

Environmental Impact Assessment in South Africa - what difference can a sustainability assessment make?

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Mini-dissertation submitted in partial fulfilment of the requirements for the degree *Masters of Environmental Management* at the North-West University

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Graduation May 2018
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ABSTRACT

Sustainability is a concept that has the objective of dealing with the immediate and future 'needs' of society while attempting to take the 'limitations' imposed by the ecological damage into account. The term sustainability is an ambiguous one which then allows it to be interpreted in many different ways. The needs of society, which change over time, are governed by the intra- and inter-generational equity aspect of sustainability. The assessment of the ecological aspect of sustainability is a snap-shot image based on the situation prevailing when the assessment is undertaken whilst having to take the dynamic nature of sustainability into account. Assessing the sustainability of a development then places both an immediate and future-based limitation on it. This study had the prime objective of defining a method of including the sustainability related aspects into the task of environmental assessment.

A comprehensive study of the literature yielded a developing attitude of making use of the applied scientific principles in the assessment process. There is a notion that the assessment of the environment should form part of the paradigm of engineering science so that the application of the scientific principles will be allowed to influence the decision making resulting from an assessment. There is a school of thought in the literature that advocates the use of system based procedures to the definition of the environment being assessed. The use of engineering based processes in conjunction with the system based definition allows the unencumbered application of the integrated environmental management procedures to achieve the goal of assessing sustainability.

Subsequent to the literature study and the resulting discussion and debate of the prescriptions contained in the literature, a system based model to allow the spatial and temporal aspects of sustainability to be included in the definition of an assessment has been described. The operation of this model has been discussed in detail. The final part of this study has been devoted to investigating whether the application of a sustainability assessment using the model proposed would have resulted in different environmental decisions arising from the application of an EIA process.

The final decision arrived at in this study is that an application of a sustainability assessment based on a system based model of sustainability together with the applicable engineering science will make a difference to EIA in South Africa. The application of a system based model will specifically ensure the application of the sustainability principles in the EIA process and ensure the holistic interpretation of a development being assessed.

Key words: Sustainability, environmental impact assessment, engineering methods, artificial intelligence, system and system based, sustainability assessment.

ACKNOWLEDGEMENTS

The following acknowledgements are made to all those that stood by me:

- To my Lord and Saviour, Jesus Christ, for giving me the wisdom, ability, support and perseverance to complete this study. All glory to Him;
- To Professor Luke Sandham for his unwavering, patient and time consuming support together with his extremely valuable comments;
- To Cindy Hayes for her help in compiling the final document; and
- To my wife and children, for their patience, support and sacrifices.

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LIST OF ABBREVIATIONS

AM	Assessment method
AP	Assessment process
BA	Basic Assessment
CA	Competent Authority
DEA	Department of Environmental Affairs
DESTEA	Free State Department of Economics, Small Business Development, Tourism and Environmental Affairs
DMR	Department of Mineral Resources
DoF	Degrees of Freedom
DSR	Draft Scoping Report
EAP	Environmental Assessment Practitioner
EA	Environmental Assessment
EAu	Environmental Authorisation
ECA	Environment Conservation Act 73 of 1989
EIA	Environmental Impact Assessment
ERA	Environmental Risk Assessment
ERM	Environmental Risk Management
ESI	Environmental Sustainability Index
FDDM	Fezile Dabi District Municipality
FSR	Final Scoping Report
FU	Functional Unit
GDARD	Gauteng Department of Agriculture and Rural Development
IEC	International Environmental Cooperation
IPC	International Pollution Control
LCA	Life Cycle Analysis
LCI	Life Cycle Inventory
M&E	Material and Energy
MCA	Multi Criteria Analysis
MeLM	Metsimaholo Local Municipality
MPRDA	Mineral and Petroleum Resources Development Act 28 of 2002
MVA	Megavolt ampere – an electrical rating
NEMA	National Environmental Management Act 107 of 1998
NEMLAA	National Environmental Laws Amendment Act 25 of 2014
NEM: AQA	National Environmental Management Air Quality Act 39 of 2004
NEM: BA	National Environmental Management Biodiversity Act 10 of 2004
NEM: WA	National Environmental Management Waste Act 59 of 2008

NFSD	National Framework for Sustainable Development
NWA	National Water Act 36 of 1998
PHH	Pollution Haven Hypothesis
PPP	Public Participation Process
RA	Risk Assessment
RoD	Record of Decision
RoM	Run of Mine
RSA	Republic of South Africa
SA	Sustainability Assessment
SAF	Submerged Arc Furnace
SAn	Scenario Analysis
SD	Sustainable Development
SEA	Strategic Environmental Assessment
SOC	State Owned Company
TBL	Triple Bottom Line
TO	Trade-off
UK	United Kingdom
USA	United States of America
UN	United Nations
VTAPA	Vaal Triangle Airshed Priority Area
WEF	World Economic Forum
WML	Waste Management Licence

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE STUDY

The concepts of social equity (inter-generational and intra-generational), economics, and ecological capacity form part of the assessment of the sustainability of a development. According to Asafu-Adjaye (2005: 303) “sustainable development has become an article of faith” or a “shibboleth” which is something that is often used but little explained. Arjaliès and Mundy (2013: 286) refer to it as being a “value-laden” concept. There is no doubt that in order to ensure the positive progress of future generations the present day activities of humankind must not be so reckless as to destroy what we as humans are stewards of.

