A Semantic Web framework to enable sustainable lodging best management practices in the USA.

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Abstract

Due to the negative environmental impact, corporate social responsibility is an important concept in today's competitive lodging industry. Hotels attribute 75% of the overall lodging industries consumption of energy, water and non-durable goods. To remain competitive, organizations implement green lodging programs to demonstrate social responsibility. However, the understanding and implementation of best practices in sustainable tourism in the United States (US) is hampered because the standards that mandate the criteria are disparate. This paper describes a framework to aggregate the variety of best management practice standards so lodging properties and patrons can more easily identify gaps in compliance to the sustainable tourism standard's criteria. The proposed framework uses standards compliance information found on property sites to infer a ranking in green tourism across twelve third party US standards bodies. Herein, a hierarchy of pre-existing and newly developed domain-specific ontologies has been combined in a semantic knowledge base to describe the relationship between best management practices and accreditation criteria from each of the sustainable tourism standards bodies. Then, inference is used to automatically evaluate a properties conformance to all other green lodging programs based on an evaluation from one. This theoretical framework could better inform hotels and tourism operators on their best management practices and consumers when choosing between green lodging properties.

Keywords:

Sustainable tourism, green lodging best management practices, Semantic Web, ontologies

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1 Introduction

Lodging organizations implement green lodging programs in the United States to not only demonstrate social and environmental responsibility but also to potentially increase their market share. The lodging industry uses extensive amounts of water and energy, which have social, economic and environmental impacts. Bohdanowicz and Martinac (2003) stated "hotels have been found to have the highest negative impact on the environment of all commercial/service buildings, with the exception of hospitals". The industry has an opportunity to promote corporate responsibility through educating its staff and customers, embracing eco-friendly practices, and influencing complementary industries such as hotel suppliers (Rahman et al. 2012). Green lodging programs have emerged to quantify these educational and eco-friendly practices so properties can identify their gaps in the sustainable tourism criteria with less difficulty and patrons can use the information when making purchasing decisions.

The number of lodging businesses that now engage in "green" practices and eco-tourism is increasing rapidly (Foster et al. 2000; Schubert et al. 2010). However, the understanding and implementation of best practices in sustainable tourism is hampered because the standards organizations available in the United States that mandate the criteria are disparate. For example, Totem Tourism (2013) reported there are over 180 organizations that offer green tourism certifications for tourist attractions, destinations and hotels. They studied 137 agencies and concluded that over 36% of the green tourism certification bodies did not require third party verification. EcoGreen Hotel (2010) stated that there are so many green hotel certification programs that "the sheer volume of different programs and options has led to uncertainty among travelers, meeting planners and even the hotel operators themselves" (para 1). In the United States, there are twenty-seven states that currently have green lodging programs that are accredited via twelve third party certification bodies (Green Lodging News 2014). The US was the chosen geographical domain for this study due to the number of third party certification bodies compared to other countries. Currently, the evaluation criteria from each standards organization are available via Web but there are no simple ways to cross connect between them to ensure compliance with all relevant benchmarks.

Software systems can be used to automate data discoveries but barriers exist where data is stored in disparate data silos and content about standards criteria are only in human readable form on the Web. However, computers can be "taught" the meaning behind data and content with semantic technologies, which define standards that create "intelligent links" between concepts and "things" such as data, people and processes (Börner et al. 2012; Heath and Bizer 2011; Myers et al. 2013). If there is enough contextual information in a form that is available to, and processable by software then the systems can automatically infer linkages between disparate data. In other words, the process of revealing connections between the criteria for best management practice standards can be automated. Once automated, properties that conform to one certification body will be inferred to conform to all other relevant green lodging certification bodies.

This paper compares the best management practice criteria of twelve third party US green lodging certification bodies and describes a knowledge representation framework to align the variety of best practice standards using semantic technologies. The aim is to enable properties and patrons to identify the gaps in compliance to the sustainable tourism criteria with less difficulty. The proposed framework integrates data from property sites to infer a ranking in green tourism. Herein, a hierarchy of ontologies has been combined in a *Semantic Knowledge Base* (SKB) to describe to a computer the relationship between the criteria of best management practices from each of the green lodging programs. This study uniquely proposes semantic web technology to assist in the standardization and categorization of the green lodging program. By automating the evaluation process, consumers, hotels and tourism operators benefit as they can more easily discern between the criteria of the green lodging programs to make decisions of patronage and *Best Management Practices* (BMP).

The paper is organized as follows: Section 2 provides background on the twelve green lodging certification bodies and an overview of semantic technologies. Section 3 describes the methods applied to develop the comparison matrix of green lodging certification criteria as a foundation for the ontologies. Section 4 shows example outputs from the SKB and discusses the ramifications of the inferred outcomes. Section 5 provides some concluding remarks.

2 Background

2.1 Background on green lodging programs for sustainable lodging Best Management Practices (BMP)

In areas where tourism is imperative to the economy, such as Florida in the United States (US), the development of sustainable best practices in lodging is important to increase the industry's competitiveness and subsequent growth (Bohdanowicz 2005; Leslie 2007; Mensah 2006; Myung et al. 2012; Nicholls and Kang 2012; Pizam 2009; Rahman et al. 2012; Richins and Scarinci 2009). According to Jackson (2010) green lodging is defined as "deliberate and concerted efforts and activities taken to reduce or eliminate the negative environmental externalities associated with hotel operations. These negative externalities typically manifest themselves in energy usage, water usage, waste generation and air quality degradation" (p. 226). The average size hotel purchases more products in one week than 100 families buy in one year. A typical hotel room uses four times the amount of water than an average household due to all water related facilities and maintenance of grounds. The lodging industry also generates large volumes of waste including paper. Paper accounts for 40% to 60% of a property's waste (Environmental Protection Agency 2006). Through green lodging programs, the lodging industry is taking action to become socially responsible and reduce this enormous consumption of energy, water and waste.

