An application of an adaptive quantitative method to measure the sustainability of the Gold Coast, Australia

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ABSTRACT

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The coastal city of the Gold Coast, Australia is the first of eighteen sub-domain studies within South East Queensland (SEQ) that has been measured using the index of sustainable functionality (ISF). As a quantitative definition of sustainability, the ISF offers an adaptive method of measurement. It does so based on an engineering standpoint that institutes stable energy and mass transfer indicate longevity over spatial and temporal scales. Sustainability trends are measured using adaptive sustainability which incorporates complex interactions by making use of a matrix-based approach. Twenty-three functions were utilised in the study and measured against a total of 53 indicators. The span of the research is between the years 2000 to 2005. The results of the study indicate that the ISF of the Gold Coast can assist in improving the overall sustainability of the region. The overall result shows sustainability trends have slightly improved and are heading toward a sustainable blueprint for rapidly developing regions. Monitoring of trends would reduce future unsustainable action and optimise the ISF to the region and beyond.

ADDITIONAL INDEX WORDS: *index of sustainability functionality, sustainability indicators, environmental management, sustainable development*

INTRODUCTION

Living within a sustainable world is increasingly becoming harder to achieve. Immediate cooperation is required from grassroots communities to the uppermost international level. This cooperation is essential in creating a universal understanding that humankind is placing extreme pressure on Earth's current control mechanisms. Sustainable living is one elementary notion contemporary society continues to be struggling with. It continues to clash between economic advancement, environmental awareness, societal pressures from rich and poor, pollution creation, population growth and climate change. It is unclear exactly what repercussions such extreme pressures will have on humanity, but undoubtedly negative environmental backlash and societal extremism are some ramifications. If nothing is done to fashion a more balanced sustainable planet serious irreversible affects will continue to transpire. To contest this issue, a massive contingent of communities, non-governmental organisations, international agencies and the like are working to influence the greater global population that sustainability is a key aspect to our survival and key to a better global standard of living.

With the continual worldwide expansion of unsustainable development it is apparent that improved methods of sustainability are needed. Locally, within the State of Queensland, the past two decades has seen SEQ grow into Australia's fastest-growing region. The city of the Gold Coast is at the apex of this growth (Queensland Government Staff, 2005). In addition to such development, the Gold Coast, which falls within the Southern Regional Organisation of Councils (Figure 1), is a coastal city that benefits from beaches to lush and diverse bushland and rainforests of its hinterland (Figure 2). It is this diversity which appeals to the ISF's application of the Gold Coast.

The concept of the ISF was first used by IMBERGER *et al.* (2005); it is derived from previous related sustainability literature and from existing indices. Some of these indices include the Environmental Sustainability Index, the Human Development Index, the Index for Sustainable Economic Welfare, the Gross National Happiness Indicator, the Ecological Footprint, and the Genuine Progress Indicator (Centre for Water Research Staff, 2004). The ISF is an adaptive, multi-criteria method that examines and measures sustainability. It is hopeful this concept is transposable to many regions throughout Australia and internationally. In terms of the Gold Coast, the ISF has demonstrates a constructive approach to adaptively calculate sustainability and without doubt marks an innovative quantitative definition of sustainability for the region. Sustainability in a quantitative sense has been lacking throughout the literature and

via experimentation. It is this lack of knowledge-base that emphasises one possible outlook of where future sustainability research can grow from.