There are a plethora of questions about sustainability: How is sustainability defined and what is it? Why is it important? To what does it apply? To whom does it apply? Is there a different view of sustainability depending on where the development is taking place? What measures of sustainability are applied in differing social contexts? Is sustainability measured by a change in quality of life? How is quality of life defined? How does one ensure inter-generational equity? How are improvements in technology going to affect sustainability? How much ecological degradation is acceptable? To whom is it acceptable? and so on. This all revolves about ‘wellbeing’ and the answers to these questions depend on to whom the question is directed.

The core facets of sustainability are i) the economic situation, ii) the ecological situation, and iii) the social situation. There is no doubt that economics is, in the view of many, the overriding principle in the three facets given above. With economic principles being very rigidly defined and controlled, this results in the environmental assessment process having to be biased towards the ecological and social facets. This opens the door for science, and all its ramifications and ambiguities, in the assessment sphere.

The term sustainability had its origins in the recognition of the deteriorating relationship between global ecology and the need for (economic) development (Faber *et al.*, 2005: 340). The fact that development in the statement above is preceded by the word economic in brackets can be interpreted as meaning that there is a deteriorating relationship between global ecology and all types of development. As the process of development is ongoing and has different requirements in different locations there is also a spatial and temporal scale on sustainability. This is a complicating factor that is present in the assessment process.

Sustainability and sustainable development are not interchangeable terms as they represent two different situations – sustainability is the description of a system together with the manner in which it performs and sustainable development refers to a process of development that is allowing sustainability to be maintained. An economic analogy is that ‘sustainability’ would be a ‘stock’ variable and ‘sustainable development’ would be a ‘flow’ variable. The potential discrepancy between the terms sustainability and sustainable development that is noted is in direct contradiction with the decision in some of the literature to use the terms interchangeably (Morrison-Saunders *et al.*, 2014: 39; Pope *et al.*, 2017: 207). As a result of the interpretation based on the stock-variable and flow-variable concept, in the remainder of this mini-dissertation, reference will be made to sustainability and sustainable development as different concepts. In respect of this sustainability assessment (“SA”) will assess whether sustainability criteria, that are normally imposed in an environmental assessment process, are met.

1.2 SUSTAINABLE DEVELOPMENT AND SUSTAINABILITY ASSESSMENT

The concept of sustainable development (“SD”) had its origins in the late 1980s where it was an aspirational principle that was encompassed by most, if not all, governments as something to be attained. The term SD, however, remains problematic as the concept of SD is value-based (Bond *et al.*, 2011: 1158). The Brundtland Report is commonly believed to have provided the basis for the consideration of sustainable development at international policy level as a result of public attention being focused on the poor planning of resource use (Bond & Morrison-Saunders, 2011: 1). Although the idea of sustainability, which is the foundational concept of SD, seems to have been a feature of international legal relations since 1893, the Brundtland Report stressed two important (key) concepts that have been adopted as the foundation of sustainability (Sands & Peel, 2012: 206). These are

- “The concept of needs, in particular the essential needs of the world’s poor, to which overriding priority should be given; and
- The idea of limitations imposed, by the state of technology and social organization, on the environments ability to meet present and future needs”.

The concept of needs is addressed by ensuring that the needs of the present are satisfied without depleting the resource base. The concept of limitations is based upon the inter-generational equity aspect of sustainability. The difficulty involved in being able to quantify the limitations aspect has resulted in governments traditionally focusing on the first one of the key concepts, i.e. the needs, and not the second one, i.e. the limitations (Sheate, 2005: 19).

In spite of noting that SD is an ambiguous, complex and confusing concept (Faber *et al.*, 2005, 337; Carter, 2007: 208; Hansson, 2010: 274), it has rapidly developed and been instrumental in shaping international policy towards the environment (Carter, 2007: 208). The result has been a general understanding of the concept and that it is not something that can be ignored (Morrison-Saunders & Retief, 2012: 34). This has given rise to the situation that “sustainable development has become a principle which all governments seemingly aspire to abide by” (Bond & Morrison-Saunders, 2011: 1). This has resulted in most countries seemingly taking sustainability seriously. South Africa is one of these countries with a requirement to consider the sustainability principles in the assessment of the environment being made in the over-arching environmental legislation (South Africa, 1998).

SD is, in respect of policy, a very important concept as all societies are dependent on the environment for the provision of their needs (Brinkman, 2008: 1). This renders SD an indispensable part of any governmental policy. With this in mind Carter (2007: 218-225) note the “core principles” of SD as being

- “Equity;
- Democracy and participation;
- The precautionary principle (sic);
- Policy integration; and
- Planning”.

Although all the core principles (Carter, 2007: 218-225) noted above are important in the concept of sustainable development, the aspects of the precautionary principle and policy integration are the most significant in respect of the discussion in this mini-dissertation. The judicious application of scientific principles in the assessment process will enable the robust assessment of sustainability related issues in the Environmental Assessment (“EA”) process while applying the inherent precautionary aspects of engineering based scientific investigation.

