GREEN RATING INTEGRATION PLATFORM – A DECISION MAKING TOOL FOR MULTI-MODAL FACILITIES: CREDIT HARMONIZATION AND A SUSTAINABLE WATER & MATERIAL PRACTICES CASE STUDY

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ABSTRACT

There are multitudes of sustainability rating systems and guidelines, and it is difficult to decide which ones to use and how to use them. In addition, multi-modal projects have different focal areas and associated rating systems related to each mode or other aspect of the project. Five green ratings systems representative of aspects of a multi-modal ferry facility had previously been selected and were used in a four step methodology to synthesize into a strategic decision making platform. This current research focuses on how to make more detailed decision making harmonization amongst the credits in the rating systems. Using an analytical hierarchy process (AHP) of the credits in the rating systems, it was determined that the two main groups of information that could be used for harmonization were key intents or goals (KI) and key strategies or practices (KS). A short cursory case study example of how these KIs and KSs might be further cross-coded in an open database with the credit subcategories and corresponding rating systems is also presented. The database can filter the credit subcategories across the rating system for a specific key intent or key strategy. The harmonized lists and database may facilitate decision makers and construction managers in correlating intents and methodologies for a project across multiple rating systems.

KEYWORDS

Sustainable construction, water, materials, green rating systems, intents/goals, strategies/technologies, GRIP

INTRODUCTION

Sustainable design and construction have become more common with the development of any kind of infrastructure or system (Curwell and Deakin, 2002). Global climate variability and increased urbanization, together with associated environmental problems, have activated the growing interest in sustainable construction. As a result, numerous sustainability rating systems and guidelines have evolved around the world as a means to facilitate this change. Various rating systems focus on different aspects of sustainable development. Although there are some commonalities in these rating categories, they vary for each country reflecting the climate and socio-economic condition of the country (Gomes et al., 2008; Reed *et al.*, 2009, Haselbach 2010). The sustainability rating systems may vary within the regions of one country

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to satisfy particular regional requirements to achieve the intended sustainability. In addition, there is variability in rating systems as to the main type of project that is its focus, i.e., a building, a transportation system, or marine infrastructure.

Recent research has compared different rating systems to analyze the specific requirements to attain sustainability for individual projects. Retzlaff (2008) analyzed nine different green building rating systems to assess building requirements during the planning phase. The different rating systems that were analyzed are Earth Craft Communities, Earth Craft House, Enterprise Communities, Green Globes, Health House, LEED-H, LEED-ND, LEED-NC, and NAHB. LEED NC 2.2 was incorporated in the building information modeling (BIM) software to enhance awareness among the designers about the different sustainable design aspects in the early design phases (Biswas *et al.*, 2008). A Sustainable Systems Integration Model (SSIM) model has been developed for the city of Tanggu-Baitang in China (Georgoulias *et al.*, 2009). This integration software evaluates the efficacy of the sustainable design concepts in terms of cost, and provides alternative development scenarios and design options. Instead of considering any specific green rating system, the model requires the input of the alternative concepts of sustainable design, and the software then analyzes the different concepts and ranks them.

This study builds upon previous research where topical categories across five different green rating systems were synchronized in a four step process to develop a green rating integration platform or GRIP (D'Agneaux, 2009; Thompson *et al.*, 2013). Although the integration platform was developed with a focus on ferry facilities, it is applicable to most multi-modal construction projects. The four steps were first (1) selection of applicable rating systems and then (2) development of a preliminary set of GRIP main categories such as site selection, materials, energy, water, air quality, or traffic and parking. These categories were then (3) synchronized across the rating systems and finally (4) the various credits were then synthesized across the topical categories in a single spreadsheet format platform to make the comparison of the rating systems easier for achieving the green building and construction intents on a strategic level. However, research was still needed to further harmonize the credits across the rating systems for detailed decision making, and for formatting into a more readily accessible database with flexibility for the rapidly changing developments in sustainability.

The research question that is answered by this work is the determination of what characteristics of the various rating systems and their credits might be able to be harmonized in order to facilitate more detailed decision making. In addition, a case study on what this harmonization might look like for credits with a focus area of water and materials is detailed.

METHODOLOGY

The rating systems and main topical categories as previously synthesized for a ferry terminal GRIP by Thompson et al. (2013) were chosen as the basis for this study. Other similar rating systems could have been just as readily used in this or other case studies. Two of the rating systems have landside focus at the terminal, while the other three rating systems are applicable for upland, marine-side, and intermodal aspects of a project. The rating systems and their focus areas are – a) GreenLITES – Upland(NYDOT, 2011), b) LEED New Construction– Landside(USGBC, 2009), c) Sustainable Sites Initiative (SSI) – Landside(SSI, 2009), d) draft Sustainable Infrastructure Guidelines by the Port Authority of New York and New Jersey (SIG) – Intermodal(TPA, 2010), and e) draft Marine Vessel Environmental

Performance Guidelines (MVeP) – Marine-Side(SNAME, 2010). These five rating systems were synchronized with the set of seven topical categories (traffic/parking, community/social, energy, water, materials, air quality, and construction phase), into the single green rating

FIGURE 1. Integrated green rating systems and credit subcategories (Courtesy J. of Green Building) (*6*).