There are three levels of green lodging certification programs classified by Jackson (2010) as first-party, second-party and third-party certifications. First-party certification refers to the hotel conducting a self-certification, which is not validated by any other independent organization. Second-party certification is an assessment conducted by an outside organization from the same sector of the hospitality industry. Third-party certifications are managed by independent, unbiased organizations using preset criteria for evaluation. For the purpose of this study, we have compared third party certification programs within the United States based on their certification criteria that include the aforementioned negative externalities in the definition of green lodging (Appendix A). This section will include a brief background and description of the twelve green lodging certification programs described by Green Lodging News (2014).

1) ***Florida Green Lodging Program*** **(FGLP):** The *Florida Department of Environmental Protection* (FDEP), as a subdivision of the *Environmental Protection Agency* (EPA), created the FGLP because of the need for lodging businesses to meet green lodging standards (Florida Department of Environmental Protection (FDEP) 2012). The FGLP was established to encourage the hospitality industry to continuously improve environmental performance through education and certification programs. There are currently 689 FGLP certified hotels and resorts within Florida. The FGLP certifies facilities based on environmental practices in six areas of sustainable operations (listed in Appendix A) and properties must follow ten specific guidelines that include (Florida Department of Environmental Protection (FDEP) 2012; Richins and Scarinci 2009):

    1) Identify an environmental champion.
    2) Obtain top management commitment.
    3) Create a green team.
    4) Conduct an environmental assessment.
    5) Establish goals and identify environmental improvement projects.
    6) Submit environmental baseline data to the FGLP.
    7) Implement environmental improvement projects.
    8) Evaluate and monitor the program.
    9) Schedule on-site certification visit.
    10) Practice continual improvement.

2) **Audubon International** is a nonprofit organization, which promotes environmental education and sustainable resource management (Audubon International 2013). The Audubon "GreenLeaf" pilot program began in 2009 in conjunction with the New York State Department of Environmental Conservation (NYSDEC) to certify lodging properties for sustainable practices. Audubon International has since updated the one to five "GreenLeaf" program to the Bronze, Silver, Gold or Platinum status. In August of 2012, they partnered with the FDEP Green Lodging Program and in December 2012 the FGLP updated their application to include the same criteria as Audubon International. Now both FDEP and Audubon

International use the best management practice standards in water quality, water conservation, waste minimization, resource conservation and energy efficiency, communication and education and indoor air quality. The Audubon International Green Lodging Program has approximately 150 certified hotels in New York and Florida (EcoGreen Hotel 2010).

3) **EcoRooms & EcoSuites (2011)** have 23 properties from 13 states listed on their web site as certified green lodges. They base their certification on eight criteria, shown in Appendix A. .

4) **Fresh Air Lodging (2013)** is part of the Wilmes Hospitality Consulting and Management Solutions and is a for profit organization that provide the fresh air lodges program along with other management services. There are only 17 properties in four states on their web site. To become certified in Fresh Air Lodging a hotel must meet at least 15 requirements continuously in four key areas. These key areas include:

    1) Capital improvements, which involves 24 possible requirements including energy star, water and air quality, etc.;
    2) Social responsibility, which involves 12 possible requirements in recycling and waste;
    3) Company policies, which involves 17 possible requirements in air quality(i.e., non smoking environments) and paperless programs; and
    4) Volunteerism, which involves four possible requirements for participation within the local community (Fresh Air Lodging 2013).

    This green lodging program would qualify as a second-party certification program since it is reviewed by another hospitality organization.

5) **The Green Concierge Certification** is a green lodging certification program provided by Hospitality Green LLC (2013). This nationally recognized third party certification program was developed in 2008 and has approximately 60 facilities currently certified. The program consists of three tiers (Bronze, Silver and Gold) and each property is evaluated on performance-based improvements with sustainable best practices in resource use, conservation and environmentally conscious practices (Hospitality Green LLC 2013). The use of the 13 criteria for certification, which are shown in Appendix A, were permitted by the founder of Hospitality Green for the purpose of this paper (E. Giannini 2012, personal communication, September 26).

6) **The Green Business Bureau (GBB)** (2013) is a nationally recognized, third-party Green Business Certification Program that provides green certification for small to medium sized lodging properties. They use a green lodging assessment that uses the EPAs initiatives as well as other areas from the hospitality industry. For the purpose of this study, the GBB gave permission to use the 15 hotel specific criteria, which have been included in the green lodging matrix (Appendix A) (Ashok 2013, personal communication, September 24).

7) **Green Globe International Inc. (GGII)** (2010) is a publicly traded "green" holding company. GGII owns the Green Globe brand, which is an independent certification of sustainable green travel and tourism businesses. The key performance areas include Greenhouse gas emissions, energy efficiency, conservation and management, management of freshwater resources, wastewater management and solid waste management. The Green Globe Certification Standard is based on 337 compliance indicators and four criteria in sustainable management, social/economic, cultural heritage and environmental factors. For the purpose of this study, the base line environmental assessment areas were used in the comparison matrix (Appendix A) (Green Globe International Inc. 2013, page 5)

8) **Green Seal** (2013) is a non-profit organization that assists shoppers to find real green products. Green Seal established a specific standards program for lodging properties in 1999, referred to as the GS-33. The GS-33 establishes specific requirements for hotels and lodging properties to follow to become Green Seal Certified. There are three levels of certification: bronze, silver and gold, and the requirements focus on six areas shown in Appendix A (Green Seal 2013).