Figure 1.1 is one which represents the environment as a subset of the universe in which we, as human beings, co-exist with the remainder of creation. Within this system of the universe, with the sub-system of the environment, mankind has arranged a situation whereby the natural resources contained within the environment are used to support the economic relationship that has been created by, and is a function of, the interaction between the producers and consumers. The content of Figure 1.1 is constructed on the concept of a system and sub-systems. A comprehensive definition of system and sub-systems is given in the next chapter but within an engineering context, a system can be described as being an

arbitrary portion (or part) of a whole process that is to be considered for analysis (Himmelblau & Riggs, 2004: 137).

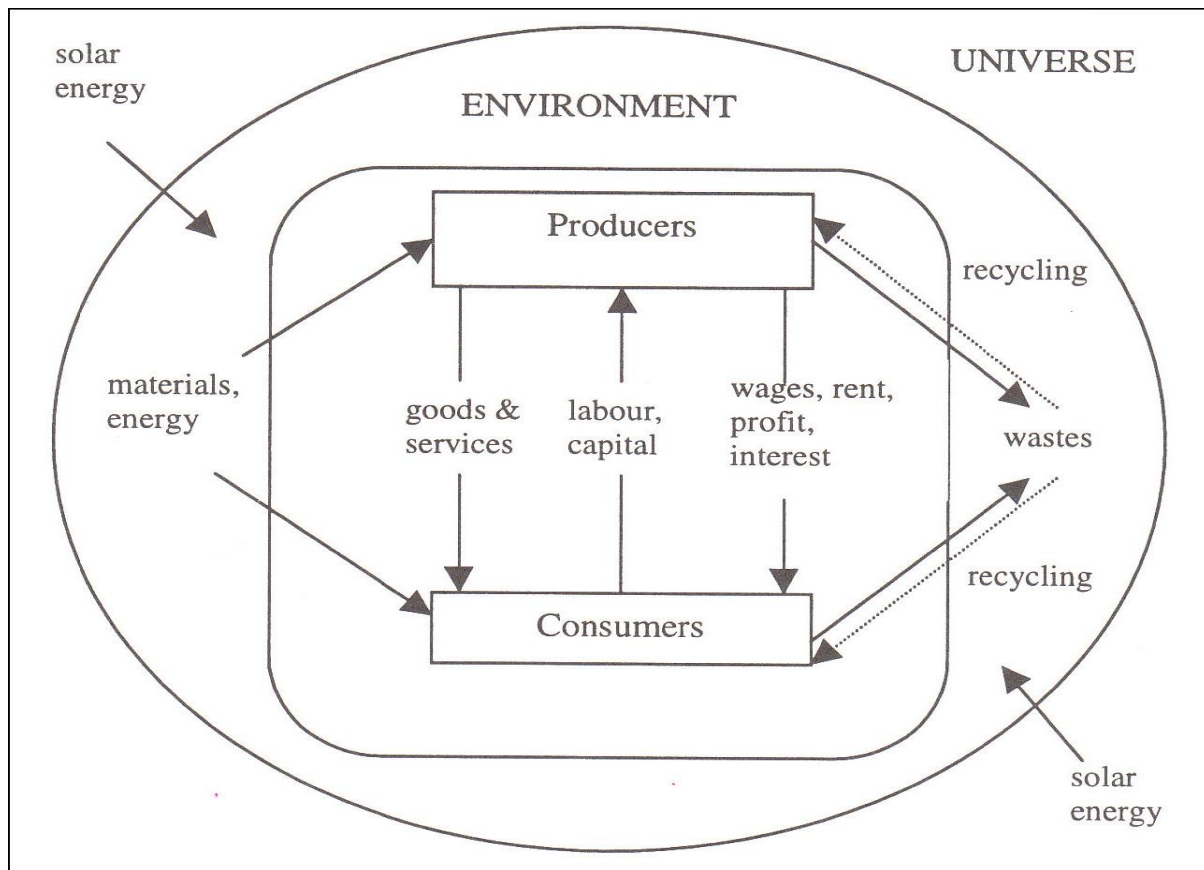


Figure 1.1: Schematic representation of the universe/environment (Asafu-Adjaye, 2005: 17)

The limits of a system are defined by the 'system boundary' which is represented by a line enclosing the portion of the system that is being analyzed or studied (Himmelblau & Riggs, 2004: 137-139;; Morvay & Gvozdenac, 2008: 9; Oloman, 2009: 98). An open system, also referred to as a flow system, is one where material crosses the system boundary and a closed system is one where no material crosses the system boundary (Himmelblau & Riggs, 2004: 137). The ramifications of this are important as once an item has left a system it is no longer part of the system and not included in the study of the system.

A steady state system represents equilibrium conditions prevailing over a length of time, and unsteady state conditions would represent an upset to the equilibrium within the system. The sustainability of a system is the equilibrium which is the result of complex dynamic interactions between the environmental, social and economic issues (Faber *et al.*, 2005: 341; Ness *et al.*, 2007: 498).

In the representation given in Figure 1.1 the following two aspects are important. The first is that no distinction is made, or considered, as to the nature of the process or system that makes use of the indicated resources. This ensures that the diagram illustrates the generic

situation in its extreme generality enabling users of any assessment process to adjust the details of the situation being studied. This results in each individual assessment being as unique as possible. The second is that waste is explicitly indicated in the Figure. Waste is a fact of life no matter how many noble initiatives are undertaken to reduce the generation of or eliminate waste completely so it is an important part of any EA process.