METHODS

The ISF provides a novel methodology for measuring sustainability. Compared to other alternative indices it is far more advanced as a result of its engineering scope and matrix-based approach (BROWN, 2006). As a quantitative definition of sustainability, its engineering scope institutes the notion that stable energy and mass transfer point toward longevity as the basis over spatial and temporal scales (POLE et al., 1994). What this entails is that advancement in sustainability measuring utilises adaptive sustainability which, in turn, incorporates complex interactions, recorded over time, to establish traceable records of sustainability trends. The process of contributing and/or being able to adapt to the trends of

The method of the ISF of the Gold Coast is divided into two parts: construction and configuration. Firstly, the construction of the ISF of the Gold Coast is made up of six linear defined steps; these steps make up the flow chart of how the ISF is put together. In their study, IMBERGER et al. (2005) classify these steps as the methodology for measuring adaptive sustainability (Figure 3). Secondly, the methodology is pieced together via its configuration, for the ISF of the Gold Coast it is the assigned definitions of each step in its quantified form. The six steps' configurations are elucidated to show how the research was carried out.
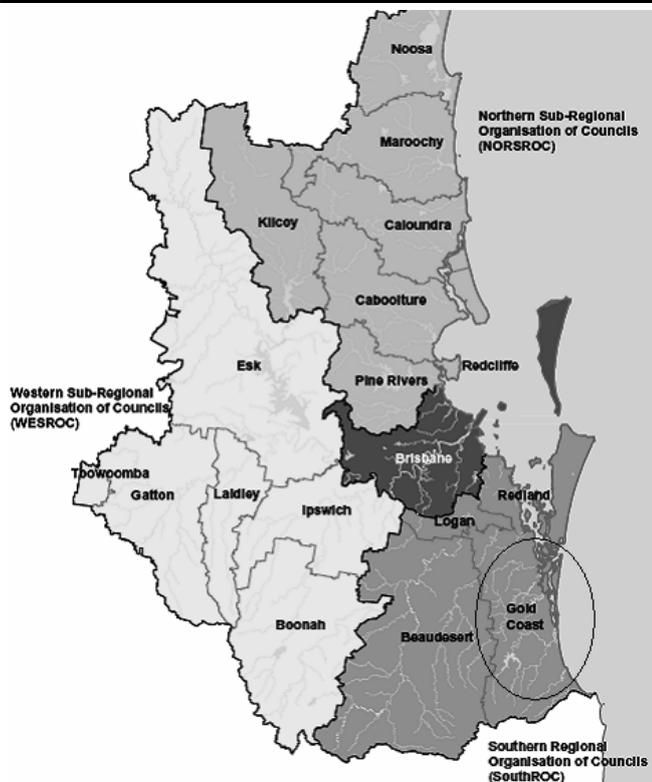

Figure 1. The Gold Coast is located in the southeastern corner of SEQ. It makes up one of four regions within the Southern Regional Organisation of Councils (Queensland Government Staff, 2005).

Figure 2. The Gold Coast is a coastal city sandwiched between long stretches of beaches and inland hinterland. (Tourism Australia Staff, 2006).

Step 1. Define the Domain (and Sub-Domains)

First, to formulate the definition of the ISF the definition of various terms must be assigned to variables. The region in which the study is going to take place is labeled the domain (D). Sub-domains (D_i) may exist and are a spatial resolution within the domain itself (IMBERGER et al., 2005). It should be noted at this point that the application of the Gold Coast is one part of a greater application of the whole of SEQ; however since there are no other sub-domains being examined in this paper the Gold Coast will represent the domain.

Step 2. Define the Systems and Perspectives

Second, the systems (S_{ij}) and perspectives (N^k_{ij}) are defined to create the comprehensive matrix-based approach (Figure 4). The systems of the ISF are defined as the fundamental mechanisms of the domain which, collectively, correspond to all aspects of its sustainability. There are four systems for the Gold Coast categorised as natural, social, individual and economic. The perspectives are intra or interdomainal viewpoints (BROWN, 2006) that use a cross-reference pattern against the related systems. Moreover, the perspectives are regularly influenced by the domain (IMBERGER et al., 2005) and framework the viewpoint in which a function would be selected for measurement. For this study there are three perspectives: social, environmental and economic.

Step 3. Define the Functions

Third, via the definition of the ISF, systems must have the aptitude to preserve certain functions (F^k_{ijl}) (Centre for Water Research Staff, 2004; CIRELLA, 2006); that being, functions are the activities that a specific system should be performing for a particular perspective (IMBERGER et al., 2005). Functions utilise a system-perspective approach that has specific indicators tested against them. The functions totaled 23 and were determined from sources such as government documents, interviews and literature.