9) **The Sustainable Travel International STEP Program** (2013) offers two distinct certifications for lodging depending on whether the property is standard or luxury accommodation. The Eco Certification Program is for all types and sizes of accommodations whereas the Luxury Eco-certification program is specifically for luxury accommodations (5 star diamond or higher rating). The criteria and standards for the certifications

are based on the Global Sustainable Tourism Criteria established by the *Global Sustainable Tourism Council* (GSTC). There are over 70 best practices with multiple levels from a base line program (bronze) intermediate (silver), advanced (Gold), and industry leader (Platinum) (Sustainable Travel International 2013). The Senior Director of Standards and Certification for Sustainable Travel International stated that the STEP Eco-Certification has eight main sections shown in Appendix A (R. Chappell 2013, personal communication, September 26)

10) **The Trip Advisor Green Leaders Program** (2013) rates a lodging property based on their holistic approach to green lodging practices. They offer four levels of certification including Bronze, Silver, Gold or Platinum with six sections of the questionnaire related to environmental practices (Appendix A).

11) **The UL Environment** (2013) provides environmental solutions for businesses and offers third party certification for hotels. UL certifies, validates, tests, inspects, audits and advises businesses on sustainable practices. They have five business areas including product safety, verification services, life and health, knowledge services and environment. However, the UL Sustainable Company Certification is the focus of this paper. UL has a *Sustainability Quotient (SQ), which i*s a comprehensive system of assessing, rating and certifying a business's sustainable practices. A company can apply for full enterprise level certification or focus area certification. To gain certification using the SQ there are 22 core indicators that are assessed, shown in Appendix A, according to the UL Getting Started Guide (2013).

12) **The United States Green Building Council (USGBC)** (2013) is a nonprofit organization committed to a sustainable future through cost-efficient and energy-saving green buildings. The USGBC is a group of leaders in the building industry who are working to promote environmentally sustainable buildings. The *Leadership in Energy and Environmental Design* (LEED) *Green Building Rating System* (GBRS) was created by the USGBC (Taylor et al. 2013) and measures performance in eight categories shown in Appendix A.

2.2 The Semantic Web technologies

Contextual information in a form that is processable by software can allow the system to automatically infer linkages and reveal connections between the criteria for best management practice standards. The Semantic Web links data so it can be accessed, reused and/or manipulated more readily by the machine (Antoniou and van Harmelen 2008). The technologies make available contextual information about the data, and thus make the data automatically processable by the computer to find hidden links, answer questions and infer conclusions. This form of machine processing enables the automation of tasks such as data fusion and data integration. When automated, the process of connecting related data can be used to explicitly connect implicit links between the green lodging certification's criteria.

Semantic technologies integrate information that is currently available on the Web with contextual definitions written in ontologies (Heath and Bizer 2011; W3C 2012). Ontologies describe "things" that exist within a domain, whether they are abstract or specific (e.g., a property, a green lodging program, a specific BMP criteria, components of that criteria, etc.) (Antoniou and van Harmelen 2008; Guarino et al. 2009). They specify the terms that describe the entities and relationships of a concept and constrain the interpretation of the concept with axioms and restrictions (Allemang and Hendler 2011; Hitzler and Parsia 2009). Logic systems such as propositional logic and *Description Logics* (DL) are then employed to derive decisions based on the explicit descriptions and constraints (Antoniou and van Harmelen 2008).

Ontologies can span many levels of complexity, dependent on the concept to be captured and purpose for the knowledge representation. The main difference between the types of ontologies is the degree of specificity that is required, which can range from formal or 'heavyweight' through to informal or 'lightweight' when defining a concept (Chandrasekaran et al. 1999; Lassila and McGuinness 2001). Heavyweight ontologies are applications of formal logical definitions (e.g., Description Logic axioms), to automate conclusions, assumptions and subsumptions through classification and inference. An advantage of a more formal logical definition include finer granularity when defining concepts, which makes possible detailed explicit descriptions of entities and a deeper reasoning over Web resources. In contrast, lightweight, informal ontologies such as domain vocabularies, thesauri or taxonomies, are less complex constructs, which is advantageous when the

ontology is required to be generic and flexible (Fernandez-Lopez and Corcho 2010). Specifically, the informal approach fosters simplicity for the creation and maintenance of the ontologies, and flexibility to maximise reuse (Allemang and Hendler 2011).

Ontologies can bridge disparate data held in data silos or available via Web (Antoniou and van Harmelen 2008). There are competing approaches to amalgamate heterogeneous data sources including data warehousing and data mining. However, the application of ontologies for these integration tasks is potentially more flexible as they can resolve the semantic conflicts in definitions that invariably arise from the application of diverse schematic sources such as those found in the different green lodging standards (Bikakis et al. 2013). Similar to the Semantic Reef project (Myers and Atkinson 2012; Myers et al. 2010), the ontologies created in this project range from lightweight to heavyweight to form a flexible, dynamic SKB where disparate data from a diverse range of sources are ingested so reasoning and inferences can be applied to extract latent connections among the BMP criteria within. Then, properties that conform to one certification body can be inferred to conform to all other relevant green lodging certification bodies.

2.3 Other ontologies that describe tourism concepts

2.3.1 The ContOlogy

The CONCERT framework is a model for context information management on visitors of a particular destination (Lamsfus et al. 2011; Lamsfus et al. 2010). CONCERT is based on a network of ontologies known as the ContOlogy Ontology, which incorporates the requirements identified in the field of human mobility and implements them in terms of motivation, preferences-demographics and roles. The framework aims for contextual computing in tourism where the network of ontologies focuses on the visitor and exploits context information to select relevant tourist objects (e.g., availability of a tourist destination, the feasible travel time, etc.).