	Upland GreenLITES	Land Side LEED retail	Land Side Sustainable Sites Initiative	Intermodal Port Authority	Intermodal WSU Ferry Guidelines	Marine Side MVeP
Traffic/Parking	☐ E-1: Improve Traffic Flow ☐ E-4:Bicycle/Pedestrian Facilities	☐ SSc4-Alternative Transportation		☐ IS-37: Optimize Traffic Safety ☐ IS-39:Enhance Intermodal Connectivity ☐ IS-20:Transportation System Management ☐ IS-23:Transportation Technologies	☐ Promote HOV ☐ Encourage walk-ons ☐ Encourage bicycle use ☐ Facilitate drop-off ☐ Park-and-ride program ☐ Shared-car program ☐ Optimize traffic flow ☐ Reservation system ☐ Peak periods prices ☐ Allow future growth	
Community/Social	☐ S-2: Context Sensitive Solutions ☐ S-3: Land Use Planning ☐ S-4: Protect Wildlife Habitat ☐ S-5: Protect Plant Communities ☐ E-5: Noise Abatement ☐ E-6: Stray Light Reduction	☐ SSc2-Community Connectivity ☐ SSc5.1-Protect or Restore Habitat ☐ SSc5.2-Maximize Open Space ☐ SSc7-Heat Island Effect ☐ SSc8-Light Pollution Reduction ☐ EAp3-Refrigerant Management ☐ EAc4-Refrigerant Management ☐ EQc6-Controllability of Systems ☐ EQc7-Thermal Comfort ☐ EQc8-Daylighting and Views	☐ SSp8.2-Protect floodplain functions ☐ SSp8.3-Preserve wetlands ☐ SSp8.4-Preserve endangered species ☐ SSc1.6-Select sites in communities ☐ SSc1.7-Accessible to public transit ☐ SVp8.1-Control invasive plants ☐ SVp8.2-Use non-invasive plants ☐ SVp8.3-Soil management plan ☐ SVc6.5-Preserve special status veg. ☐ SVc6.6-Daylighting and Views ☐ SVc6.7-Use native plants ☐ SVc6.8-Preserve native plants ☐ SVc6.9-Restore native plants ☐ SVc4.12-Reduce heat island effect ☐ SVc4.13-Reduce wildfire risk ☐ HHc6.1-Equitable site development ☐ HHc6.2-Equitable site use ☐ HHc6.3-Sustainability education ☐ HHc6.4-Protect historical places ☐ HHc6.5-Optimum site accessibility ☐ HHc6.6-Outdoor physical activity ☐ HHc6.7-Views of vegetation ☐ HHc6.8-Outdoor spaces ☐ HHc6.9-Reduce light pollution	☐ IS-5: Protect Ecological Health ☐ IS-6:Maintain Absorbent Landscapes ☐ IS-8:Utilize Appropriate Vegetation ☐ IS-14: Mitigate Heat Island Effect ☐ IS-15:Minimize Light Pollution ☐ IS-16: Optimize Public Environments	☐ Architecturally blend ☐ Visitor center ☐ Include guided tours ☐ Prevent flood damage ☐ Allow change in activity ☐ No ozone depleting substances ☐ Light Pollution Prevention ☐ Noise Pollution Prevention ☐ Wildlife Considerations	☐ GM3.1-Aquatic Life Impact ☐ GM3.2-Shore Protection ☐ AE6-Ozone-Depleting
Energy	☐ E-2: Reduce Electrical ☐ E-3: Reduce Petroleum	☐ EAp2-Minimum Energy Performance ☐ EAc3-Optimize Energy ☐ EAc2-On-site Renewable Energy ☐ EAc5-Measurement and Verification ☐ EAc6-Green Power	☐ SVc4.10-Minimize heating ☐ SVc4.11-Minimize cooling ☐ OMc8.4-Reduce energy consumption ☐ OMc8.5-Use renewable energy	☐ IE-1: Optimize Energy Performance ☐ IE-2:Electrical and Mechanical Systems ☐ IE-3: Utilize End Use Metering ☐ IE-4: Use On-Site Renewable Energy ☐ IE-5: Protect Ozone Layer ☐ IE-6: Provide Alternative Fueling Stations	☐ Produce renewable energy ☐ Use waste heat from engine ☐ Use local material ☐ Minimal embodied energy ☐ Daylight harvesting ☐ High-efficiency systems ☐ Individual control in offices ☐ Automatic control in public ☐ Automatically turn off lights ☐ High reflectance	☐ EE1.1-Lighting ☐ EE1.2-HVAC ☐ EE1.3-Pump Systems ☐ EE1.4-Mechanical Equipment ☐ EE1.5-Hull/Propeller ☐ EE1.6-Route Optimization ☐ EE1.7-Vessel Speed ☐ EE1.8-Energy Recovery ☐ EE1.9-Hull Optimization ☐ EE2.1-Other Fuels ☐ EE2.2-Renewable Energies ☐ EE3-Carbon Footprint
