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A mathematical decision-making procedure to assist in the development of sustainability plans based on the STARS framework

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Abstract

Purpose – The purpose of this study was to establish an objective mathematical decision-making procedure to help universities prioritize credits, while using the Sustainability Tracking, Assessment and Rating System (STARS) framework developed by the Association for Advancement of Sustainability in Higher Education (AASHE), when pursuing their sustainability goals in the short-, medium- and long-term. The authors used the assessment data from Dominican University of California (DUofC), as our case study.

Design/methodology/approach – Two criteria, the number of possible points available and overall priority, were developed to classify credits in the STARS version 1.2 framework into six groups from lowest to highest level of difficulty. Two mathematical credit-selecting models based on how many points were available per credit, partial or full amount, were also established to produce short-, medium- and long-term plans.

Findings – Our results show that DUofC can reach the Silver level in three years by working on 25 credits; Gold level in nine years by focusing its efforts in 28 additional credits; and Platinum level in 15 years by improving another 10 credits.

Originality/value – The procedure developed in this study can be applied to other universities and other versions of the STARS framework.

Keywords STARS, Campus sustainability, Education management, Decision-making, Linear programming, AASHE

Paper type Research paper

Introduction

Sustainability is a critical challenge that all organizations are confronting in the 21st century (Rusinko, 2010). Its concept has become well-known worldwide since the 1970s (Meadows, 1972; Brundtland, 1987; Lozano, 2006; Wigmore and Ruiz, 2010), and it has evolved into organizational management that considers not only economic but also integrates environmental and social plans into all facets of decision-making (Richards

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and Gladwin, 1999). An enhanced overall description of sustainability is shown in Figure 1, which illustrates its three dimensions in the form of a concentric circle, representing environmental, economic and social needs (UNGA, 2005), as well as the processes that can lead to the achievement of its goals; environmental quality can be improved and maintained by cleaner technology, society can become more aware of sustainability issues by education and greater economic gain can be achieved by foresighted holistic decision-making.

A university, like a small city, influences the environment by its campus activities. But even beyond that, universities being centers of education have a pivotal role in training new leaders and therefore a great responsibility in modeling sustainable practices in their entire learning environment. Toward that goal, many universities are trying different integrated management systems for minimizing their environmental impacts (Kaplowitz *et al.*, 2009; Nouri *et al.*, 2010), as well as incorporating changes in their curriculum and programs offered (Cusick, 2009; Uwasu *et al.*, 2009; Fisher and Bonn, 2011; Shephard and Furnari, 2012; Drayson *et al.*, 2013), increasing their outreach to the community (Rojas *et al.*, 2007; Nordtveit, 2009; Petry *et al.*, 2011), adopting more sustainable practices regarding their operations (OP) and infrastructure (Cotton *et al.*, 2009; Harris and Probert, 2009; Zhang *et al.*, 2011), making administrative plans that take into account the triple bottom line (Lukman and Glavic, 2007; Blum, 2008; Anderson and Kumari, 2009; Evangelinos *et al.*, 2009) and other initiatives (Xiao and McPherson, 2005; Savanick *et al.*, 2007; Onuki and Mino, 2009; Meehan and McDonnell, 2010).

Although a comprehensive sustainability assessment system for businesses or corporations has been available since 2000, the "Sustainability Reporting Guidelines" developed by the "Global Reporting Initiative" (GRI, 2000), until recently no such framework had been developed, specifically for universities. Some attempts to develop a more targeted assessment for educational institutions were created as early as 2006 (Lozano, 2006; Velazquez *et al.*, 2006; Cotton *et al.*, 2009; Rusinko, 2010) but none of them was truly comprehensive. One exception, however, was the "Green League System" developed in 2007 by "People and Planet", which designed a ranking methodology for universities in the UK according to a very complete list of environmental and ethical performances (People and Planet, 2014). Yet, arguably, the most comprehensive system assessing sustainability in higher education developed so far is the "Sustainability

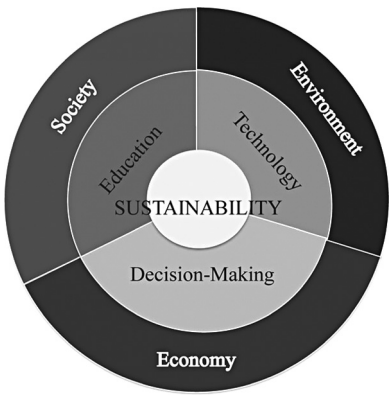

Figure 1.
The enhanced concept of sustainability including the triple bottom line: environment, society and economy (Brundtland, 1987; United Nations General Assembly, 2005) and key processes needed to achieve its main goals

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Tracking, Assessment & Rating System" (STARS), developed in 2010 by the "Association for the Advancement of Sustainability in Higher Education" (AASHE, 2014a). STARS is a self-reporting framework which is currently open to any higher-education institution in the USA or Canada and possibly will become available to other countries in the near future, as an international pilot program is already in place (AASHE, 2012). It has four major purposes:

(1) to provide an easily understandable framework;
(2) to offer a comparable measurement for institutions;
(3) to advance information sharing about sustainable practices; and
(4) to establish a diverse campus sustainability community (AASHE, 2012).

It takes into account four main categories:

(1) education and research (ER);
(2) OP;
(3) planning, administration and engagement (PAE); and
(4) innovation (IN).

Depending on their scores, institutions are placed in one of five levels from lowest to highest:

(1) Reporter;
(2) Bronze;
(3) Silver;
(4) Gold; or
(5) Platinum.

The rating is valid for three years.