The framework proposed in this paper is orthogonal to the CONCERT framework. The objective of the CONCERT framework is to assist tourists to make better-informed travel decisions via personalized, up-to-date on-trip assistance about tourist objects (e.g., attractions, accommodation, restaurants, etc.). In contrast, the proposed framework is specifically concerned with the level of green standards of a lodging property. The inferred results from the framework described in this paper could be ingested into the CONCERT framework to help travelers make decisions on not only lodging availability, but also whether a suggested accommodation aligns with their preferences in environmental friendly practices.

2.3.2 The HarmoNET ontology

The HarmoNET ontology is the central element within the *Harmonisation Network for the Exchange of Travel and Tourism Information* (HarmoNET) that aims to create an international network for harmonization and data exchange in the tourism industry (Fodor and Werthner 2005; HarmoNET 2013). The ontology describes the concepts of four specific areas in the tourism domain:

1) Events (e.g., conferences, marketing, etc.);
2) Accommodation (e.g., bed and breakfast, hotels, guesthouses, etc.);
3) Attractions (e.g., museum, a natural phenomenon, or a cultural district within a city, etc.); and
4) Gastro (i.e., food and drink entities).

The HarmoNET ontology evolved from the Harmonise ontology, which was modeled in RDFS and allows members of the HarmoNET network to share data with all other members through automated mapping services. This process aims to expose each member's tourism information to third parties in a format supported by all other members of the network, which enables the packaging of combined offerings, the creation of portals, etc (HarmoNET 2013).

The HarmoNet RDF Schema is a lightweight ontology that defines the vocabulary and relationships of the tourism domain. According to the Harmonise website "The primary role of the ontology is to provide a formal, common reference model for concepts and semantic information within the tourism area or domain. The ontology acts as a common language, or lingua franca, to which the local information dialects are mapped" (HarmoNET 2013). This ontology has been implemented in this framework as the foundation of the SKB where lodging property details can be ingested as instance data to the available class and property structure.

3 Design methodology

3.1 The green lodging certification criteria matrix

Three data collection methods were employed to ensure the validity and accuracy of the data, which was criteria information on each green lodging certification program. The methods included content analyses of the accreditation bodies' web sites, verbal communication via phone interviews using a semi-structured format and follow-up emails. The content analyses of the web sites identified and categorized the specific certification criteria. The phone interviews were conducted to verify the categorization and criteria that was collected from the web sites to clarify any ambiguities. Communications via email were conducted when the authorized contact from the certification organization was not available by phone.

The sample framework used to structure the comparison matrix (Appendix A) was obtained from the green lodging news web site, which offered a credible and comprehensive list of third party green lodging certification programs (Green Lodging News 2014). This study focused only on the US green certification programs where data was collected and the certification criteria were categorized, coded and analyzed using a content analysis method. The certification bodies that did not list the criteria were contacted by phone and a follow up email was used to increase the response rate.

A comparative study method was used to evaluate and compare the criteria from each of the green lodging standards bodies. The matrix of criteria was created to inform the development of the BMP GLCC ontology and to verify the accuracy the logical axioms defined in the ontology. To validate the SKB, a reverse-hypothesis approach was taken. This approach involved comparing the inferred outcome from the SKB to a manually calculated outcome; that is, to ground-truth the system. Properties in the south-east district of Florida that had earned a *Green Lodge Certification* from the FDEP were chosen to test the accuracy of the SKB as a tool to automatically align lodging properties with green programs (Scarinci and Myers 2013).

Appendix A shows the comparison matrix of the twelve green lodging certification programs. The criteria were compared between each standards body to determine which were similar (equivalencies) and which were subsets ("is a") of a broader category. The criteria number that is registered within each specific certification is listed under the equivalent criteria in the matrix.

3.2 The development of the Green Lodge Certification Criteria (GLCC) Ontology

The SKB developed for this project consists of the pre-existing HarmoNET ontology and the newly developed *Green Lodge Certification Criteria* (GLCC) ontology. The GLCC ontology is a domain-specific ontology created as part of this project to describe the relationships between the certification criteria from twelve third-party green lodging standards bodies. The GLCC ontology aligns to the HarmoNET ontology to enlist the pre-existing descriptions of tourism concepts and is written in OWL-DL so reasoning is possible (Allemang and Hendler 2011). The GLCC ontology extends the HarmoNET ontology with classes for BMP criteria and the transitive or equivalent relationships that exist between the criteria. These ontologies have been combined in a hierarchy to describe to a computer the relationship between the green lodging standards and the criteria they use in evaluating properties that take part in the various green lodging programs. Data on property conformance to a certification program is ingested to the SKB so reasoning and inferences can be applied to extract latent connections among the BMP criteria within.

The SKB ontologies, written in OWL, describe the relationships between the standards criteria from each standards body. The criteria matrix (Appendix A) was used to develop the GLCC Ontology. Each criteria from the standards were assessed to determine equivalencies and "is a" relationships that were then expressed in OWL DL (McGuinness and van Harmelen 2004). Essential to the development of this tourism/informatics project was the cross-discipline collaboration that entailed the combined perspectives from a green lodging specialist with human/computer translation functionality for the SKB (Myers and Atkinson 2012).

The SKB was developed using the Protégé free open source ontology editor (Protégé 2013). The Protégé framework was chosen as the basis of the SKB infrastructure because it offers wide developer and user support through an active development community for use-case applications such as described in this paper. Protégé offers a range of direct and indirect support for a variety of reasoning engines, such as Pellet (Mindswap

2007) and FaCT++ (2011). The automated classification processes are handled by a reasoner, or classifier. Reasoning engines are complex applications able to infer logical consequences from a set of asserted facts or axioms. They are utilised in this project to make assumptions and subsumptions based on the context and meaning defined in the axioms. Additionally, inference rules can be applied dynamically using a rule engine such as Jess and used to infer new knowledge from the existing OWL SKB (Jess 2011). Inference rules can be applied to determine partial membership of a superset green standard program. Development via the *Application Program Interface* (API) is possible because the open source nature of the licence permits full access to the source files, which will make future work to integrate a text mining component that can automatically ingest lodging property information to the SKB possible.