Step 4. Define the Indicators

The fourth step in the definition of the ISF is the definition of indicators; that is, they are tools through which data can be

analysed and simplified for changes in sustainability. The rules of an indicator are: they must clearly be associated with the function they are testing against, be scientifically valid and be available over time and for comparison to thresholds (BROWN, 2006). The indicators for the ISF of the Gold Coast totaled 53 (CIRELLA, 2006). Each indicator was rationally fitted to measure its related function.
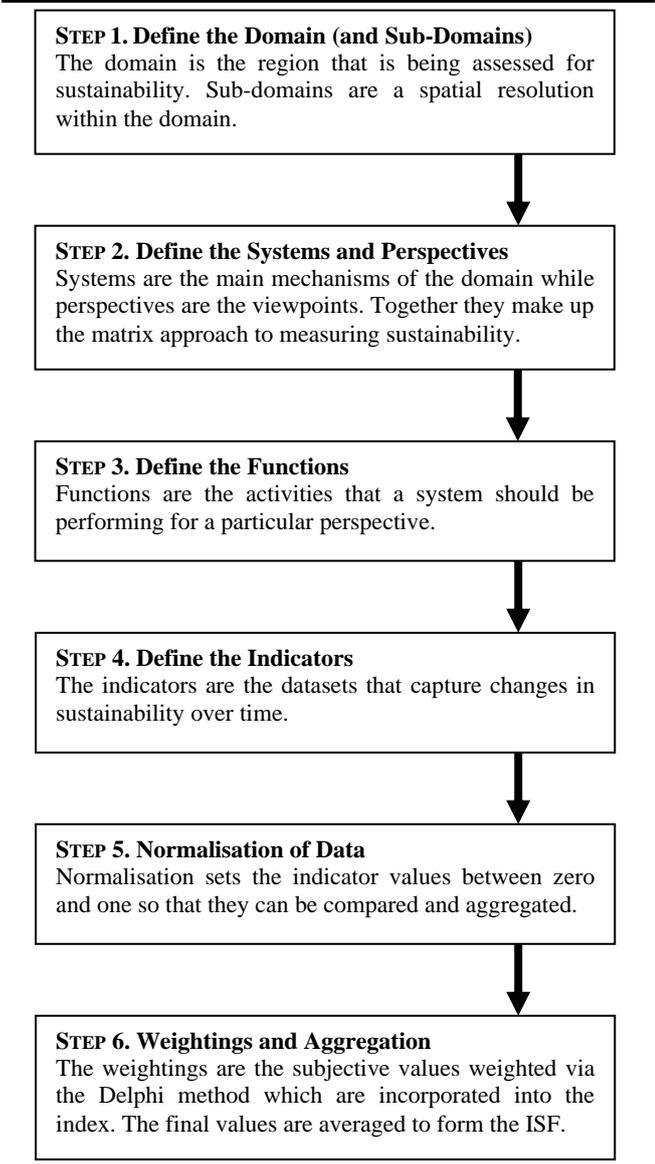
STEP 1. Define the Domain (and Sub-Domains)
The domain is the region that is being assessed for sustainability. Sub-domains are a spatial resolution within the domain.

STEP 2. Define the Systems and Perspectives
Systems are the main mechanisms of the domain while perspectives are the viewpoints. Together they make up the matrix approach to measuring sustainability.

STEP 3. Define the Functions
Functions are the activities that a system should be performing for a particular perspective.

STEP 4. Define the Indicators
The indicators are the datasets that capture changes in sustainability over time.

STEP 5. Normalisation of Data
Normalisation sets the indicator values between zero and one so that they can be compared and aggregated.

STEP 6. Weightings and Aggregation
The weightings are the subjective values weighted via the Delphi method which are incorporated into the index. The final values are averaged to form the ISF.