Despite the clear framework provided by STARS, it can be difficult for universities to decide how to prioritize their efforts when considering their future sustainability goals if pursuing a higher rating. There are so many credits that can be pursued; it raises the question, which ones should be chosen first? Currently, there is no objective, mathematical decision-making model that can assist administrators to develop future sustainability plans based on this framework. The goal of the present study was to create such procedure, using data from the sustainability assessment conducted by Dominican University of California (DUofC), USA, as a case study. Although DUofC's assessment was based on the STARS technical manual version 1.2, the approach proposed in this paper is a general decision-making procedure and can be used with any version of the STARS framework for any university.

Methods

In this section, we describe the methodology used to assess sustainability at DUofC in 2012, the procedure applied to establish the criteria used in categorizing credits for the decision-making approach and, finally, the mathematical models used to produce short-, medium- and long-term plans.

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Data collection and assessment of sustainability

We used the STARS version 1.2 framework for assessing campus sustainability. This assessment system includes four main categories and many sub-categories, comprising 139 credits. Depending on the results of the assessment, five rating levels can be reached:

(1) Platinum, if a minimum score of 85 is reached;
(2) Gold, 65;
(3) Silver, 45;
(4) Bronze, 25; and
(5) Reporter, below 25 (AASHE, 2012).

The score is determined using three steps:

(1) calculate the percentage of applicable points in each of the first three categories;
(2) average all three values; and
(3) add the point(s) earned in Category 4.

The details of how each credit were evaluated and scored were described in the technical manual (AASHE, 2012). In this subsection, we present only an overview of the process:

- *Timeframe*. The period of STARS reporting is one year, in this case study from January 9, 2012 to January 8, 2013.
- *Sampling and Data*. Based on the STARS reporting criteria for each credit, the investigators identified organizational stakeholders to contact, as well as the type of information needed to determine if DUofC could claim credits. Methods of data collection varied depending on the credit. In some cases, phone conversations, face-to-face interviews or e-mail correspondence served as means to identify if points for a certain credit could be claimed. In other instances, the team developed questionnaires, which were administered online to faculty, staff and/or students through SurveyMonkey (a free online questionnaire tool, www.surveymonkey.com), e.g. transportation and research surveys. The technical manual provided guidelines on when institutions may use a representative sample to measure performance. To determine other credits, university documents and reports were obtained from relevant departments and offices. In measuring performance or reporting from these sources, the protocols and standards described in the technical manual were adhered to.
- *Scoring and reporting*. All points were calculated following the examples provided in the manual; in some cases, we were only able to claim partial points for a specific credit. For each credit that DUofC claimed, the required information was entered into fields that appear in the STARS Online Reporting Tool.

Criteria used to categorize credits for the decision-making approach

Only credits found in the first three categories will be considered in this study because credits in Category 4 that are claimed in one assessment cannot be used again in the next assessment (AASHE, 2012), and they are also difficult to predict. Thus, only the 135 credits for categories 1-3 were used in the development of the decision-making approach.

To establish short-, medium- and long-term plans, we selected credits based on two criteria, as follows:

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(1) *Criterion 1* – number of possible points available.

Zero (Z): a credit that was completed and no more points were available;

Partial (P): a credit that was partially completed, with some possible points still available; and

Full (F): a credit with full points available.

(2) *Criterion 2* – overall priority.

Three priority levels, high, medium and low, were assigned to credits based on the perceived level of difficulty in achieving them, as reflected in the information gathered during the assessment:

(1) High (H): low cost and/or easy to improve;

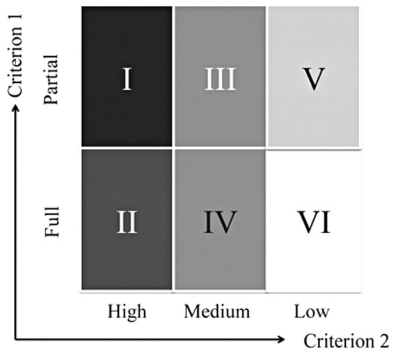
(2) Medium (M): medium cost and/or relatively difficult to improve; and

(3) Low (L): high cost and/or very difficult to improve.

As Figure 2 shows, we used Criterion 1 to select all credits in the Full and Partial groups. Credits in the Zero group had already been completed and were not included in the models. Additionally, we assumed that credits for which the university had already received some points for (Partial group) were generally easier to improve than those with no points (Full group). Then, Criterion 2 was used to select High, Medium and Low priority credits. After both criteria were applied to the credits, six groups were formed, with the easiest ones to achieve clustered in Group I and the most difficult in Group VI.

Conceptual credit-selecting (CS) models

The models assume that whatever level of sustainability-related achievements DUofC has reached thus far will continue to exist and/or be maintained. Two linear programming models were established to identify which credits should be targeted first for improvement. The formula is as follows:



Notes: Roman numerals represent the selected group of credits that should be pursued in incremental order when developing short-, medium- and long-term plans

Figure 2.
The matrix of the result of the selection of credits based on Criterion 1, number of possible points available, and Criterion 2, priority level assigned to the credit based on the perceived level of difficulty in achieving it

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(1) Partial credit-selecting (PCS) model for Groups I, III and V:

$$Minimum \sum_{j \in J} \sum_{k \in K} G_{kj} \times c_{kj} \tag{1a}$$

Subject to:

$$\sum_{j \in J} \sum_{k \in K} G_{kj} \times c_{kj} \geq 3 \times \left(S_{all} - \sum_{n \in N} S^*_{n-1} \right) \tag{1b}$$

$$c_{kj} \geq 0, \ \forall kj \tag{1c}$$

$$c_{kj} \in Integer \ 0 \ or \ 1, \forall kj \tag{1d}$$

Where k is an individual credit within a pre-determined sequence of credits; K is the total number of credits; j is an individual category within a pre-determined sequence of categories; J is the total number of categories; n is an individual group within a pre-determined sequence of groups; N is the group that the model has been applied to up to the present in a scenario; c_{kj} is the decision-making parameter that will be provided by the model for choosing the credit k in category j or not; G_{kj} is the percentage difference between possible points and actual points already obtained of applicable points for credit k in category j; S_{all} is the additional STARS overall score needed to achieve the intended goal (i.e. next STARS level); S^*_{n-1} is the STARS overall score gained in last group; $3 \times (S_{all} + \Sigma_{n \epsilon N} S^*_{n-1})$ is the percentage of applicable points of this group gained in three categories; equation (1a) is the objective function, which aims to choose the minimum number of credits that almost reach the total number of points possible; equation (1b) targets only the additional amount of points that this study intends to achieve at a given time; equation (1c) limits each credit k in category j as non-negative, as required by linear modeling; and equation (1d) limits the parameter as 0 or 1 integer.