There is a need to link between the disparate standards programs that will allow management to align their BMPs among multiple programs and further offer more information about green practices so consumers can choose according to compliance. These linkages are not apparent, but instead hidden within the criteria of each program, which cannot easily be aggregated and synthesized by a human. The rationale of implementing a SKB as a solution is the facility to connect latent dots. That is, the reasoning engine's function is to extract hidden connections in the data based on explicit axioms about the relationships within and environment. The proposed framework can be extended to incorporate all levels of green programs and to include different country's programs.

3.2.1 The proposed framework - the HarmoNET ontology and the GLCC Ontology

The base level HarmoNET ontology is a lightweight ontology that defines descriptions of tourism concepts and is imported into the higher-level domain-specific GLCC OWL-DL ontology. Description logic is used to explicitly state the equivalency axioms and the relationships between the green lodging programs. A subset of the property axioms, which explicitly state the requirements of each standards body's certification requirements, is shown in Figure 1. This shows the criteria for the Audubon International Program is a subset of the criteria required for the EPA accreditation. Therefore, any property that has acquired EPA certification would also fill the requirements of Audubon International program.

The GLCC Ontology has been developed to clearly define the accreditation criteria from each of the twelve green lodging standards bodies to automate the evaluation process. This automation will show the full alignment (or lack of) to all green lodging programs for a tourist property based on only one evaluation. This knowledge can be applied to both management decisions to streamline BMP activities. Additionally, this information is valuable to the consumer so they can easily determine the properties green ranking to make an informed decision and potentially increase the consumer confidence in the Green Lodging Certification Programs. A decrease in "greenwashing" is also possible because the criteria for each of the certification bodies will be transparent. The outcome of the semantic inference can also be integrated with systems such as HarmoNET and/or CONCERT to assist consumers to make decisions on green lodging.

The proposed framework incorporates the HarmoNET ontology and the GLCC Ontology as the foundation of the SKB. The HarmoNET ontology lays a base vocabulary to describe the tourism domain. The GLCC ontology extends the HarmoNET ontology with detailed definitions of the green lodging programs and their specific accreditation criteria. Axioms are created to constrain the Boolean data type properties to list the criteria a property conforms too. For example, the Bahia Mar Beach Resort, Fort Lauderdale, set along the Intracoastal Waterway, has gained EPA certification. To state that the "Property" class instance, Bahia Mar, has explicitly passed the EPA evaluation for waste reduction can be written in N3 as[1]:

```
GLCC:has_waste_reduction_criteria rdfs:domain Property
GLCC:has_waste_reduction_criteria rdfs:range xsd:boolean
```

[1] Notably, the N3 statements shown are a subset of the full ontology axioms.

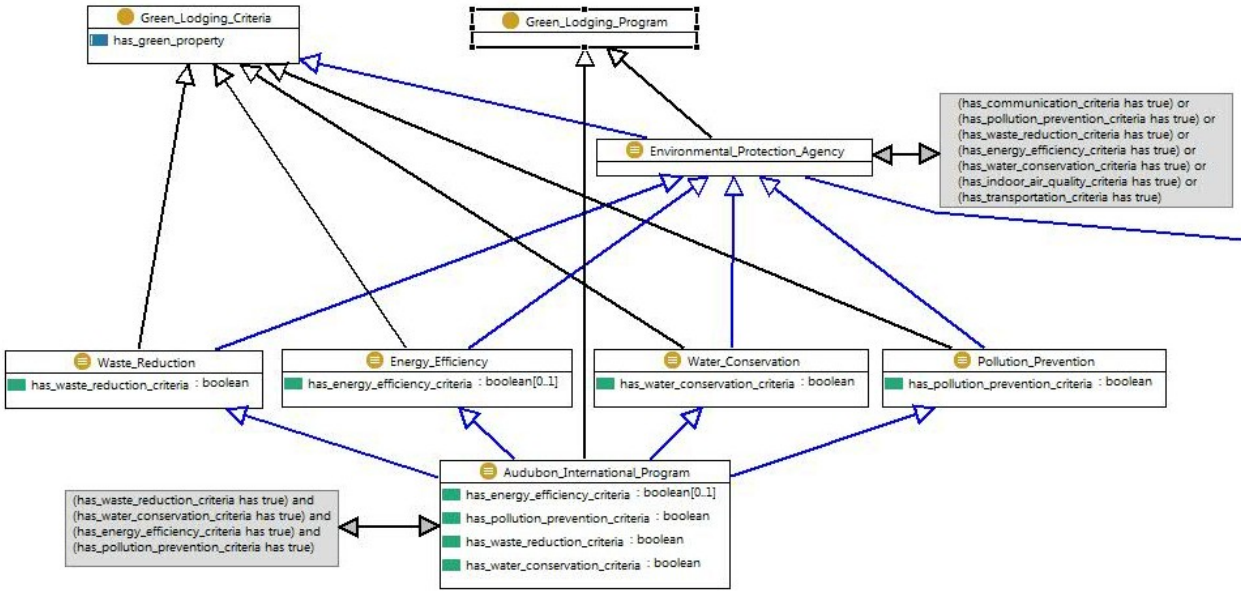

Figure 1 – A subset of the *Green Lodge Certification Criteria* (GLCC) Ontology to show at a base level the property restrictions that infer lodging property instances to automatically conform to other Green Lodging Program Certifications.

```
GLCC:has_waste_reduction_criteria_EPA rdfs:subPropertyOf
       has_waste_reduction_criteria
GLCC:Bahia_Mar rdf:type Property
GLCC:Bahia_Mar has_waste_reduction_criteria_EPA owl:hasValue "true"
```