Water	☐ W-1: Stormwater Management ☐ W-2:BMPSs	☐ SSc6.1-Stormwater Quantity Control ☐ SSC6.2-Stormwater Quality Control ☐ WEp1-Water Use Reduction ☐ WEc1-Water Efficient Landscaping ☐ WEc2-Innovative Technologies ☐ WEc3-Water Use Reduction	☐ Wp3.1-Reduce landscape irrigation ☐ Wc3.2-Reduce landscape irrigation ☐ Wc3.3-Protect/Restore buffers ☐ Wc3.4-Rehabilitate streams ☐ Wc3.5-Manage stormwater on site ☐ Wc3.6-On-site water resources ☐ Wc3.7-Use stormwater for landscape ☐ Wc3.8-Maintain water features ☐ OMp8.1-Sustainable maintenance	☐ IS-7: Utilize Pervious Pavement ☐ IS-9: Use Turfgrass Appropriately ☐ IM-1: Implement Stormwater BMPs ☐ IM-2: Implement Rainwater Neutrality ☐ IM-3: Reduce Use of Potable Water ☐ IM-4: Utilize End Use Metering ☐ IO-1:Sustainable Landscape Maintenance ☐ IO-2: Maintain Soil Quality	☐ Emergency plan for spills ☐ Oil separation equipment ☐ Non toxic paint ☐ High-efficiency fixtures ☐ Prevent leaks ☐ Reduce potable water ☐ Reduce city water ☐ Treat wastewater on-site ☐ Implement UDs ☐ Collect runoff/rainwater ☐ Treat water on boat ☐ Maintain ballast tanks ☐ Exchanges off-shore	☐ WE1-Oily Water ☐ WE2-Non-Indigenous Species ☐ WE2.1-Ballast Water/Sediment ☐ WE2.2-Hull Fouling ☐ WE3-Sanitary Systems ☐ WE4-Solid Waste ☐ WE5-Incidental Discharges ☐ WE6-Protection of Oil ☐ GM2-Hotel Water Use
Materials	☐ M-1: Reuse of Materials ☐ M-2: Recycle content ☐ M-3: Locally Provided Material ☐ M-4: Bioengineering Techniques ☐ M-5: Hazardous Minimization	☐ MRp1-Recyclables ☐ MRc1.1-Building Reuse-Exterior ☐ MRc1.2-Building Reuse-Interior ☐ MRc2-Waste Management ☐ MR3-Materials Reuse ☐ MRc4-Recycled Content ☐ MRc5-Regional Materials ☐ MRc6-Rapidly Renewable Materials ☐ MRc7-Certified Wood ☐ EQc4-Low-Emitting Materials	☐ MSp5.1-Eliminate threatened wood ☐ MSc5.2-Maintain often ☐ MSc5.3-Design for deconstruction ☐ MSc5.4-Reuse salvaged materials ☐ MSc5.5-Recycled content materials ☐ MSc5.6-Use certified wood ☐ MSc5.7-Use regional materials ☐ MSc5.8-Reduce VOC emissions ☐ MSc5.9-Sustainable plant production ☐ MSc5.10-Sustainable manufacturing ☐ OMp8.2-Collect recyclables ☐ OMc8.3-Recycle organic matter	☐ IS-10: Amend and Reuse Existing Soils ☐ IS-11: Balance Earthwork ☐ IM-1: Use Recycled Materials ☐ IM-2: Use Local/Regional Materials ☐ IM-3: Reuse Materials ☐ IM-4: Use Durable Materials ☐ IM-5:Sustainably Harvested Wood ☐ IM-6: Minimize Toxic Materials ☐ IM-7: Enhance Pavement Lifecycle ☐ IM-8: Utilize Thin Surface Paving ☐ IM-9: Utilize WMA Technology	☐ Reduce waste due to activity ☐ Recycling dumpsters ☐ Sort waste for recycling ☐ Recycle bins ☐ High-recyclable materials ☐ Hazardous waste plan ☐ Sustainable materials ☐ Low-emitting materials	☐ GM1-Materials ☐ GM4-Inventory Program ☐ GM5-Ship Recycling
Air Quality		☐ EQp3-Minimum IAQ ☐ EQp2-ETS control ☐ EQc1-Outdoor Air Monitoring ☐ EQc2-Increased Ventilation ☐ EQc5-Indoor Pollutant Control	☐ OMc8.6-Minimize tobacco smoke ☐ OMc8.7-Minimize greenhouse gases ☐ OMc8.8-Reduce emissions		☐ Outside air intake ☐ Natural ventilation ☐ Minimize chemical use ☐ Reduce flying dirt ☐ Limit engines running ☐ Avoid fossil fuel engines	☐ AE1-NOx Reductions ☐ AE2-Sox Reductions ☐ AE3-PM Reductions ☐ AE4-VOC ☐ AE5-GHGs ☐ AE7-Port Air Emissions
Construction Phase	☐ S-1: Alignment Selection	☐ SSp1-Pollution Prevention ☐ SSc1-Site Selection ☐ SSc3-Brownfield Redevelopment ☐ EAp1-Fundamental Commissioning ☐ EAc3-Enhanced Commissioning ☐ EQc3-Construction IAQ	☐ SSp1.1-Limit farmland development ☐ SSc1.5-Select brownfields ☐ POp2.1-Pre-design assessment ☐ POp2.2-Integrated site development ☐ POc2.3-Engage users in site design ☐ SVp6.4-Minimize soil disturbance ☐ Cp7.1-Control construction pollutants ☐ Cp7.2-Restore disturbed soils ☐ Cc7.3-Restore disturbed soils ☐ Cp7.4-Divert materials from disposal ☐ Cp7.5-Reuse soil ☐ Cp7.6-Minimize emissions	☐ IS-1:Integrated Team Approach ☐ IS-2: Prepare a Site Assessment ☐ IS-3:Previously Developed Sites ☐ IS-4:Known Contaminated Sites ☐ IS-12: Coordinate Utility Work ☐ IS-13: Utilize Trenchless Technology ☐ IS-18:Roadway Alignment Section ☐ IC-1: Minimize Pollution ☐ IC-2: Protect Existing Natural Systems ☐ IC-3:Transportation Management ☐ IC-4:Green Construction Equipment ☐ IC-5: Reduce Noise and Vibration ☐ IC-6:Waste Management ☐ IC-7:Integrated Pest Management	☐ Brownfield site ☐ Clean polluted water ☐ Reduce construction waste ☐ Dredging	