(2) Full credit-selecting (FCS) model for Groups II, IV and VI:

$$Minimum \sum_{j \in J} \sum_{k \in K} \frac{c_{kj}}{W_{kj}} \tag{2a}$$

Subject to:

$$\sum_{j \in J} \sum_{k \in K} W_{kj} \times c_{kj} \geq 3 \times \left(S_{all} - \sum_{n \in N} S^*_{n-1} \right) \tag{2b}$$

$$c_{kj} \geq 0, \ \forall kj \tag{2c}$$

$$c_{kj} \in Integer \, 0 \, or \, 1, \ \forall kj \tag{2d}$$

Where W_{kj} is the percentage of the total possible points for credit k in total applicable points of category j; other variables are the same as those used in

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equation (1); equation (2a) is the objective function, which aims to identify the minimum number of credits that close to achieve the intended goal (i.e. next STARS level); and equation (2b) targets only the additional amount of points that this study intends to achieve at a given time.

Establishing short-, medium- and long-term plans

The models provided credit lists to be considered in future plans to achieve incrementally higher sustainability assessment ratings, as follows:

- *Short-term plan (Scenario A)*. The short-term plan goal is to reach Silver level (45 STARS overall score) from the current Bronze level achieved by DUofC (34.59 STARS overall score) in 2012 in three years, which is one assessment cycle, and most of the selected credits were considered relatively easy to be improved.
- *Mid-term plan (Scenario B)*. The medium-term plan goal is to reach Gold level (65 STARS overall score) from Silver level (45 STARS overall score) in nine years, which covers three assessment cycles, and most of the selected credits were considered relatively more difficult to be improved.
- *Long-term plan (Scenario C)*. The long-term plan goal is to reach Platinum level (85 STARS overall score) from Gold level (65 STARS overall score) in 15 years, which covers five assessment cycles, and most of the selected credits were considered the most difficult to be improved.

Results

This study's goal was to establish a procedure to facilitate the decision-making process of choosing which credits to improve first to achieve higher sustainability ratings in the STARS framework. It takes into account two criteria as well as PCS and FCS models, as explained previously. The classification of credits and the results of each scenario are as follows.

Classifications of credits

The credits used in this paper, including DUofC applicable points, points received, criteria and group, are listed in the Appendix (Tables AI–AIII). The percentages of applicable points that DUofC earned in each of the three main STARS categories are shown in Figure 3; Category 1, ER, got the highest score and Category 2, OP, got the lowest.

The percentages of points that DUofC received in each sub-category of categories 1-3 are shown respectively in Figures 4-6. In Category 1, ER, the highest score was in the subcategory curriculum and the lowest in co-curricular education. In Category 2, OP, the highest score was in the subcategory water and the lowest in buildings. In Category 3, PAE, the highest score was in the subcategory human resources and the lowest in investment.

Considering all 135 credits regarding Criterion 1, DUofC received full points for 44 of them, partial points for 23 and no points for 68. Criterion 2 was then applied to the 91 credits that the university could receive partial or full points for in the future (Table I). Most credits (6 out of 17) in Category 1, ER, fall in Group IV; and most credits in Category 2, OP, and 3, PAE, (18 of 51, and 13 of 23, respectively) fall in Group VI (Table I). Credits in Groups I-IV were applied in the short-term plan, in Groups IV and V in the medium-term plan and in Groups V and VI in the long-term plan.

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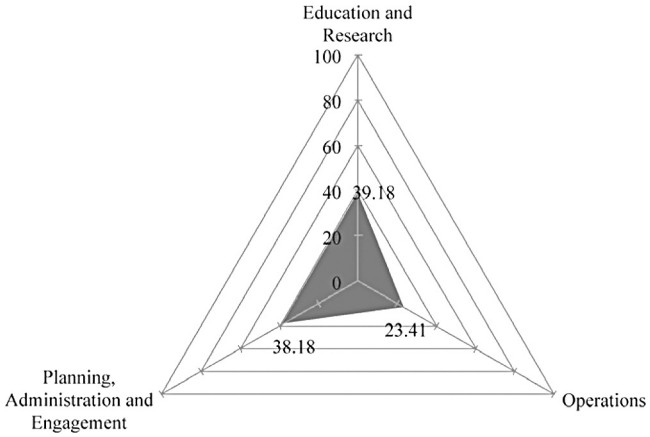

Figure 3.
The percentage of applicable points DUofC earned in 2012 in each of three main categories according to the STARS version 1.2 framework