By creating axioms to constrain the automated membership to the Fresh Air Lodging Program class a combination of union statements to cover all criteria pertaining to the program can be written as:

```
GLCC:Audubon_International_Program owl:Class
   owl:unionOf(
     [owl:restriction:
       owl:onProperty GLCC: has_waste_reduction_criteria_FAL
         owl:hasValue true]
     [owl:restriction:
       owl:onProperty GLCC: has_energy_efficiency_criteria_FAL
         owl:hasValue true]
     [owl:restriction:
       owl:onProperty GLCC:has_communication_criteria_FAL
         owl:hasValue true]
     [owl:restriction:
       owl:onProperty GLCC: has_water_conservation_criteria_FAL
         owl:hasValue true])
```

On running the reasoning engine the Property class instance, Bahia Mar, would be subsumed to also be a member of the Fresh Air Lodging Program. Notably, the Fresh Air Lodging and the Green Globe International Inc. Program are subsets of the EPA program so all properties that pass the EPA criteria should automatically belong to them as well.

A reverse-hypothesis approach was used to validate the outcome of the reasoning engine. All properties used in the testing phase were manually aligned to belong to specific programs and then compared with the output of the reasoner. This method validates the accuracy of the SKB for the purpose of subsuming properties to belong to multiple green programs simultaneously.

4 Results and discussion

Table 1 shows an extract of the SKB outcome after the reasoning engine has subsumed properties to be members of other standards bodies. Appendix B presents the full outcome, post reasoning, of all twelve certification programs to categorize full subsets, partial subsets and the partial subset's shortfalls.

Table 1: Example outcome post reasoning subsumes properties to automatically belong to other certification classes.

Actual property accreditation	Inferred equivalent accreditation	Inferred partial accreditation	Shortfall from partial accreditation
EPA	Fresh Air Lodging	Audubon International	Indoor Air Quality
	Trip Advisor	EcoRooms & EcoSuites	Communication
		Green Concierge	Indoor Air Quality
		Green Business Bureau	Communication & Indoor Air Quality
		Green Globe	Communication & Indoor Air Quality
		Green Seal	Communication & Indoor Air Quality
		Sustainable Travel Int. (STEP)	Indoor Air Quality
		UL Environment	Indoor Air Quality
		US Green Building Council	Waste Reduction
Audubon International	Sustainable Travel Int. (STEP)	EcoRooms & EcoSuite	Communication & Pollution Prevention
	UL Environment	EPA	Pollution Prevention
		Fresh Air Lodging	Pollution Prevention
		Green Concierge	Pollution Prevention
		Green Business Bureau	Communication & Pollution Prevention
		Green Globe	Communication & Pollution Prevention
		Green Seal	Communication & Pollution Prevention
		Trip Advisor	Pollution Prevention
		US Green Building Council	Waste Reduction & Pollution
UL Environment	NA	NA	
US Green Building Council	NA	NA	

Given a property's current certification status, it can be inferred automatically to be compliant with other certification standards if the certification criteria are a subset of its current accreditation. There is also the ability to ascertain automatically specific criteria that are shortfalls for that property to be certified by a different standards body.

Some criteria listed in Appendix A have been declared as equivalent within the ontology. For example, "communication", "training", "employee involvement and training", "stakeholder/community engagement" and "shareholder engagement" are equivalent but were listed separately because they are the certification program-specific labels. Axioms explicitly stated these equivalencies in the GBCC so certification programs will be subsumed as a subset of another as long as they have one of the communication-focused criteria checked. Other groupings of criteria that have been stated as equivalent include:

- "Environmental sensitive purchasing", "green seal certified or equivalent cleaning products", "green seal or equivalent paper products", "bathroom feature amenity dispensers", "Environmental Policy (EPP)" and "chemical criteria"; and
- "Resource reduction" and "waste reduction".

When applying the equivalency axioms the original 26 are condensed to sixteen criteria.

The certification programs that met all of the criteria were listed under the inferred equivalent accreditation column (Table 1). Programs were inferred to be partial subsets of another if they matched all criteria except one to two of the superset's criteria. Propositional rules written in the *Semantic Web Rules Language* (SWRL) inferred the partial subsets that are listed under the inferred partial accreditation. The one to two criteria these programs were missing are listed as shortfalls from partial accreditation. The shortfall information can be used by properties to easily assimilate the missing criteria within their organization to be

eligible for other green lodging certifications. Significantly, if patrons had access to this information, they could use these shortfalls and lists of partial accreditations to make decisions on patronage with the confidence of knowing an establishment is accredited by one program but also close to many others.

Two certification programs did not have any subsets, UL Environment and the US Green Building Council, because no other program met the majority of their set criteria (Table 1). UL Environment has sixteen of the 26 criteria and the US Green Building Council has seven (Appendix A). Even after applying the criteria equivalency axioms, which condenses all criteria to 16, UL Environment still maintained twelve, which minimizes the possibility of having a subset that matches all but one or two criteria. Notably, the certification-specific agenda impacts on the possibility of others becoming a subset. For example, some, such as the US Green Building Council, are predominantly used for new construction and others, such as Green Seal, are focused on product certification.

