Description	References	Role (As Per MICMAC)	Action
CLD_{final} **	The proximity of hotel location to urban area	The distance between a hotel location and the urban area. The shorter the distance, the closer the hotel to the urban area.	Adjusted by stakeholders during I/WS		Evolve from 'Hotel location'.
CLD_{final} **	Electricity retailer options	A number of electricity retailer options available for a hotel to choose.	Added by stakeholders during I/WS		

* M = MICMAC; ** CLD final = the final CLD.

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