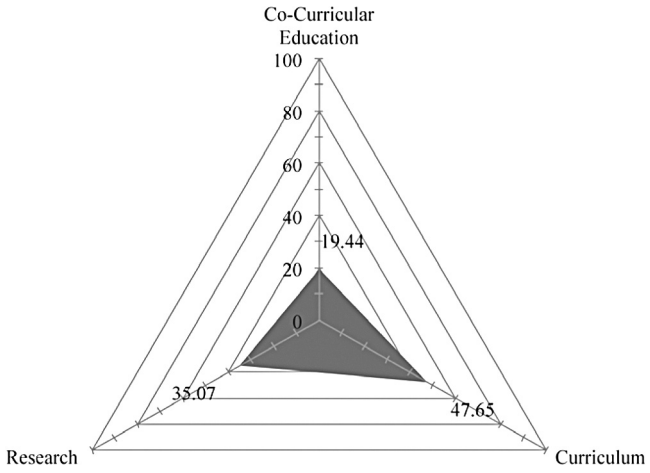

Figure 4.
The percentage of applicable points DUofC earned in 2012 in each of the sub-categories of Category 1, "Education and Research", according to the STARS version 1.2 framework

Short-term plan (Scenario A)

The short-term plan for DUofC is to reach Silver level (45 STARS overall score) within three years. Except for the one point earned in Category 4, the average of the percentage of applicable points in the other three categories is 33.59. Thus, in Scenario A, the goal is to achieve an additional 11.41 STARS overall score or 34.23 per cent of applicable points in the three categories. The models selected credits from Groups I-IV that would provide the number of points necessary to achieve that total (Table II). According to the possible amount of percentage points in each group, the total for Groups I, II and III is 33.72. Therefore, all credits in Groups I, II and III must be improved, and, at least one credit in Group IV also needed to be included in this scenario to achieve the 34.23 per cent of applicable points.

The results for Scenario A are listed in Table II; there are 25 credits that need to be improved in three years to reach a STARS overall score of 46.83, which will place the university at the Silver level.

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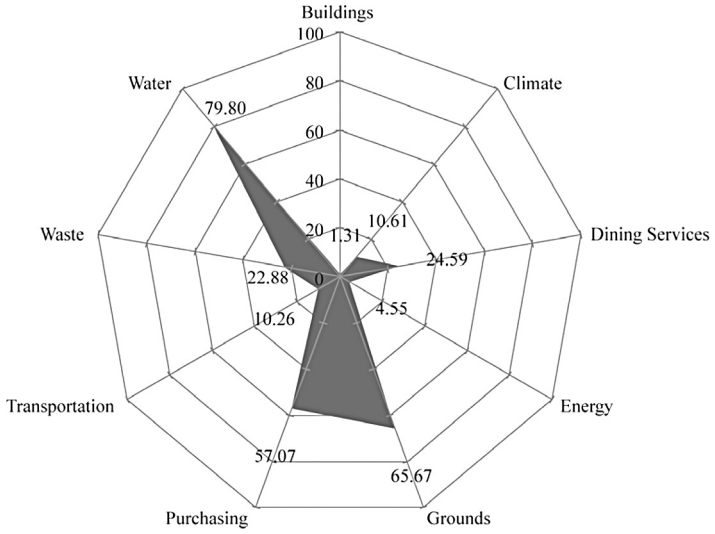

Figure 5.
The percentage of applicable points DUofC earned in 2012 in each of the sub-categories of Category 2, "Operations", according to the STARS version 1.2 framework

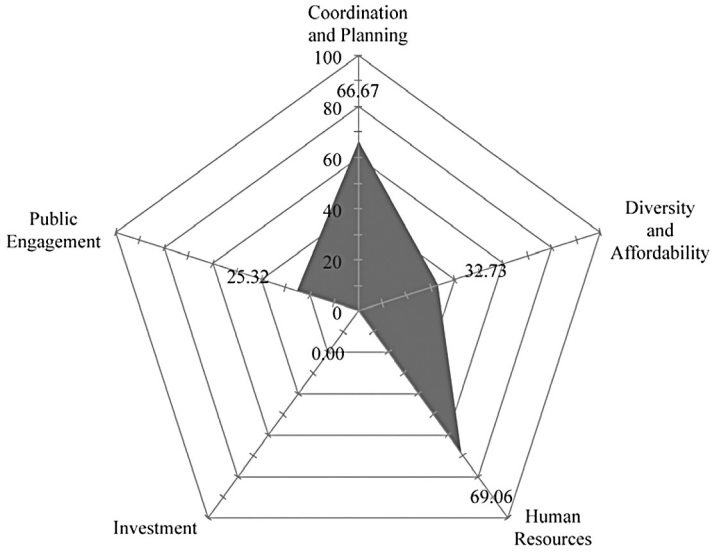

Figure 6.
The percentage of applicable points DUofC earned in 2012 in each of the sub-categories of Category 3, "Planning, Administration and Engagement", according to the STARS version 1.2 framework

Mid-term plan (Scenario B)

The mid-term plan for DUofC is to reach Gold level (65 STARS overall score) within nine years. In Scenario B, the goal is to achieve an additional 20 STARS overall score or 60 per cent of applicable points in the three categories. The models selected credits from Groups IV and V that would provide the number of points necessary to achieve that total (Table III). According to the possible amount of per cent points in each group, the total for Group IV is

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40.06. Therefore, all credits in group IV must be improved, and some credits in Group V also needed to be included in this scenario to achieve the 60 per cent of applicable points.

The results for Scenario B are listed in Table III; there are 28 credits that need to be improved in nine years to reach a STARS overall score of 66.83, which will place the university at the Gold level.

Long-term plan (Scenario C)

The long-term plan for DUofC is to reach Platinum level (85 STARS overall score) within 15 years. In scenario C, the goal is to achieve an additional 20 STARS overall score or 60 per cent of applicable points in the three categories. The models selected credits from Groups V and VI that would provide the number of points necessary to achieve that total (Table IV). According to the possible amount of percentage points in each group, the total for Group V is 19.39. Therefore, all credits in Group V must be improved, and some credits in Group VI also needed to be included in this scenario to achieve the 60 per cent of applicable points.

The results for Scenario C are listed in Table IV; there are 10 credits that need to be improved in 15 years to reach a STARS overall score of 88.39, which will place the university at the Platinum level.