5 Conclusions and implications

This paper described a knowledge representation framework that automates data discoveries on green tourism lodging best management practices. The framework aggregates and aligns the variety of best practice standards to automatically infer a lodging property's compliance to multiple standards bodies based on a single evaluation of one standard program. This way, properties can identify their gaps in the sustainable tourism criteria with less difficulty and patrons can use the information to make more informed purchasing decisions.

Initially, the best practice criteria of twelve North American green lodging certification bodies were compared and analyzed to develop the GLCC ontology. There is a rapid increase in the number of lodging businesses that now engage in "green" practices and eco-tourism. However, the understanding and implementation of best practices is hampered because the standards organizations available in the United States that mandate the criteria are disparate. The domain-specific GLCC ontology is combined in a SKB with the pre-existing HarmoNET ontology, which lays a base vocabulary to describe the tourism domain, to describe the relationships between the criteria from each of the green lodging programs. The GLCC ontology contains contextual information about the BMP assessment criterion, written in a form that is available to and processable by software, to reveal connections between the criteria for best management practice standards. Once automated, properties that conform to one certification body were inferred to conform to all other relevant green lodging certification bodies. The GLCC ontology will benefit the lodging industry by making the green lodging certification best management practices transparent and increase the consumers' confidence in the green lodging programs.

This study uniquely proposed the application of semantic web technologies to assist in the standardization and categorization of the green lodging programs in the United States. Consumers, hotels and tourism operators would benefit by the automated evaluation process because they would be better able to discern between the criteria of the green lodging programs to make decisions of patronage and BMP. There is an increased attention towards environmental protection due to climate change, which has made green lodging a corporate social concern. The implications of this study are to build the body of knowledge of green lodging best management practices and increase consumer confidence in the green lodging industry.

This paper described a theoretical framework for applying ICT to sustainable tourism. As such, the implementation to date has produced a proof of concept that has been validated via a ground-truthing method, which compared the outcome of the SKB with a manual analysis to ensure accuracy. This use-case framework was developed with twelve US green lodging certification programs, which constrained the scope for the initial development. The SKB is capable of aligning lodging properties with green lodging certifications based on only one evaluation because the natural hierarchy of the criteria involved can be categorized in supersets and subsets. That is, some programs are a subset or partial subset of other programs. The reasoning engine and inference engine can subsume properties to comply with multiple green lodging certifications automatically.

Future work will integrate a *Natural Language Processing* (NLP) component that can automatically text mine the lodging property information from the respective websites for ingestion to the SKB. Once fully automated, the outcome of the SKB can be feed back to the organizations to inform their BMP by showing the

links between the disparate standards programs. Management can then align their BMPs among multiple programs and further offer more information about green practices so consumers can choose according to compliance. Also in future work, the proposed framework will be extended to incorporate other countries programs and all levels of green standard programs.

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Appendix A - Comparison matrix of green lodging certification program in the USA.

Green Lodging Certification Program	Criteria																									
	Jurisdiction /State	Communication -employees/customer	Waste Reduction (Reuse &Recycling)	Water Conservation	Energy Efficiency	Indoor Air Quality	Transportation	Hazardous Substance Management	Environmentally Sensitive Purchasing	Pollution prevention	Green building construction	Green Seal Certified or equiv. cleaning products	Green Seal or Equivalent paper products	Bathroom feature amenity dispensers	Facility Policy & planning	Environmental Policy (EPP)	Resource tracking	Chemical criteria	Training	Employee Involvement and Training	Resource reduction	Innovation and Design	Employee Health & Safety	Stakeholders/Community Engagement	Shareholder Engagement	Human Rights Risk Assessment	Customer Health & Safety & Satisfaction
Audubon International	Selkirk, New York	5	2	3	1					4																
EcoRooms & EcoSuites	Saint Charles, Montana		5	4 - 7	4 - 6	8 -						1	2	3												
Environmental Protection Agency FDEP	Florida	1	2	3	4	5	6																			
Fresh Air Lodging	Duluth, Minnesota	5	4	2	1	3																				
Green Concierge Certification, HospitalityGreen LLC	Catskill Watershed, New York	12	6, 9	8	7				5						1	2	3	4	10	11	13					

Green Lodging Certification Program	Criteria																									
	Jurisdiction /State	Communication -employees/customer	Waste Reduction (Reuse &Recycling)	Water Conservation	Energy Efficiency	Indoor Air Quality	Transportation	Hazardous Substance Management	Environmentally Sensitive Purchasing	Pollution prevention	Green building construction	Green Seal Certified or equiv. cleaning products	Green Seal or Equivalent paper products	Bathroom feature amenity dispensers	Facility Policy & planning	Environmental Policy (EPP)	Resource tracking	Chemical criteria	Training	Employee Involvement and Training	Resource reduction	Innovation and Design	Employee Health & Safety	Stakeholders/Community Engagement	Shareholder Engagement	Human Rights Risk Assessment	Customer Health & Safety & Satisfaction
Green Business Bureau	Houston, Texas		1,3,6, 14, 15	2, 10	7-10, 12, 13				5, 11					4													
Green Globe International Inc.	USA, Europe, Latin America, China, Middle East and Caribbean		3	2	1		4																			
Green Seal	Washington DC		1	3, 4	2			5	6																	
Sustainable Travel International (STEP)	USA, Costa Rica, Malaysia, Taiwan, Brazil	7	4	4	4			4	5	4					1, 8					3			2	6			
Trip Advisor Green Leaders Program	Massachusetts	6	3	2	1	5			4																		