Sustainability is an integrative (Gibson, 2006b: 390) and a future-oriented (Goeminne & Paredis, 2010: 691) concept and so the thinking of sustainability in the overly simplified and compartmentalized manner must be relegated to the past (Sheate, 2005: 20, 21). This negates the thinking of sustainability in the economic, social and environmental boxes with the sustainability assessment being included in an overall governance regime (Sheate, 2005: 21). Ness *et al.* (2007: 498) refer to there being a need to understand the complex and dynamic interactions. This must be the objective of EA and so confirms the requirement to develop a 'new way' of considering EA. This new way is SA.

1.3 RESEARCH QUESTION

The question posed for the research is

Environmental Impact Assessment
in South Africa
- what difference can a sustainability assessment make?

South Africa uses the EIA at a project level to authorize the facilitation of a development. There are no other legally-binding processes available apart from authorizations in terms of legislation that is subservient to NEMA (South Africa, 1998) that have to be obtained. There are sustainability aspects considered in the policy related assessments, such as Strategic Environmental Assessments ("SEAs") but there is no formal process to assess the sustainability of a development using the EIA process.

Sustainability Assessment ("SA") has been termed the third generation of impact assessment by Bond *et al.*, (2012: 56) with it being a process directing decision making towards sustainability (Morrison-Saunders *et al.*, 2014: 38). With sustainability being an ambiguous concept that can mean different things to different people, it is a difficult concept to apply practically (Hansson, 2010: 274) but the process that is applied to an assessment must incorporate a significant articulation of the concept of sustainability (Morrison-Saunders *et al.*, 2014: 39). The nebulosity and value-based interpretation of the sustainability concept

makes it very difficult to decide in advance what and how an assessment must be done as it depends on the situation under review (Bond *et al.*, 2011: 1158).

1.3.1 Objectives of the study

The objectives of this study are discussed in detail in section 1.4 but are restricted to the following

1. To debate the concept of sustainability assessment by giving consideration to the literature aspects of the sustainability issues.
2. To propose a system based model that could be used in applying a practical starting point to address sustainability assessment in EIA.
3. To evaluate the difference that a system based model could have effected on the authorisation decision for the case studies.

By addressing the objectives as given above, a final answer to the research question as given will be forthcoming.

1.3.2 Methodology

The methodology applied is dictated by the objectives given in the previous section 1.3.1 with inputs applicable to achieving the objectives as given. The methods to be followed are:

1. To investigate and debate the literature to gather opinions and views of eminent authors on the subject of sustainability and sustainability related issues together with the factors that would influence the process of sustainability assessment;
2. Propose a system based model based on engineering principles to implement a sustainability assessment within the environmental assessment process; and
3. Use the case studies to quantify the difference that a sustainability assessment may have made to the authorisation obtained. The case studies selected are:
 - a. DMR 30/5/1/2/2/10015MR – Proposed Panfontein Colliery.
 - b. GAUT 002/12-13/E0145 – Proposed demolition of ferroalloy furnaces.
 - c. DESTEA EMS/6, 28/16/09 – Calcination Plant.

Each case study that will be considered has been selected based on the particular aspects in the case that would have been influenced by undertaking a SA in order to test the emerging theory proposed in Chapter 3. In this manner a logical answer to the research question can be formulated. It must be noted that the data that was used in each case was not collected with SA in mind and so its applicability may not be entirely valid.

1.4 ORGANIZATION OF THE MINI-DISSERTATION

The reference to sustainability assessment in the question above refers to the assessment of the issues affecting the sustainability of the proposal under examination for which authorisation is required. The reference is made to EIA as it is the only legally mandated process in South Africa to gain environmental authorisation.

1.4.1 Chapter 1

Chapter 1 of the dissertation provides background information to the study.

The chapter also gives detailed consideration and explanation of the objectives to be achieved as well as the methodology to be applied in achieving the given objectives.

1.4.2 Chapter 2

This chapter covers the detailed consideration of the literature addressing environmental assessment, sustainability and sustainability assessment related issues. The aim here is to investigate and debate the literature so as to crystallize a methodology that will be applied in the sustainability assessment model proposed in the following chapter. With the diversity of opinions, together with the different views on sustainability and sustainability assessment, the detailed consideration of the relevant aspects given in this chapter form the basis for the sustainability assessment model that is developed in the next chapter. Included in this literature review attention is given to the role of science in EIA as well as the investigation of the use of engineering based procedures in the EIA process.

1.4.3 Chapter 3

Chapter 3 is the methodology of the mini-dissertation by containing the detailed description of the sustainability assessment model that is proposed. The aim here is to propose a model that addresses the current thinking of the literature while at the same time being able to effectively integrate sustainability assessment into the EIA process as applied in South Africa.

1.4.4 Chapter 4

This chapter comprises the presentation and analysis of the three case studies using the model proposed in Chapter 3. Without having direct and original information available to evaluate the efficacy of applying the proposed model to the cases noted, the evaluation is reduced to a decision whether the model proposed would have made a difference to the

authorization decision resulting from the original assessment given the information originally used in the assessment.

1.4.5 Chapter 5

This chapter contains a synopsis of the information contained in the previous chapters that is used to determine the answer to the original question. Consideration is also given to the objectives given and whether the objectives, as originally given, have been met.

These objectives form the backbone of the study and any deviation identified will, on a macro level, define further work that has to be done to ensure that sustainability appraisal becomes a process that is entrenched in environmental authorisation in South Africa.