There were 28 credits not selected by the models for the short-, medium- and long-term plans, as listed in Table V.

The percentage of credits selected by the models in each category for the three scenarios are shown in Figure 7. The data show that although improvement is needed in all categories, Category 2 is the most important one to be improved in all plans.

Discussions

So far, 305 higher-education institutions have been rated regarding their sustainability performance using the STARS framework; 7.5 per cent received a STARS Reporter rating, 22.0 per cent Bronze level, 51.5 per cent Silver, 19.0 per cent Gold and none have reached the highest level Platinum (AASHE, 2014b).

Once a campus-wide sustainability assessment has taken place and the baseline has been established, universities can move forward taking different paths. One may be a top-down approach in which the university's higher administration decides on the credits to pursue first. Another could be a more inclusive method that incorporates a broader representation of the campus community and uses its response on what the priorities should be to move forward. Yet, another possibility may be dependent on what funding agencies or philanthropists would be willing to sponsor, as clearly some upgrades demand more resources than others. Yet, presently, there are no studies on

Group	All credits	ER credits	OP credits	PAE credits	Total points
I	6	2	4	0	5.06
II	12	2	8	2	10.02
III	6	1	3	2	18.64
IV	23	6	13	4	46.06
V	11	4	5	2	39.34
VI	33	2	18	13	80.11

Notes: ER–Category 1, OP–Category 2, PAE–Category 3

Table I. Number of credits in each group and the possible amount of percentage points that can be achieved in the future according to the two criteria that were applied to all credits

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CI	CT	CA	MPPP
Group I			
OP 4	Greenhouse gas emissions inventory	2	0.25
OP 20	Electronic waste recycling program	2	0.5
ER 8	Sustainability courses by department	1	0.09
OP 22	Water consumption	2	0.83
OP 12	Office paper purchasing	2	1.39
ER 4	Sustainability materials and publications	1	2.00
Group II			
ER 14	Incentives for developing sustainability courses	1	3.00
ER 19	Interdisciplinary research in tenure and promotion	1	2.00
PAE 8	Support programs for underrepresented groups	3	2.00
OP 21	Hazardous waste management	2	1.01
OP T2-10	Recycled content napkins	2	0.25
OP T2-20	Wildlife habitat	2	0.25
OP T2-24	Historically underutilized businesses	2	0.25
OP T2-25	Local businesses	2	0.25
OP T2-36	Prohibiting idling	2	0.25
OP T2-38	Materials exchange	2	0.25
OP T2-42	Move-in waste reduction	2	0.25
PAE T2-1	Gender neutral housing	3	0.25
Group III			
OP 9	Integrated pest management	2	0.53
OP 23	Storm water management	2	1.01
OP 18	Waste diversion	2	2.41
PAE 23	Community service hours	3	4.50
PAE 22	Community service participation	3	4.71
ER 9	Sustainability learning outcomes	1	5.48
Group VI			
ER 18	Sustainability research incentives	1	6.00

Notes: CI: credit ID, CT: credit title, CA: category, MPPP: more percentage points possible

Table II.
Credits selected by the models for the short-term plan or Scenario A

structured analyses that would provide an objective and comprehensive approach on how a university could best plan to move forward.

In the present study, we used the STARS assessment as our basic framework to develop strategic sustainability planning. Resources are often limited and, although ideally, deciding on priorities should involve broad campus participation, it can be very difficult to reach a consensus from the campus community on how to prioritize what to do next. The approach proposed in this study offers impartial guidelines for future planning by providing what is perceived to be the easiest initial path to advance, while considering information gathered from the different departments on campus and, thus, reducing conflict.

To reach increasingly higher STARS levels, our models chose several credits from different categories with clear guidelines not only in the short-term but also for medium and long-term plans. This procedure is also flexible and allows for feedback; for example, the models can be refined by further discussing priorities for credits with the different departments that were involved in providing data or changed according to the

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CI	CT	CA	MPPP
Group IV			
OP 17	Waste reduction	2	5.04
ER 1	Student sustainability educators program	1	5.00
ER 2	Student sustainability outreach campaign	1	5.00
PAE 17	Shareholder advocacy	3	5.00
ER 10	Undergraduate program in sustainability	1	4.00
PAE 3	Physical campus plan	3	4.00
PAE 10	Affordability and access programs	3	3.00
ER 13	Sustainability literacy assessment	1	2.00
ER 3	Sustainability in new student orientation	1	2.00
PAE 20	Inter-campus collaboration on sustainability	3	2.00
OP T2-7	Pre-consumer food waste composting	2	0.25
OP T2-8	Post-consumer food waste composting	2	0.25
OP T2-9	Food donation	2	0.25
OP T2-12	Reusable to-go containers	2	0.25
OP T2-21	Tree campus USA	2	0.25
OP T2-26	Bicycle sharing	2	0.25
OP T2-29	Mass transit	2	0.25
OP T2-30	Condensed work week	2	0.25
OP T2-31	Telecommuting	2	0.25
OP T2-32	Carpool/vanpool matching	2	0.25
OP T2-41	Chemical reuse inventory	2	0.25
OP T2-44	Waterless urinals	2	0.25
Group V			
OP 11	Cleaning product purchasing	2	0.34
OP 3	Indoor air quality	2	1.84
OP 16	Employee commute modal split	2	2.60
ER 17	Departments involved in sustainability research	1	3.71
PAE 21	Sustainability in continuing education	3	4.00
ER 6	Sustainability-focused courses	1	7.45

Notes: CI: credit ID, CT: credit title, CA: category, MPPP: more percentage points

Table III.
Credits selected by the models for the mid-term plan or Scenario B

response from the campus community over time. Additionally, the models can be adjusted if budgetary information is available. Finally, the models can accommodate additional credits and be used in another version of the STARS framework in future assessments. For instance, the credits selected in this paper are based on the STARS version 1.2 framework, if the university uses a different version of the framework in the next assessment three years from now, then after the data are collected, the models can be rerun to obtain new plans for improvement.