Figure 3. The construction of the ISF of the Gold Coast is based on these six steps (IMBERGER *et al.*, 2005; BROWN, 2006).

Step 5. Normalisation of Data

Fifth, the normalisation of data provides a common ground of measurement between the different scales and units each indicator presents. Normalised indicators (I^k_{ijlm}) are set with upper and lower functional bounds which then transfer to bounds of zero to one (IMBERGER *et al.*, 2005; BROWN, 2006). When the system operates at full functionality it is regarded as being at the uppermost level or equal to one. In direct contrast, when the

system is at zero, it is considered to be at the lowermost level of functionality – representing a dysfunctional value. Linear interpolation is used to link these two bounds (BROWN, 2006; CIRELLA, 2006).

	SYSTEM (S_{ij})			
PERSPECTIVE (N^k_{ij})	**Natural**	**Social**	**Individual**	**Economic**
Social	Function(s) of the **Natural System** as determined by the *social* perspective	Function(s) of the **Social System** as determined by the *social* perspective	Function(s) of the **Individual System** as determined by the *social* perspective	Function(s) of the **Economic System** as determined by the *social* perspective
Environmental	Function(s) of the **Natural System** as determined by the *environmental* perspective	Function(s) of the **Social System** as determined by the *environmental* perspective	Function(s) of the **Individual System** as determined by the *environmental* perspective	Function(s) of the **Economic System** as determined by the *environmental* perspective
Economic	Function(s) of the **Natural System** as determined by the *economic* perspective	Function(s) of the **Social System** as determined by the *economic* perspective	Function(s) of the **Individual System** as determined by the *economic* perspective	Function(s) of the **Economic System** as determined by the *economic* perspective

Figure 4. The comprehensive matrix-based approach for the ISF of the Gold Coast (IMBERGER *et al*, 2005).

Step 6. Weightings and Aggregation

Finally, the sixth step which involves the weightings (W^k_{ijlm}) and the aggregation of the data explicates the final preparation of the data for formulation for the ISF equation. The weightings of the data are done in terms of each indicator's significance to its associated function. The weightings for the ISF of the Gold Coast were executed via the Delphi method (STOCKARD, 2006; WRIGHT, 2004) of examination (Figure 5). The Delphi method took a panel of experts via a survey and asked each to rate each indicator-function relationship. The aggregate of the weightings from the panel of experts assisted in defining the significance of each function.

The aggregation is the summation of all normalised datasets, weighted in order, to formulate the overall ISF for the domain. The ISF of the Gold Coast utilised the following formulae format developed by IMBERGER *et al.* (2005). The formulation of the weightings measure equation was used to measure the relative importance of each function (F^k_{ijl}). It should be noted here, that since there is only a domain, the Gold Coast, and not any sub-domains, the value of *m* is one.

$$W^k_{ijl} = \frac{1}{F^k_{ijl}} \sum_{m=1}^{m=F^k_{ijl}} W^k_{ijlm} \qquad (1)$$