integration platform (GRIP) in the previous work. Figure1 provides the resulting platform in a simple spreadsheet format, which is intended to be a tool for strategic decision making (Thompson *et al.*, 2013). An example of an alternative multi-modal project that could follow the same procedure is an airport, with roads, buildings, site work, the intermodal facility and then the aviation side, possibly all with different sustainability metric systems applied.

In this paper, the credit subcategories of the topical categories 'Water' and 'Materials' within the five rating systems were analyzed for harmonization. Each of the rating systems has specific formats for its subcategories to achieve the sustainability credits. The numerous variables that the credit formats might include are intent, requirements, potential technologies and strategies, approach and implementation, calculations, examples, numerical credit points, exemplary performance, definitions, etc. Intents, strategies, and credit point details are the most common recurrence in the credit format for most of the rating systems. (Some of the rating systems refer to the methodology as technologies, while other rating systems call these strategies, thus in this paper, strategies has been used for methodology or technology. In some rating systems, the credit intent was designated as the purpose or objective. This paper will refer to this as the intent.) The credit formats of the rating systems that have been considered in this research are listed in Table 1. Only the fundamental variables were listed for correlating the credit format across the rating systems.

TABLE 1: Credit formats of the rating systems.

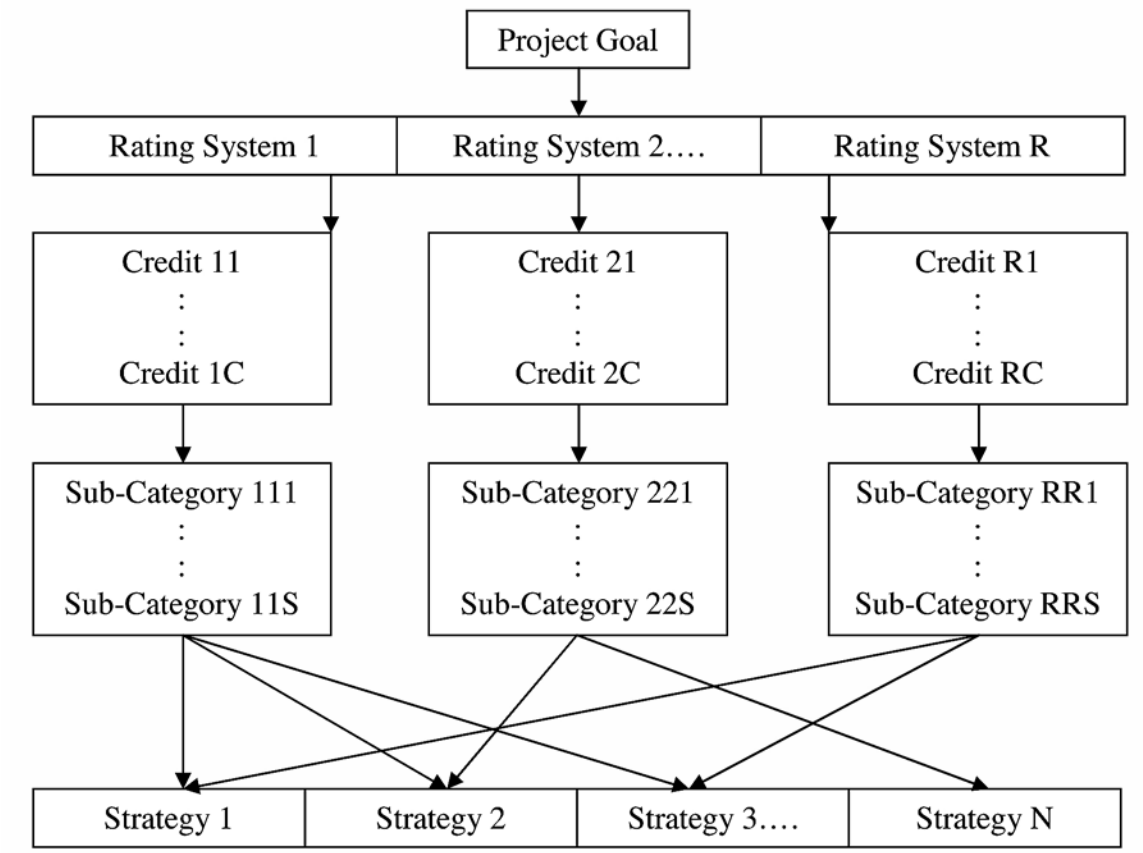
Credit Format Variables	Rating Systems				
	GreenLITES	LEED	SSI	SIG	MVeP
Intents	√	√	√	√	--
Requirements	--	√	√	√	--
Strategies/ Methods	--	√	√	--	√
Calculations	--	√	√	--	--
Credit Points	√	√	√	√	--
Credit Point Details	√	√	√	√	√

While GreenLITES and SIG do not specifically describe the strategy, the credit point details contain specific methodologies to obtain certain credit points. LEED and SSI frequently provide equations/calculations to calculate the credit points. However, not all of the credit subcategories have explicit equations or estimation tools to achieve credit points. Although, MVeP does not have numerical values for credit points, it defines its sustainability achievement by prerequisite followed by standard, good, best, and zero impact methodology, listing these beyond the prerequisite as Level 1, Level 2, Level 3 and Level 4 as sustainability credits, respectively. While achieving Level 1 indicates the project meets standard environmental performance, Level 4 indicates the project has zero impact on the environment.

However, further harmonization is needed for detailed decision making, correlation, and analysis. For most problems, the decision making process is a two way approach: take a decision from a holistic point of view in which it is assumed that the adopted decision is best, or decompose the decision into components to better understand the problem (Golden et al., 1989). This technique of decision making by decomposing the problem is known as an analytical hierarchy process (AHP). The first step of AHP is to decompose the problem into a goal, criteria, sub-criteria, and alternatives (Bhushan and Rai, 2004). This process was applied to each of the rating system credits and the formats as listed in Table 1. The rating systems were

stepwise paired and the format variables in Table 1 compared to look for similar relationships. Although the credit format variables might have different titles, what was found was that there was always reference to an intent or goal, and strategies or practices to attain these intents. This is outlined in Figure 2 which shows that there is always an interrelationship between the project intents and the credit strategies.