In some cases, it may be easier for administrators to deploy follow-up decision-making processes for credits which gained partial points than those without any points, but this assumption is not always true for all credits. Additionally, our models do not take into account that some credits are relative with others and can gain more points by improving other credits, e.g. pursuit of the Building Operations and Maintenance credit (OP7) can increase the points of the Greenhouse Gas Emissions Reduction credit (OP5). Although the procedure proposed in this paper is not perfect, it

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CI	CT	CA	MPPP
Group V			
PAE 11	Sustainable compensation	3	0.86
OP 14	Campus fleet	2	1.25
OP 6	Food and beverage purchasing	2	4.70
ER 16	Faculty involved in sustainability research	1	5.82
ER 7	Sustainability-related courses	1	6.77
Group VI			
OP 5	Greenhouse gas emissions reduction	2	14.11
PAE 18	Positive sustainability investments	3	9.00
OP 7	Building energy consumption	2	8.06
OP 1	Building operations and maintenance	2	7.05
OP 8	Clean and renewable energy	2	7.05

Notes: CI: credit ID, CT: credit title, CA: category, MPPP: more percentage points

Table IV.
Credits selected by the models for the long-term plan or Scenario C

CI	CT	CA	MPPP
PAE 15	Employee sustainability educators program	3	5
OP 2	Building design and construction	2	4.03
OP 15	Student commute modal split	2	4.03
PAE 9	Support programs for future faculty	3	4
PAE 24	Sustainability policy advocacy	3	4
PAE 25	Trademark licensing	3	4
PAE 5	Climate plan	3	2
PAE 16	Committee socially responsible investment	3	2
OP 13	Vendor code of conduct	2	1.01
OP T2-1	Air travel emissions	2	0.25
OP T2-2	Local offsets program	2	0.25
OP T2-4	Vegan dining	2	0.25
OP T2-6	Guidelines for franchisees	2	0.25
OP T2-15	LED lighting	2	0.25
OP T2-16	Vending machine sensors	2	0.25
OP T2-17	Energy management system	2	0.25
OP T2-27	Facilities for bicyclists	2	0.25
OP T2-28	Bicycle plan	2	0.25
OP T2-35	Local housing	2	0.25
OP T2-37	Car sharing	2	0.25
ER T2-3	Model room in residence hall	1	0.25
ER T2-5	Sustainable enterprise	1	0.25
PAE T2-4	Childcare	3	0.25
PAE T2-7	Student-managed SRI fund	3	0.25
PAE T2-8	Socially responsible investment policy	3	0.25
PAE T2-9	Investment disclosure	3	0.25
PAE T2-10	Graduation pledge	3	0.25
PAE T2-12	Farmer's markets	3	0.25

Notes: CI: credit ID, CT: credit title, CA: category, MPPP: more percentage points

Table V.
Other possible credits not selected by the model

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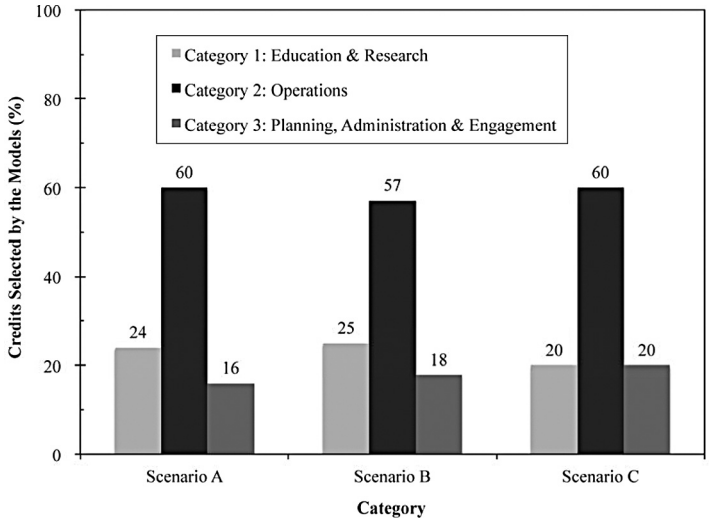

Figure 7.
The percentage of credits selected by the models per category in each of the three scenarios

provides a university that is in the beginning stage of the STARS rating system with a process to choose which credits should be pursued among several credits.

Because the STARS framework may change over time, future planning based on this framework can be challenging, as universities will be dealing with a moving target. For instance, recently STARS released its version 2.0 framework (AASHE, 2014c); some of the credits present in version 1.2 were no longer present (Table VI), and the scoring methods for many others became more rigorous.

Yet, if a university makes improvement plans based on the version of the framework that it used for its last assessment, it will know how much it has improved in relation to its initial baseline while moving toward its sustainability goals.

Conclusions

This paper proposed an approach that consists of two criteria, number of possible points available and overall priority and two linear mathematical models, which selected credits for short-, medium- and long-term sustainability plans that the university which is in the earlier

CI	CT
ER 8	Sustainability courses by department
ER 17	Departments involved in sustainability research
OP T2-5	Trans-Fats
OP T2-10	Recycled content napkins
OP T2-25	Local businesses
OP T2-33	Cash-out parking
OP T2-36	Prohibiting idling
PAE T2-12	Farmer's markets

Notes: CI: credit ID, CT: credit title

Table VI.
Credits removed in the version 2.0 draft framework to version 1.2

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step of the STARS rating system can use as a guideline and that provides an objective starting point for campus community discussions on what can be improved. Ultimately, each higher-education institution needs to choose the best approach for its own sustainability long-term goals, and we hope the approach discussed in this paper will help them with this process. Future research on this and other types of optimization tools applicable to diverse frameworks would be valuable in helping accelerate the transition toward greater sustainability in higher education worldwide.