The final part of the chapter involves defining, as far as possible, the direction of future work that has to be done. This is important in attempting to ensure that 'the wheel is not reinvented' but to expand on the work that has already been done.

1.5 CONCLUSION

This chapter has given consideration to providing the background of SA with respect to its position of being a third generation EA method. At this point in time the separate process of SA is not legally required in South Africa, although the requirement of the application of the sustainability principles in EIA is. This opens the door for 'engineering-based procedures' to be mandated for use in EA so as to ensure the integration of the sustainability related requirements. The mini-dissertation has the objective of proposing a system based method of starting the move towards SA in the EA process. Although SA has been referred to as the third generation of assessment tools, and there has been much discussion about how it should be undertaken, no proposal as to how to start the process could be located. Without making a start nothing will be forthcoming!

The final part of this chapter gives the structure of the mini-dissertation in respect of where the literature study fits in, and how the case studies are to be used. It has been noted that the final chapter of the mini-dissertation is where the answer to the original research question will be presented and discussed and the definition of the further work recommended will be given.

CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

According to Webster and Watson (2002: xiii) a “review of prior, relevant literature is an essential feature of any academic project”. This is confirmed by a statement by Randolph (2009: 1) claiming significant research cannot be performed by a researcher “without first understanding the literature in the field”. Further, Webster and Watson (2002: xvi) note that the literature review should be ordered in such a manner that the review is “concept-centric” and that the concepts form the organizing framework of the review. This method is in contrast to an “author-centric” review that fails to “synthesize” the literature (Webster & Watson, 2002: xvi).

This review of the literature is concept-centric as individual attention is given to separate concepts within the field being investigated. It may be that one, or more, authors dominate in a particular concept but this does not influence the logic of the review in any way.

It is also important to take cognizance of the view of Webster and Watson (2002: xvii) that for a literature review to be successful it must constructively inform the reader of the review of what has been “learned”. In this vein, the following quote is notable: “.... another indicator of amateurism was (is) an overly negative approach to the previous literature previous work is always vulnerable. Criticizing is easy and of little value; it is more important to explain how research builds on previous findings rather than to claim previous research is inadequate and incompetent.” (Webster & Watson, 2002: xvii). Randolph (2009: 11) notes a number of commonly made mistakes made when reviewing research literature and those that are considered applicable to this study are “.... that the researcher:

- does not clearly relate the findings of the literature review to the researcher’s own study;
- does not take sufficient time to define the best descriptors and identify the best resources to use in review literature related to one’s topic;
- relies on secondary sources rather than on primary resources in reviewing the literature;
- uncritically accepts another researcher’s findings and interpretations as valid, rather than examining critically all aspects of the research design and analysis; and
- does not consider contrary findings and alternative interpretations in synthesizing quantitative literature”.

All the above potential shortcomings have been addressed in the literature survey that follows. The “uncritical” acceptance of the work of another researcher does not give *carte blanche* to criticize the work that the other researcher is reporting on. The criticism that may be levelled must be constructive with the acknowledgement that research is a cumulative activity where reported findings are normally a stepping-stone to more advanced revelations. All comments and analysis of the literature in this mini-dissertation are meant in the vein of being constructive and of furthering discussion on the subject under consideration.

The internal validity of the emerging theory is enhanced by literature and although Eisenhardt (1989: 544) notes that a broad range of literature should be consulted, there is still a challenge in ensuring that the literature consulted is “most useful” for the study in question (Frankel & Devers, 2000: 256). In undertaking this literature review an attempt has been made to consult as wide a body of literature as possible. The subject of sustainability related matter is wide as a result of it being noted in ecological, social, engineering, process and economic literature. The transdisciplinary nature of sustainability is extensive.

The body of literature referred to in the survey that follows was referred to in order to gain the opinions and input of as large as possible author base, both academic and practical, in order to gauge the complexity of the subject of Sustainability Assessment (“SA”) as well as the diversity of issues involved.

An important input in confirming or refuting the research question comes in the form of the case studies. In respect of the role of case studies, Bhattacharjee (2012: 40) notes that “case research is an in-depth investigation of a problem in one or more real-life settings over an extended period of time”. The case studies are considered in detail in such a way that the literature provides a basis for the proposal made in the next chapter and then the proposal is tested in respect of the case study details considered.

This literature survey aims to critically engage with the literature on the subject of SA whilst at the same time attempting to gauge the perceived shortcomings, if any, of the current state of research in regard to SA. The overall objective is then to, together with the case studies to be considered later, gain an indication of whether the activity of SA would make a difference to the Environmental Authorisation (“EAu”) that is required.

2.2 DISCUSSION OF THE LITERATURE

It is evident from the literature considered that the activity of SA is very topical and there are diverse views on how it should be addressed. Much of the diversity of views on SA arises as a result of a process of the effectiveness of SA being questioned because the final goal to be achieved is very subjective and value laden (Sala *et al.*, 2013: 1664). The value-based

nature of the goal renders the activity of scoping a SA a very broad and important one, which if not focused and well-defined, can become overwhelming.