FIGURE 2. AHP for harmonizing project intents with strategies within the subcategories.



The intent, strategies, and credit point details were analyzed to list the key intents and key strategies for each credit subcategory. This was done in a very cursory expert analysis using team members in the research group at Washington State University. The team members included three engineering professors, all involved in sustainability or sustainability rating system projects, and two graduate students. Future research intends to extend this process to using a more detailed expert analysis tool with a larger pool of experts as the GRIP is refined and expanded.

After this cursory analysis, the key intents were cross-listed with the key strategies required to accomplish certain sustainability intents. Tabular cross-referencing of the key intents and key strategies has been developed to facilitate use for not just this case study, but for extension to other rating systems and project types. Additionally, a web-based database has been developed to data mine for key intents and key strategies for both this '*Water*' category and the '*Material*' category for ferry and similar multi-modal facility projects.

RESULTS AND EXAMPLES

The following summarizes the results for the development of the key intents and key strategies from the project intents and strategies for the topical categories of '*Water*' and '*Materials*' across the five rating systems. Then the next section provides the results on the cross-referencing of the key intents to the key strategies. These are followed by the details on the development of the database.

Key Intents and Key Strategies Development

The topical categories of 'Water' and 'Materials' have 22 and 38 subcategories, respectively, within these five rating systems. The number of sub-categories for each rating system investigated varied between two and twelve. Each of these subcategories has different intents, and they adopt different strategies to accomplish these intents.

The intents and strategies of the 22 credit subcategories of 'Water' were analyzed using the cursory expert method. The team used AHP to pair the rating systems and stepwise come up with a single list of key intents and a single list of key strategies. The analysis was based upon the provided detailed descriptions, intents, and strategies of the credit subcategories associated with the rating systems. For example, one key strategy might be to Use Permeable Pavements. Evaluating first credit SSc6.2, it was found that a strategy was to use pervious pavement or grid pavers. Similarly, while evaluating credit IPA-IS7, the credit was to Utilize Pervious Pavement, and it was found that credit SSI-WC3.5 had a strategy for pervious or semi-pervious surfaces. Parts of these were all then found to be applicable to the use of permeable pavements, and thus all three credits could be cross-referenced with the key strategy of Use Permeable Pavements.

It was found that these 22 subcategories could be defined through 13 intents and 53 strategies. These listings of intents and strategies may not be totally inclusive, and they are subject to modification and addition as rating systems are modified and re-evaluated and as additional expert input is provided to the process. These 13 intents were classified as key intents and the 53 strategies were named as key strategies. The analysis reveals that some subcategories have only one key intent, while some subcategories have as many as six key intents. While the number of key strategies to accomplish the intents of several credit subcategories was one, 13 key strategies were required to accomplish the intents of credit subcategory 'On-site Water Resources' under the rating system Sustainable Sites Initiative. An example of the key intents and key strategies for the corresponding credit subcategories for the GreenLITES rating system are listed in Table 2. This process was repeated for the 'Material' categories.

Key Strategies for the Key Intents

The analysis of key intents and key strategies for the credit subcategories shows that for some subcategories the number of key intents is higher than the number of key strategies and vice versa. For example, the credit subcategory *W-1: Stormwater Management* was analyzed to have six key intents and the number of key strategies for these key intents is four; by contrast, the subcategory *W-2: Best Management Practices* has two key intents but may use eight key strategies to accomplish these two sustainability intents. Thus, a harmonization between the key intents and key strategies is essential for an interactive sustainable rating system that can be more readily used by construction managers. Using the AHP by reviewing which strategies were correlated with various intents in each credit, the key strategies were correlated against the key intents to develop their inter-relationship. The full checklist of key strategy with key

TABLE 2: List of GreenLITES – water key intents and key strategies.

Rating System	Credit Subcategories	Key Intents	Key Strategies
GreenLITES	W-1: Stormwater management (Quality and Volume)	• Reduce runoff • Reduce runoff pollutants • Protect wetlands/ waterbodies • Water body restoration • Reduce non-stormwater discharge to waters • Reduce impervious area	• Stormwater retrofitting • Stream restoration • Wetland protection • Erosion and sediment control
	W-2: Best Management Practices (BMPs)	• Manage stormwater • Treat stormwater pollutants	• Strategic use of soils • Use of bio-retention • Use wet or dry swales • Use filters, i.e. sand filters • Use oil/grit separators • Use detention basin • Use retention basin • Use permeable pavements

TABLE 3: Checklist example of some key strategies to accomplish key intents.

GRIP Intent/Strategy Interaction Chart

This chart demonstrates which key intents are accomplished when a specific key strategy is implemented. Intents are grouped into materials and water categories at this time.