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Appendix

CI	CT	DAP	PR	C1	C2	G
Co-curricular education						
ER 1	Student sustainability educators program	5	0	F	M	IV
ER 2	Student sustainability outreach campaign	5	0	F	M	IV
ER 3	Sustainability in new student orientation	2	0	F	M	IV
ER 4	Sustainability materials and publications	4	2	P	H	I
ER T2-1	Student group	0.25	0.25	Z	C	F
ER T2-2	Organic garden	0.25	0.25	Z	C	F
ER T2-3	Model room in residence hall	0.25	0	F	L	VI
ER T2-4	Themed housing	0.25	0.25	Z	C	F
ER T2-5	Sustainable enterprise	0.25	0	F	L	VI
ER T2-6	Sustainability events	0.25	0.25	Z	C	F
ER T2-7	Outdoor program	0.25	0.25	Z	C	F
ER T2-8	Themed semester or year	0.25	0.25	Z	C	F
	Co-curricular education total points	18	3.5			
Curriculum						
ER 5	Sustainability course identification	3	3	Z	C	F
ER 6	Sustainability-focused courses	10	2.55	P	L	V
ER 7	Sustainability-related courses	10	3.23	P	L	V
ER 8	Sustainability courses by department	7	6.91	P	H	I
ER 9	Sustainability learning outcomes	10	4.52	P	M	III
ER 10	Undergraduate program in sustainability	4	0	F	M	IV
ER 11	Graduate program in sustainability	4	4	Z	C	F
ER 12	Sustainability immersive experience	2	2	Z	C	F
ER 13	Sustainability literacy assessment	2	0	F	M	IV
ER 14	Incentives for developing sustainability courses	3	0	F	H	II
	Curriculum total points	55	26.21			
Research						
ER 15	Sustainability research identification	3	3	Z	C	F
ER 16	Faculty involved in sustainability research	10	4.18	P	L	V
ER 17	Departments involved in sustainability research	6	2.29	P	L	V
ER 18	Sustainability research incentives	6	0	F	M	IV
ER 19	Interdisciplinary research in tenure and promotion	2	0	F	H	II
	Research total points	27	9.47			
Total ER points		100	39.18			

Table AI.
STARS v1.2 credit list for "Category 1: education and research (ER)"

Notes: CI: credit ID, CT: credit title, DAP: DUofC applicable points, PR: points received, C1: Criterion 1 and C2: Criterion 2

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CI	CT	DAP	PR	C1	C2	G
Buildings						
OP 1	Building operations and maintenance	7	0	F	L	VI
OP 2	Building design and construction	4	0	F	L	VI
OP 3	Indoor air quality	2	0.17	P	L	V
	Buildings total points	13	0.17			
Climate						
OP 4	Greenhouse gas emissions inventory	2	1.75	P	H	I
OP 5	Greenhouse gas emissions reduction	14	0	F	L	VI
OP T2-1	Air travel emissions	0.25	0	F	L	VI
OP T2-2	Local offsets program	0.25	0	F	L	VI
	Climate total points	16.5	1.75			
Dining services						
OP 6	Food and beverage purchasing	6	1.34	P	L	V
OP T2-3	Tray-less dining	0.25	0.25	Z	C	F
OP T2-4	Vegan dining	0.25	0	F	L	VI
OP T2-5	Trans-Fats	0.25	0.25	Z	C	F
OP T2-6	Guidelines for franchisees	0.25	0	F	L	VI
OP T2-7	Pre-Consumer food waste composting	0.25	0	F	M	IV
OP T2-8	Post-Consumer food waste composting	0.25	0	F	M	IV
OP T2-9	Food donation	0.25	0	F	M	IV
OP T2-10	Recycled content napkins	0.25	0	F	H	II
OP T2-11	Reusable mug discounts	0.25	0.25	Z	C	F
OP T2-12	Reusable to-go containers	0.25	0	F	M	IV
	Dining services total points	8.5	2.09			
Energy						
OP 7	Building energy consumption	8	0	F	L	VI
OP 8	Clean and renewable energy	7	0	F	L	VI
OP T2-13	Timers for temperature control	0.25	0.25	Z	C	F
OP T2-14	Lighting sensors	0.25	0.25	Z	C	F
OP T2-15	LED lighting	0.25	0	F	L	VI
OP T2-16	Vending machine sensors	0.25	0	F	L	VI
OP T2-17	Energy management system	0.25	0	F	L	VI
OP T2-18	Energy metering	0.25	0.25	Z	H	F
	Energy total points	16.5	0.75			
Grounds						
OP 9	Integrated pest management	2	1.47	P	M	III
OP T2-19	Native plants	0.25	0.25	Z	C	F
OP T2-20	Wildlife habitat	0.25	0	F	H	II
OP T2-21	Tree campus USA	0.25	0	F	M	IV
OP T2-22	Snow and ice removal	0	0	Z	C	F
OP T2-23	Compost	0.25	0.25	Z	C	F
	Grounds total points	3	1.97			

(*continued*)

Table AII.
STARS v1.2 credit list for "Category 2: operations (OP)"