Green Lodging Certification Program	Criteria																									
	Jurisdiction /State	Communication -employees/customer	Waste Reduction (Reuse &Recycling)	Water Conservation	Energy Efficiency	Indoor Air Quality	Transportation	Hazardous Substance Management	Environmentally Sensitive Purchasing	Pollution prevention	Green building construction	Green Seal Certified or equiv. cleaning products	Green Seal or Equivalent paper products	Bathroom feature amenity dispensers	Facility Policy & planning	Environmental Policy (EPP)	Resource tracking	Chemical criteria	Training	Employee Involvement and Training	Resource reduction	Innovation and Design	Employee Health & Safety	Stakeholders/Community Engagement	Shareholder Engagement	Human Rights Risk Assessment	Customer Health & Safety & Satisfaction
UL Environment	Illinois		9,10, 11	8	6, 7				14	5	12				21	13	1, 11 15			2	11		16 17 18	4	3	22	19, 20
US Green Building Council	Washington DC			3	4	6			5		1, 2									7		8					

Appendix B - SKB outcome

Actual property accreditation	Inferred equivalent accreditation	Inferred partial accreditation	Shortfall from partial certification
EPA	Fresh Air Lodging	Audubon International	Indoor Air Quality
	Trip Advisor	EcoRooms & EcoSuites	Communication
		Green Concierge	Indoor Air Quality
		Green Business Bureau	Communication & Indoor Air Quality
		Green Globe	Communication & Indoor Air Quality
		Green Seal	Communication & Indoor Air Quality
		Sustainable Travel Int. (STEP)	Indoor Air Quality
		UL Environment	Indoor Air Quality
		US Green Building Council	Waste Reduction
Audubon International	Sustainable Travel Int. (STEP)	EcoRooms & EcoSuite	Communication & Pollution Prevention
	UL Environment	EPA	Pollution Prevention
		Fresh Air Lodging	Pollution Prevention
		Green Concierge	Pollution Prevention
		Green Business Bureau	Communication & Pollution Prevention
		Green Globe	Communication & Pollution Prevention
		Green Seal	Communication & Pollution Prevention
		Trip Advisor	Pollution Prevention
		US Green Building Council	Waste Reduction & Pollution
Eco Rooms & EcoSuites	Trip Advisor	Audubon International	Indoor Air Quality & Environmentally Sensitive Purchasing
		EPA	Environmentally Sensitive Purchasing
		Fresh Air Lodging	Environmentally Sensitive Purchasing
		Green Concierge Certification	Indoor Air Quality
		Green Business Bureau	Indoor Air Quality
		Green Globe	Indoor Air Quality & Environmentally Sensitive Purchasing
		Green Seal	Indoor Air Quality
		Sustainable Travel Int. (STEP)	Indoor Air Quality

		UL Environment	Indoor Air Quality
		US Green Building Council	Waste Reduction
Fresh Air Lodging	EPA	Audubon International	Indoor Air Quality
	Trip Advisors	EcoRooms & EcoSuites	Communication
		Green Concierge	Indoor Air Quality
		Green Business Bureau	Communication & Indoor Air Quality
		Green Globe	Communication & Indoor Air Quality
		Green Seal	Communication & Indoor Air Quality
		Sustainable Travel Int. (STEP)	Indoor Air Quality
		UL Environment	Indoor Air Quality
		US Green Building Council	Waste Reduction
Green Concierge Certification	NA	Sustainable Travel Int. (STEP)	Resource Tracking
		Trip Advisor	Facility Policy and Planning & Resource Tracking
Green Building Bureau	EcoRooms & Eco Suites	Audubon International	Environmentally Sensitive Purchasing
	Green Concierge Certification	EPA	Environmentally Sensitive Purchasing
	Sustainable Travel Int. (STEP)	Fresh Air Lodging	Environmentally Sensitive Purchasing
	Trip Advisor	Green Globe	Environmentally Sensitive Purchasing
	UL Environment	Green Seal	Environmentally Sensitive Purchasing
		US Green Building Council	Waste Reduction
Green Globe International	EPA	Audubon International	Transportation
		EcoRooms & EcoSuites	Transportation
		Fresh Air Lodging	Transportation
		Green Concierge Certification	Transportation
		Green Business Bureau	Transportation
		Green Seal	Transportation
		Sustainable Travel	Transportation
		Trip Advisor	Transportation
		UL Environment	Transportation
		US Green Building	Waste Water & Transportation
Green Seal	Sustainable Travel Int.(STEP)	Audubon International	Hazardous Substance & Environmentally Sensitive Purchasing
		EcoRooms & EcoSuites	Hazardous Substance

		EPA	Hazardous Substance & Environmentally Sensitive Purchasing
		Fresh Air Lodging	Hazardous Substance & Environmentally Sensitive Purchasing
		Green Concierge Certification	Hazardous Substance
		Green Business Bureau	Hazardous Substance
		Green Globe	Hazardous Substance & Environmentally Sensitive Purchasing
		Trip Advisor	Hazardous Substance
		UL Environment	Hazardous Substance
		US Green Building	Waste Reduction & Hazardous Substance Management
Sustainable Travel Int. (STEP)	NA	Green Concierge Certification	Hazardous Substance Management
		UL Environment	Indoor Air Quality & Hazardous Substance Management
Trip Advisor Green Leaders Program	NA	Audubon International	Indoor Air Quality & Environmentally Sensitive Purchasing
		EcoRooms & EcoSuites	Communication & Environmentally Sensitive Purchasing
		EPA	Environmentally Sensitive Purchasing
		Fresh Air Lodging	Environmentally Sensitive Purchasing
		Green Concierge	Indoor Air Quality
		Green Business Bureau	Communication & Indoor Air Quality
		Green Seal	Communication & Indoor Air Quality
		Sustainable Travel Int. (STEP)	Indoor Air Quality
		UL Environment	Indoor Air Quality
		US Green Building Council	Waste Reduction
UL Environment	NA	NA	
US Green Building Council	NA	NA	