KEY STRATEGY	Credit: Materials													Credit: Water												
	KI 1: Reduce waste	KI 2: Recycle	KI 3: Reuse materials off-site	KI 4: Reuse materials on-site	KI 5: Conserve resources	KI 6: Retain cultural resources	KI 7: Reduce haul distances	KI 8: Support local businesses	KI 9: Use rapidly renewable materials	KI 10: Support responsible forest mgt	KI 11: Reduce indoor air contaminants	KI 12: Minimize hazardous materials	KI 13: Support sustainable businesses	KI 14: Increase natural hydrological features	KI 15: Manage stormwater	KI 16: Protect wetlands/water bodies	KI 17: Reduce heat island impact	KI 18: Reduce impervious area	KI 19: Reduce non-indigenous species	KI 20: Reduce non-stormwater discharge	KI 21: Reduce runoff	KI 22: Reduce runoff pollutants	KI 23: Reduce water usage	KI 24: Treat stormwater pollutants	KI 25: Water body restoration	KI 26: Water reuse onsite
Adopt construction waste management plan	√																									
Balance "cut-and-fills"				√	√	√																				
Size and functionality of recycling areas		√	√																							
Crush on-site pavement for aggregate				√	√																					
Limit certain metal use near water bodies												√														
Avoid pollutant potential materials											√	√					√					√				
Ballast water treatment system																√				√						
Biologically-based water treatment system														√												
Buy in bulk																√										
Clean vessel exterior																				√						
Constructed wetland																			√		√	√		√		
Stormwater harvesting														√							√			√		√

intent is available on the website (https://greenintegration.cee.wsu.edu/), with a few examples of the strategies given in Table 3. (In developing the relationship, emphasis was given to the definition of the key intent and the details of the subcategory associated with that key intent.)

Harmonization of the key intents and strategies also produced several strategies that could be connected with key intents from both of the 'Water' and 'Materials' categories. These unique strategies could be sought after by decision makers who want to incorporate a single

key strategy in order to accomplish several intents across different rating systems and topical categories. These strategies can become even more valuable as further categories are added to the GRIP allowing for more key intents to be connected with current and new strategies.

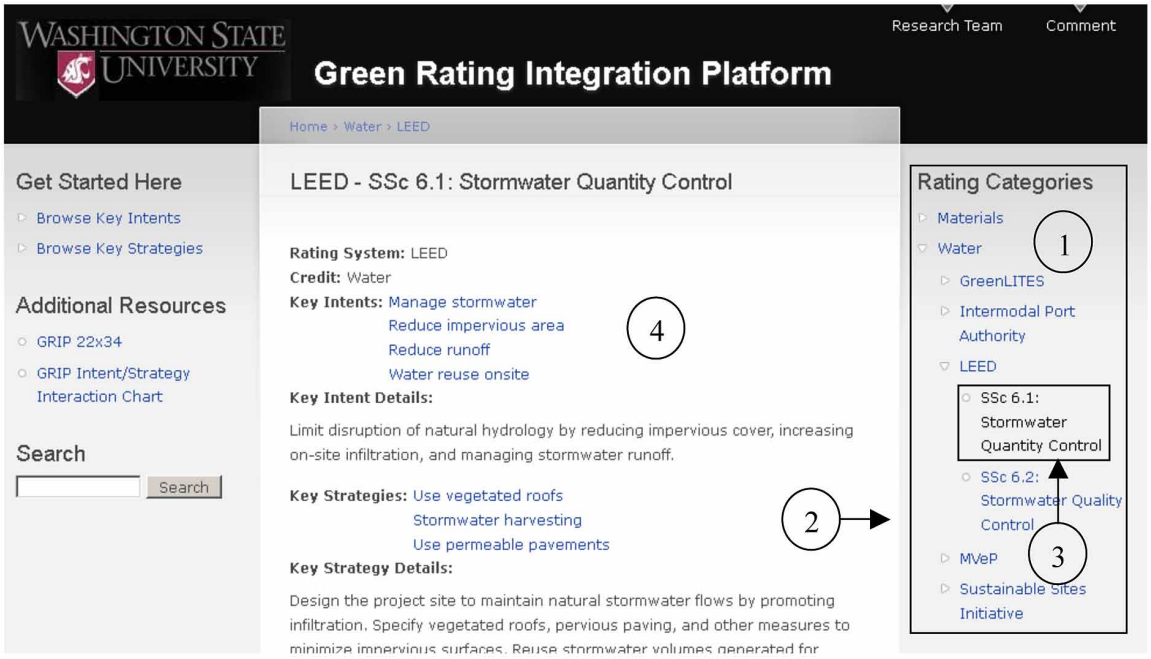
Database Development

As sustainability is becoming a key element in infrastructure design and construction, there is a need for interconnected tools to more readily identify and cross-reference sustainability practice methods. From that perspective, an open database has been developed so that sustainability practitioners and construction managers can access the information and receive simplified summary outputs. The database platform is based upon an open content management system named Drupal (http://drupal.org/). This database has been launched in the virtual world (https://greenintegration.cee.wsu.edu/). Currently, the database contains the details of the topical categories of 'Water' and 'Materials'. The database has the capability of data mining for key intents and key strategies. This is also an open database so that users can write comments and modify or update the analysis that has been performed to synthesize and harmonize the intents and strategies of these and other credit subcategories of various rating systems.

- ***Data Mining***

The objective of this database is to facilitate data mining for the key intents and key strategies and provide the user with a simplified output across the rating systems for impact analysis. The key intents and key strategies of different credit subcategories were programmed and scripted in such a way that, when a key intent or key strategy is selected, the database filters the credit subcategories, and returns a list of credit subcategories associated with that specific key intent or key strategy. The credit subcategories in the database were denoted to represent the rating systems the credit subcategories belong to.

FIGURE 3. List of key intents and key strategies for a credit sub-category.



There are various ways to data mine for key intents or key strategies. One way is to select a key intent or key strategy from inside the credit subcategories located in the dropdowns of the right sidebar under Rating Categories. Four notable features in Figure 3 represent right sidebar, topical categories menu, credit subcategories for LEED, and content area, respectively. The right sidebar dropdown contains the list of the five rating systems under each topical category while an additional dropdown lists the subcategories under specific topical category. Once the credit subcategory is selected, the detail description of the credit subcategory pops out in the content area. The details include the list of key intents and key strategies for the specific credit subcategory along with their details and credit points. Selection of a key intent or key strategy from this content area will list the credit subcategories associated with that specific key intent or key strategy.