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CI	CT	DAP	PR	C1	C2	G
Purchasing						
OP 10	Computer purchasing	2	2	Z	C	F
OP 11	Cleaning product purchasing	2	1.66	P	L	V
OP 12	Office paper purchasing	2	0.62	P	H	I
OP 13	Vendor code of conduct	1	0	F	L	VI
OP T2-24	Historically underutilized businesses	0.25	0	F	H	II
OP T2-25	Local businesses	0.25	0	F	H	II
	Purchasing total points	7.5	4.28			
Transportation						
OP 14	Campus fleet	2	0.76	P	L	V
OP 15	Student commute modal split	4	0	F	L	VI
OP 16	Employee commute modal split	3	0.42	P	L	V
OP T2-26	Bicycle sharing	0.25	0	F	M	IV
OP T2-27	Facilities for bicyclists	0.25	0	F	L	VI
OP T2-28	Bicycle plan	0.25	0	F	L	VI
OP T2-29	Mass transit	0.25	0	F	M	IV
OP T2-30	Condensed work week	0.25	0	F	M	IV
OP T2-31	Telecommuting	0.25	0	F	M	IV
OP T2-32	Carpool/vanpool matching	0.25	0	F	M	IV
OP T2-33	Cash-out parking	0	0	Z	C	F
OP T2-34	Carpool discount	0	0	Z	C	F
OP T2-35	Local housing	0.25	0	F	L	VI
OP T2-36	Prohibiting idling	0.25	0	F	H	II
OP T2-37	Car sharing	0.25	0	F	L	VI
	Transportation total points	11.5	1.18			
Waste						
OP 17	Waste reduction	5	0	F	M	IV
OP 18	Waste diversion	3	0.61	P	M	III
OP 19	Construction and demolition waste diversion	1	1	Z	C	F
OP 20	Electronic waste recycling program	1	0.5	P	H	I
OP 21	Hazardous waste management	1	0	F	H	II
OP T2-38	Materials exchange	0.25	0	F	H	II
OP T2-39	Limiting printing	0.25	0.25	Z	C	F
OP T2-40	Materials online	0.25	0.25	Z	C	F
OP T2-41	Chemical reuse inventory	0.25	0	F	M	IV
OP T2-42	Move-in waste reduction	0.25	0	F	H	II
OP T2-43	Move-out waste reduction	0.25	0.25	Z	C	F
	Waste total points	12.5	2.86			
Water						
OP 22	Water consumption	7	6.18	P	H	I
OP 23	Storm water management	2	1	P	M	III
OP T2-44	Waterless urinals	0.25	0	F	M	IV
OP T2-45	Building water metering	0.25	0.25	Z	H	F
OP T2-46	Non-potable water usage	0.25	0.25	Z	C	F
OP T2-47	Xeriscaping	0.25	0.25	Z	H	F
OP T2-48	Weather-informed irrigation	0.25	0.25	Z	C	F
	Water total points	10.25	8.18			
Total OP points		99.25	23.23			

Notes: CI: credit ID, CT: credit title, DAP: DUofC applicable points, PR: points received, C1: Criterion 1 and C2: Criterion 2

Table AII.

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CI	CT	DAP	PR	C1	C2	G
Coordination and planning						
PAE 1	Sustainability coordination	3	3	Z	C	F
PAE 2	Strategic plan	6	6	Z	C	F
PAE 3	Physical campus plan	4	0	F	M	IV
PAE 4	Sustainability plan	3	3	Z	C	F
PAE 5	Climate plan	2	0	F	L	VI
	Coordination and planning total points	18	12			
Diversity and affordability						
PAE 6	Diversity and equity coordination	2	2	Z	C	F
PAE 7	Measuring campus diversity culture	2	2	Z	C	F
PAE 8	Support programs for underrepresented groups	2	0	F	H	II
PAE 9	Support programs for future faculty	4	0	F	L	VI
PAE 10	Affordability and access programs	3	0	F	M	IV
PAE T2-1	Gender neutral housing	0.25	0	F	H	II
PAE T2-2	Employee training opportunities	0.25	0.25	Z	C	F
PAE T2-3	Student training opportunities	0.25	0.25	Z	C	F
	Diversity and affordability total points	13.75	4.5			
Human resources						
PAE 11	Sustainable compensation	8	7.14	P	L	V
PAE 12	Employee satisfaction evaluation	2	2	Z	C	F
PAE 13	Staff professional development in sustainability	2	2	Z	H	F
PAE 14	Sustainability in new employee orientation	2	2	Z	C	F
PAE 15	Employee sustainability educators program	5	0	F	L	VI
PAE T2-4	Childcare	0.25	0	F	L	VI
PAE T2-5	Employee wellness program	0.25	0.25	Z	C	F
PAE T2-6	Socially responsible retirement plan	0.25	0.25	Z	C	F
	Human resources total points	19.75	13.64			
Investment						
PAE 16	Committee socially responsible investment	2	0	F	L	VI
PAE 17	Shareholder advocacy	5	0	F	M	IV
PAE 18	Positive sustainability investments	9	0	F	L	VI
PAE T2-7	Student-managed SRI fund	0.25	0	F	L	VI
PAE T2-8	Socially responsible investment policy	0.25	0	F	L	VI
PAE T2-9	Investment disclosure	0.25	0	F	L	VI
	Investment total points	16.75	0			
Public engagement						
PAE 19	Community sustainability partnerships	2	2	Z	C	F
PAE 20	Inter-campus collaboration on sustainability	2	0	F	M	IV
PAE 21	Sustainability in continuing education	7	3	P	L	V
PAE 22	Community service participation	6	1.29	P	M	III
PAE 23	Community service hours	6	1.5	P	M	III
PAE 24	Sustainability policy advocacy	4	0	F	L	VI
PAE 25	Trademark licensing	4	0	F	L	VI
PAE T2-10	Graduation pledge	0.25	0	F	L	VI
PAE T2-11	Community service on transcripts	0.25	0.25	Z	C	F
PAE T2-12	Farmer's markets	0.25	0	F	L	VI
	Public engagement total points	31.75	8.04			
Total PAE points		100	38.18			

Notes: CI: credit ID, CT: credit title, DAP: DUofC applicable points, PR: points received, C1: Criterion 1 and C2: Criterion 2

Table AIII.
STARS v1.2 credit list for "Category 3: planning, administration and engagement (PAE)"

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