SA is not a process (or procedure) that can be considered on a stand-alone basis as there are a number of processes that must be included so as to achieve a position of having assessed sustainability. On a macro (all-encompassing) basis, SA forms part of the activity of gaining EAu, or optimizing Environmental Assessment (“EA”). It is on the micro (detailed) basis that the individual aspects of sustainability must be addressed in the Environmental Impact Assessment (“EIA”). The activity of the **macro** basis of SA will occur in the EIA scoping (which is discussed in detail later) and the activity of the **micro** basis will occur in the EIA study by consideration of the detailed inputs as impacts of the development.

2.2.1 Environmental Authorisation

An Environmental Authorisation is authorisation that is given by a Competent Authority (“CA”) for an activity that arises, conceivably a project, to continue as a result of an Impact Assessment (“IA”) that has been undertaken. The EAu is the result of the EA is noted to be a very successful policy intervention undertaken by a CA (Retief *et al.*, 2016: 52).

Once the proposal has been authorized (as above) it becomes a project. In order to implement the authorisation for the project, the conditions of authorisation together with the detail of the EIA must be taken into account in developing an Environmental Management Plan (“EMP”) for the construction and operation (Aucamp, 2009: 7). Two tiers above the EIA is what is known as the Strategic Environmental Assessment (“SEA”) which integrates the sustainability requirements into national policies, plans and programs (Aucamp, 2009: 8). Figure 2.1 illustrates the positioning of EIA with respect to SEA.



Figure 2.1: Tiered relationship between SEA and EIA (Aucamp, 2009: 9)

A SEA is an extension of the EIA process to policies, plans and programs (groups of projects in time or space) (van der Vorst, *et al.*, 1999: 5). The SEA essentially conforms to the same principles as the EIA (van der Vorst *et al.*, 1999: 5). The SEA, as defined in South Africa, refers to a process that integrates the sustainability requirements into the formulation, assessment and implementation of the policies, plans and programs as indicated in Figure 2.1 (Aucamp, 2009: 8).

Legislation governing the use of SEA in South Africa does not exist but there is consensus that the sustainability imperative is being driven by SEA (Govender *et al.*, 2006: 324). It is, in fact, noted that provisions for SEA in South Africa were forthcoming in the 1990s in the form of guidelines and legislation even though no regulations have yet been promulgated. In respect of this a set of principles by which SEA in South Africa is governed exist (Govender *et al.*, 2006: 325). It is clear from these principles, contained in Table 2.1, that there is a very specific sustainability foundation for SEA.

Table 2.1: Principles governing SEA in South Africa (Govender *et al.*, 2006: 325)

PRINCIPLE	DESCRIPTION
1	SEA is driven by the concept of sustainability.
2	SEA identifies opportunities and constraints that are placed by the environment on the development of plans and programs.
3	SEA sets the levels of environmental quality and the limits of acceptable change.
4	SEA is a flexible process allowing it to adapt to the planning and the sectoral development cycle.
5	SEA is a strategic process that begins with the conceptualization of a plan.
6	SEA is part of a tiered assessment and management of the environment.
7	SEA has its scope defined within the wider context of environmental management.
8	SEA is a participative process.
9	SEA must consider alternatives in the assessment of scenarios.
10	SEA must include the 'precautionary principle' and the objective of continuous improvement.

In 1999, conceivably before any maturing of the South African assessment regime could occur so it was probably not applicable to the South African regime at the time, it was noted that the EIA focus had been expanded to take on a wider scope and as a result many EIAs examined issues that should have been the concern of an SEA (van der Vorst *et al.*, 1999: 5). With the legal and mandatory status of the EIA not being enjoyed by the other EA tools that are available for development decision making, EIA has an important role to play in the EA process (Aucamp, 2009: 8). It may then be that the project-based EIA is the only tool that can be used to evaluate sustainability (Morrison-Saunders & Retief, 2012: 34). It is for this reason that EIA is used in this discussion as the EA starting point and the proposal made proposes integration of the SA activity with EIA. In the final analysis the EIA has the legal

mandate to consider the sustainability requirement so it should be used. The legal mandate for SA is addressed later.

Morrison-Saunders and Fischer (2006: 229) refer to sustainability appraisal instead of sustainability assessment but both concepts, i.e. appraisal and assessment, have a quality related connotation so they can be used interchangeably. In the context of this mini-dissertation the reference is made to assessment. There is a concern in some literature that the importance of the environmental aspects will be reduced by applying a greater level of integration in the EA process (Morrison-Saunders & Fischer, 2006: 229). The approaches followed in EA up to now have probably in the most part given adequate results and allowed development to take place, but there should be a fundamental shift in the way EA is done by moving away from what Retief *et al.* (2016: 56) refer to as “linear thinking” to more “systems thinking”. This is confirmation of a requirement to apply a systems based approach to EA.

The world is becoming less and less predictable and future developments cannot be entirely accurately forecast and, thus, planned for. This places an obligation on EA to be more flexible and pliable (not pliable in the manipulative sense) than at present so that the stewardship that we have been entrusted with becomes more relevant both in the present and in the future (Bourgeois, 2014: 263). This will give substance to the statement by Brinkman (2008: 206) “.... that everyone, regardless of religious persuasion, share a responsibility for the upkeep and maintenance of the planet and its environment is gradually gaining wider acceptance”. EA in the past has been directed principally towards the protection of the environment but the main drivers towards sustainability are contained in the paradigm shift from the plain protection of the environment to a more integrated assessment of development (Finkbeiner *et al.*, 2010: 3309). The elements of this paradigm shift are illustrated in Table 2.2.