Another way to select a key intent or key strategy is from the list of key intents (Figure 4) or key strategies that appear under the topical category dropdown in the left sidebar. Four important features in Figure 4 are for the left sidebar, key intents and key strategies tag menu, topical categories, and list of key intents for the five rating systems, respectively. The credit categories are listed under key intents and key strategies. Each topical category can have its own key intents and key strategies that have been obtained by analyzing the credit subcategories for different rating systems. As previously stated, these have been input in the database for the 'Water' and 'Material' topical categories.

An example from the water topical category is as follows. The selection of a key intent named "Reduce runoff", either from the left sidebar of "Browse Key Intents – Water" or from the right sidebar "Water – GreenLITES- GreenLITES - W1: Stormwater management (Quality and Volume)" returns the list of credit subcategories associated with reduce runoff

FIGURE 4. List of key intents for a specific credit category.

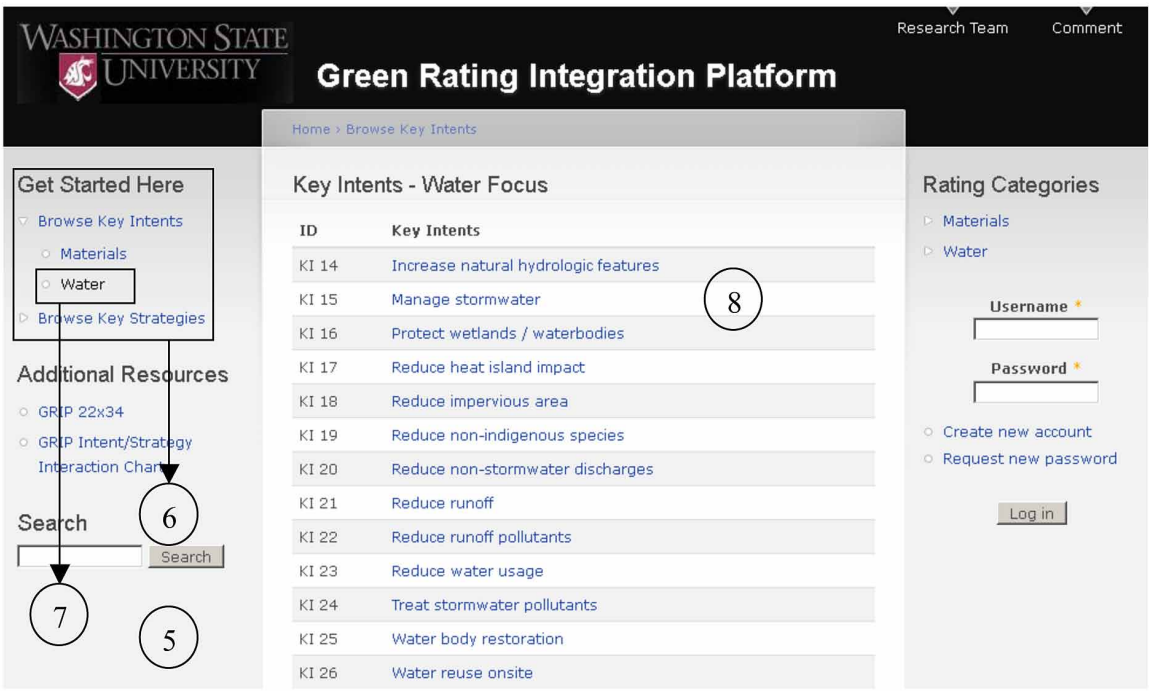
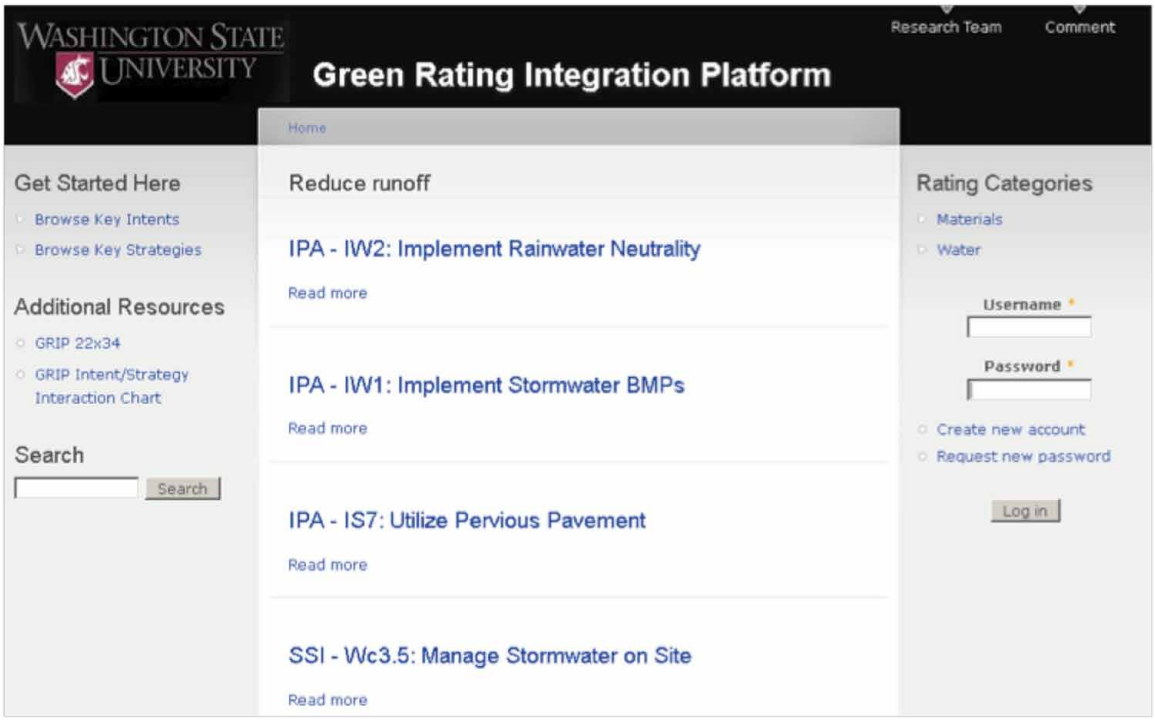