In doing so, the net normalised indicator value is the control equation that being, it places all values equal to and/or between zero and one. Noting that any value below zero will be equal zero and any value above one will be equal one.
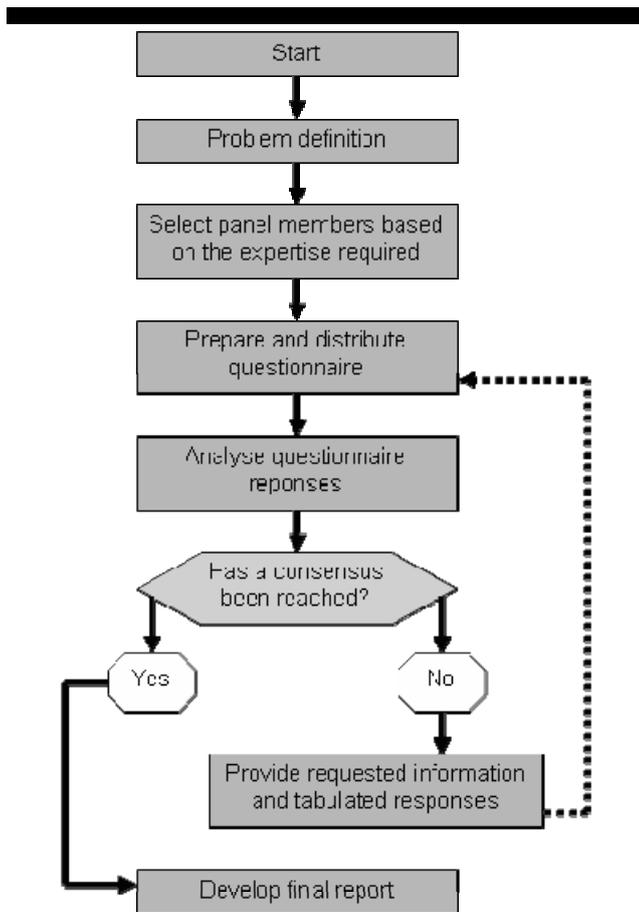
Figure 5. The flow chart of the Delphi method used for the weightings of ISF of the Gold Coast (STOCKARD, 2006; WRIGHT, 2004).

$$\lambda(I_{ijlm}^{k}) = \begin{cases} 0 & \text{for} & I_{ijlm}^{k} < 0 \\ I_{ijlm}^{k} & \text{for} & 0 \leq I_{ijlm}^{k} \leq 1 \\ 1 & \text{for} & I_{ijlm}^{k} > 1 \end{cases} \quad (2)$$

The weightings equation below formulates a pre-definition of the ISF equation equal to one.

$$1 = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ij}^{k}} W_{ijl}^{k}. \quad (3)$$

In all, the summation of each product of the indicators ($\lambda(I_{ijlm}^{k})$) and weightings (W_{ijlm}^{k}) gives a resulting value by the use of the ISF equation,

$$\text{ISF} = \sum_{i=1}^{N} \sum_{j=1}^{N_i} \sum_{k=1}^{N_{ij}} \sum_{l=1}^{N_{ij}^{k}} W_{ijl}^{k} \lambda(I_{ijl}^{k}). \quad (4)$$

Each domain gives a resulting ISF value, where:

i = domain
j = system
k = perspective
l = function
m = index or weighting.

For this study the ISF results will be tested between the years 2000 to 2005. It should be pointed out that the advantage of separating the function from the normalised indicator is that the weightings reflect the changing priorities people often associate with a defined set of functions. Whilst with normalised indicators, measurement of the absolute functionality of the system is more domain-related (IMBERGER et al., 2005).

The primary application of the ISF of the Gold Coast utilised the four systems – natural, social, individual and economic – with the integration of existing concepts of the triple bottom line and the concept of capital theory. The perspectives – social, environmental and economic – are solely based on the triple bottom line approach. It should also be noted that the sum of individual perspectives by definition are equal to social ones therefore the individual is not a perspective (IMBERGER et al., 2005). In all, the 23 functions were measured by 53 indicators. A full list of the functions and indicators utilised can be found within the technical report by CIRELLA (2006).

RESULTS

The three perspectives – social, environmental and economic – were averaged out to give the overall ISF of the Gold Coast. The data for each of the perspectives indicates the results for the years 2000 to 2005. Normalised averages for each perspective, as well as, the final averaged datasets for each year are shown in Table 1. The data clearly indicates a trend for all three perspectives. The social perspective increased, before and after, from 0.5800 to 0.6565, indicating that community actions are becoming more sustainably functional. The environmental perspective increased from 0.5694 to 0.7858; this may be a surprise to some living within the community but environmental awareness and concerns

Table 1: The perspectives and overall ISF results of the Gold Coast.