Table 2.2: Elements of the paradigm shift in EA (adapted from Finkbeiner *et al.*, 2010: 3310)

CHARACTERISTIC OF THE EVALUATION PROCESS	TRADITIONAL PROTECTION	MODERN PROTECTION
Political background	Control of risks and dangers	Sustainability
Policy Principle	Command and Control	Self-regulation
Role Player	Government	Society
Policy Setting Procedure	Confrontational (legalistic)	Co-operative
Tasks undertaken	Separation of tasks	Integration of tasks
Principles driving the action	Reactive	Proactive
Scope of the evaluation	Local	Local, national, international
Focus of the evaluation	Single process	Multiple (network) processes
Environmental Media	Individual media	Cross-cutting media (issues)
Technology utilized	Pollution mitigation	Pollution prevention

The important aspect to note is that in moving from the 'traditional' to the 'modern' method of environmental protection there is a shift from the 'separation of tasks' to an 'integration of tasks'.

It is appropriate here to define and clarify the concept of a system, and systematic. According to the Oxford Dictionary a system, as a noun, is "a collection of connected things or parts that form a whole or work together" and systematic, as an adjective, means "methodical, according to a plan and not casually or at random" (Oxford Dictionary, 1994). The implication here is also that a system can be divided into sub-systems that make up sections of the total system. The adding of the sub-systems to form the total system will be referred to as a process of aggregation of the sub-systems. The systems approach accentuates the fact that a process within a system may not just cause an impact within the system but may also influence other activities within the system (Retief *et al.*, 2016: 56).

The integration of tasks, referred to in Table 2.2, implies a system based approach where the interaction between individual activities receives consideration. Each of the individual activities within the system would be in engineering terms a 'unit process' within the total system. Each unit process would form a sub-system of the total system. The total system would consist of a collection of many of these unit processes (Raynolds *et al.*, 2000a: 96). The interaction between the individual activities, or the 'unit processes', would include any cross-media functions that would form part of the system under consideration.

An important aspect within the realm of EA, is the one of the effectiveness versus the efficiency of the assessment. Effectiveness has been noted as being a "troublesome term" as a result of it having many different meanings (Chanchitpricha & Bond, 2013: 66). In reality it does not have different meanings but what differs are the definitions of what it measures. Effectiveness can be evaluated by what it measures.

Sandham and Pretorius (2008: 229) confirm the concept of effectiveness by determining whether "... something works as intended and meets the purpose(s) for which it is designed". This differs from the efficiency which is 'how well something performs' even if it is not being effective in achieving the goal placed on it. Within the structure of SEA and EIA, the effectiveness would be defined by how well the process of evaluation answers to the requirements placed on it – requirements that are defined in detail in respect of indicators that are measured and a deviation recorded.

According to Cashmore *et al.* (2004: 296) the concept of the effectiveness makes reference to and includes the substantive and the procedural functions of EIA. In terms of this statement the evaluation of the substantive issues is the effectiveness, i.e. is it meeting its

objectives (or requirements placed on it), and the evaluation of the procedural issues is the efficiency, i.e. is it meeting the expectations placed upon it. It is reported that the research effort (to evaluate the effectiveness of the EIA) has thus far focused on the “procedural” aspects but the ultimate measure of effectiveness lies in the “substantive” parts of the assessment (Cashmore *et al.*, 2004: 296). This is then given by the measure of how well the project (the subject of the assessment) addresses the sustainability requirements.

As a final input in the debate, Chanchitpricha and Bond (2013: 66) divide effectiveness into four categories – i) procedural, ii) substantive, iii) transactive, and iv) normative. Table 2.3 gives the characteristic aspect of each category. In South Africa, society is extremely diverse and so aspects such as participation and access to information will be a very important part of the assessment process (Retief, 2013: 191). Whether this must be included as a separate category in the table below is debatable but they are important issues in the assessment (particularly in South Africa) and they will form part of the procedural aspect. also Including the aspect of effectiveness as part of the substantive requirement will definitely be a factor in gauging the success of an assessment.

Table 2.3: EA effectiveness categories (adapted from Chanchitpricha & Bond, 2013: 67)

EFFECTIVENESS CATEGORY	CHARACTERISTIC	EFFECTIVENESS or EFFICIENCY*
Procedural	Does the EA process conform to the established requirements in respect of execution?	Efficiency
Substantive	Does the EA process achieve the objectives set in respect of the assessment process?	Effectiveness
Transactive	Does the EA process deliver the outcomes at least cost and in the minimum time possible?	Efficiency
Normative	Does the EA fulfil the typical norms and standards of where the development is?	Effectiveness

* - this delineation shown in this column is based on the division given in the discussion above

It must, however, be noted that the transactive requirement contained in Table 2.3 above creates an ethical issue in that there is a commercially based competitive aspect. This places the EA in the realm of a cost-benefit analysis which will subject the EA analysis to additional external pressures that it should not have to cope with. In discussing the financial valuation aspects of the environmental aspects, Weiss (2000: 128) notes that “EIA is not the same as cost-benefit analysis” and the activity of Environmental Assessment (“EA”) should not be considered in this light of cost minimization. Further attention to this aspect does not form part of the objective of this mini-dissertation.

As far as the ‘normative’ aspect is concerned, being based on norms and standards gives it a legislative bias so it could conceivably be included in the procedural category. This, in

effect, reduces the evaluation to two categories, viz. efficiency and effectiveness, in terms of the original discussion.