FIGURE 5. List of credit sub-categories for reduce runoff key intent.



(Figure 5). The acronym at the beginning of the subcategory represents the corresponding rating systems of that subcategory.

In summary, if the 22 credit subcategories of 'Water' are designated by WC1 to WC22 (Table 4), and the intents that were designated by KI13 to KI26 in the expanded Table 3 available on the website, then the credit subcategory for each of the intents obtained from the database can be listed as shown in Table 5. The highest recurring key intent is "Reduce non-stormwater discharge", mainly for marine side facilities. The other most appearing key intents are "Reduce runoff" and "Reduce runoff pollutants".

• ***Difference in Outputs between Search Bar and Data Mining***

In addition to data mining, a search bar located at the left sidebar of the website can be used. There are significant differences in the outputs from the search bar and tag search or data mining from the list of key intents and key strategies or from inside the credit subcategories. "*Reduce runoff*", a key intent selection, screens the credit subcategories and returns the list of credit subcategories that have "*Reduce runoff*" as a key intent as shown in Figure 5, while the reduce runoff search using the search bar returns a list of all items that includes these terms.

• ***Open Database***

The key intents and key strategies are listed based on the analysis of intents or objective, general strategies, methodology, credit point details, and sustainability judgment. Since the analysis is open ended, the database is open for the users and construction managers to write additional content for the analysis of key intents and key strategies. The database then can be updated reflecting the analysis.

TABLE 4: Designation for water credit sub-categories.

Designation	Credit Subcategory
WC1	W-1: Stormwater management (Quality and Volume)
WC2	W-2: Best Management Practices (BMPs)
WC3	SSc 6.1: Stormwater Quantity Control
WC4	SSc 6.2: Stormwater Quality Control
WC5	Wc3.3: Protect/Restore buffers
WC6	Wc3.4: Rehabilitate Streams
WC7	Wc3.5: Manage Stormwater on Site
WC8	Wc3.6: On-site Water Resources
WC9	Wc3.7: Use Stormwater for Landscape
WC10	Wc3.8: Maintain Water Features
WC11	IS-7: Utilize Pervious Pavement
WC12	IS-9: Use Turfgrass Appropriately
WC13	IW-1: Implement Stormwater BMPs
WC14	IW-2: Implement Rainwater Neutrality
WC15	IO-2: Maintain Soil Quality
WC16	WE1: Oily Water
WC17	WE2.1: Ballast Water/ Sediment
WC18	WE2.2: Hull Fouling
WC19	WE3: Sanitary Systems
WC20	WE4: Solid Waste
WC21	WE5: Incidental Discharges
WC22	WE6: Protection of Oil

TABLE 5: Water credit subcategories for the key intents.

Key Intents	Credit Sub-categories
Increase natural hydrologic features	WC10 WC15
Manage stormwater	WC2 WC3 WC7 WC11 WC14
Protect wetlands/ waterbodies	WC1 WC5 WC6
Reduce heat island impact	WC11
Reduce impervious area	WC1 WC3 WC8 WC11
Reduce non-indigenous species	WC1 WC17 WC18
Reduce non-stormwater discharge	WC6 WC16 WC17 WC19 WC20 WC21 WC22
Reduce runoff	WC1 WC3 WC7 WC11 WC13 WC14
Reduce runoff pollutants	WC1 WC4 WC5 WC8 WC11 WC13 WC14
Reduce water usage	WC12
Treat stormwater pollutants	WC2 WC4 WC6 WC8
Water body restoration	WC1 WC5 WC6
Water reuse onsite	WC3 WC9

CONCLUSION

An analytical hierarchy process method together with an example expert analysis were adopted to develop a spreadsheet for key intent sand key strategies for water and material sustainability issues across multiple rating systems related to a multi-modal construction project. Efforts to harmonize the key intents and key strategies have resulted in a preliminary cross-listing for further harmonization and synchronization in these topical categories (Table 3). In addition, an open database has been developed to filter key intents and key strategies. Selection of a key intent or a key strategy from the database lists the credit subcategories across the rating systems, thus enabling practitioners and construction managers to decide which key intents or key strategies might be the most appropriate for the green certification of their facility for multiple aspects of a project. The green rating integration platform, together with the harmonized key intent and key strategy cross-listings, create a more detailed decision making tool for evaluating which key strategy might accomplish the maximum number or extent of sustainability intents for a construction project. The open database will further facilitate this decision process.

Future research requires using expanded expert analysis methods for these topical categories and the associated credit subcategories to refine and list their key intents and key strategies. Another important aspect may be the inclusion of credit point analyses and then normalization of the credit points across the rating systems, since the different rating systems have different credit point options. In addition, sustainability includes not only environmental considerations, but economic and social ones as well. Decision makers and construction managers will need to include these other impact aspects in their final decisions. Enhanced access might also be provided with the establishment of an app application.

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