Year	Social	Environmental	Economic	Averaged Dataset
Before	0.5800	0.5694	0.7545	0.6346
2000	0.5740	0.5474	0.7448	0.6221
2001	0.6141	0.6621	0.6445	0.6402
2002	0.6214	0.6887	0.7865	0.6989
2003	0.6255	0.6814	0.7564	0.6878
2004	0.6194	0.7508	0.7611	0.7104
2005	0.6595	0.7705	0.7215	0.7172
After	0.6565	0.7858	0.7965	**0.7463**

alike clearly have begun to sink into the region's environmental design processes. The economic perspective increased from 0.7545 to 0.7965. The expected economics of the Gold Coast, as one of Australia's top tourism destinations overwhelms the data and reflects its flourishing image of development and business sense. All three perspectives support the notion of increased functionality over time.

Overall, the data clearly shows a trend in functionality from 0.6346 before the year 2000 to 0.7463 after the year 2005. This data has been graphed to clearly illustrate this trend (Figure 6). The graph of the ISF of the Gold Coast was also computed alongside population, gross regional product (GRP) and infrastructure budgeted expenditure per capita. All three of these additional pieces of information show similar accenting results which reflect regional change. An increase in population, GRP and infrastructure expenditure per capita clearly reflect the growth and change the Gold Coast has been facing over the period. The resulting ISF data shows this change has been done in a sustainable manner via increased functionality.
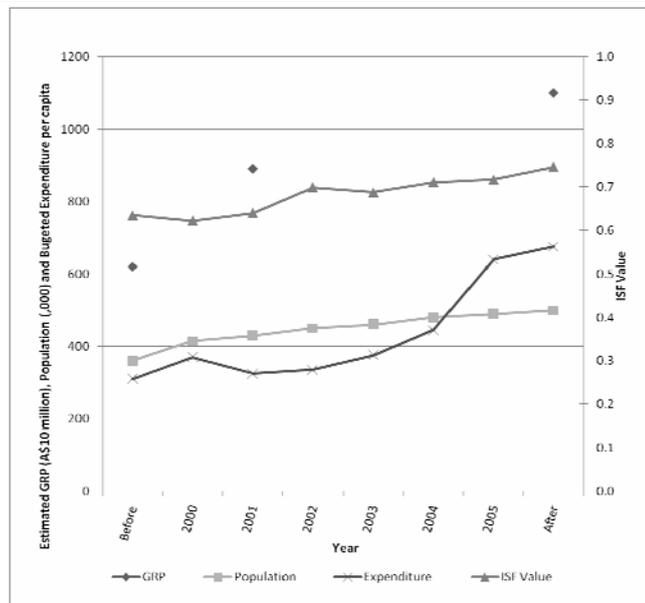

Figure 6. The ISF of the Gold Coast is computed in conjunction with population, GRP and infrastructure budgeted expenditure per capita (Gold Coast City Council Staff, 2005). The GRP data is stated with three available estimates.

CONCLUSION

It is clear that the Gold Coast, and the whole of SEQ, can benefit from such an appraisal as it places the region at the forefront of index-based sustainability and advises the community, and the powers that be, of what is being done fittingly and what is not. The ISF findings can be utilised for future reference and tracked for progress. To expand the project, the ISF research could also be dated farther back in time to impart a clearer present-day situation; that is, as a tool for measuring sustainable functionality the larger the historical scope on data, the better the representation on directional trend.

Sustainability is a concept that is at the heart of societal human existence. Some key pieces to the sustainability puzzle include education, the act of understanding and defining what sustainability is; restoration, the process of repairing previous

unsustainable failures; and progressiveness, the practice of developing current and future development in a sustainable, sound manner. The concept of the ISF focuses mostly on management and in turn clearly fits into the education and progressiveness brackets considered. It is clear there is a past, present and future aspect to sustainability – and in that a clear aspect to managing it better. Added to this, the global context of sustainability urges an improved need to better our societies and cooperatively choose better options relating to societal development. This linkage is the next generation design in sustainability tools and is the key idea to the ISF.

ACKNOWLEDGEMENTS

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