A strategic issue in the entire EA loop revolves around the capacity (or ability) of the CA to evaluate the EA reports submitted by the Environmental Assessment Practitioner (“EAP”) so that an EA decision can be made. In addition the CA must be competent enough to be able to specify authorisation specific conditions in the Record of Decision (“RoD”) that specifies the granting of EAu. In order to assist and empower the CA in the decision making process there is a legal provision allowing the CA to access specific expertise to evaluate conditions related to a specific issue in the EA studies (South Africa, 1998). In connection with this aspect there has been a concern related to the South African government’s ability to fulfil the mandate of the CA (Duthie, 2001: 215) but the effect of this does not influence the process proposed in this mini-dissertation.

2.2.2 Environmental Management

The positive role that Environmental Impact Assessment (“EIA”) has played in the process of EA and protecting the environment is not disputed. After first being introduced in the United States of America (“USA”) in 1969 (Bartlett & Kurian, 1999: 416; Hildebrandt & Sandham, 2014: 20), when it was considered to be a very successful policy intervention (Sandham *et al.*, 2008b: 701), it was adopted as being mandatory in the South African legislation in 1997 by virtue of the promulgation of a set of regulations in terms of the Environment Conservation Act (“ECA”) (South Africa, 1989). In 1998 the ECA was partially repealed by NEMA (South Africa, 1998) with the final repeal of ECA (South Africa, 1989) by the coming into effect of the 2006 regulations of NEMA (South Africa, 1998; Sandham *et al.*, 2008b: 701). The EIA was then, legally, the tool of choice for EA.

2.2.2.1 Integrated Environmental Management

There is a link between SEA and EIA (as shown in Figure 2.1) but in the South African context EIA is the only legislated assessment tool (Retief, 2013: 187) and it forms one part of the suite of tools that make up the process of Integrated Environmental Management (“IEM”). Within the ambit of IEM, Integrated Pollution Control (“IPC”) is very important as regulations over the release of a pollutant to one environmental medium, i.e. air, water, ground, etc., can cause the pollutant to be transferred to another environmental medium (Sands & Peel, 2012: 131). It is thus important that a holistic view be taken of an impact which supports the IEM concept.

Kotzé (2005: 44) defines IEM in respect of the following:

- “the ‘precautionary approach’;
- The ‘polluter pays’ principle;
- The ‘cradle-to-grave’ principle;
- The principle of an ‘integrated and holistic’ approach;
- The principle that due consideration must be given to all alternatives; and
- the principles of continuous improvement, accountability and liability, transparency and democracy”

The issues of importance in the vein of the discussion of this dissertation are firstly, the principle of an integrated and holistic approach, and secondly the assertion that the IEM defines Environmental Management (“EM”) as the application of management skills and techniques to achieve the principles of sustainability (Kotzé, 2005: 44). This is confirmed by Bond *et al.* (2001: 1011) that note that “the growing acceptance of sustainable development as an overarching policy goal has stimulated interest in assessing the impact of particular interventions on sustainable development, and has led to the emergence of integrated impact assessment, based on the use of a number of sustainable development principles and indicators, as one method for according the same level of consideration to economic, social and environmental impacts”.

The consequence of this statement by Bond *et al.* (2001) is that if the principles of sustainability (through sustainability assessment) are applied to a project, the embedded principles of IEM are automatically followed. The next section then gives cursory consideration to the application of the EIA in South Africa.

2.2.2.2 Environmental Impact Assessment

The EIA is an established legal (both domestically and internationally) process governing the inclusion of socio-economic development requirements and environmental considerations into the decision-making activity (Sands & Peel, 2012: 601). The principle of “rational planning” constitutes an essential tool in the EIA (Sands & Peel, 2012: 602).

Cashmore *et al.* (2004: 295) define EIA as: “.... a decision tool employed to identify and evaluate the **probable environmental consequences** of certain proposed development actions in order to facilitate informed decision-making and **sound environmental management**” (emphasis added). The EIA was, according to one of the authors of the original text, to “enhance the rationality of the ultimate decision” (Bond *et al.*, 2011:1161). This implies that sound environmental management is based the rationality of the decisions emanating from the EIA. Rationality is a “philosophical rather than a scientific” concept

(Bond *et al.*, 2011: 1161) and decision making is not always rational but the aspect of rationality has a role to play in EA.

An EIA has the objective of not only providing information and so, with decision making not always being rational, there is an opportunity for irrational desires and beliefs to over-rule some substantive issues in the EA process. One of the models of EIA proposed is the “information processing model” which is based on the information gathering and transmitting function (Bartlett & Kurian, 1999: 417). Within the notion of the information processing model falls the concept of ‘bounded rationality’ where the decision making process takes place within ‘bounds’ of having limited subjectivity while maximizing objectivity (Nilsson & Dalkmann, 2001: 205). Science, and technological development, can play an important role in expanding the boundaries.

In the South African context, it is noted by Sandham *et al.* (2013: 1350013/4) that EIA is undertaken with “scientific rationality” being implicitly assumed. For the EIA to reflect reality as far as possible the basis on which decisions are made must be as well defined as possible which implies scientific robustness. This can be achieved by including a SA in the EIA process with the SA being based on the systems approach.

In the definition of EIA given by Cashmore *et al.* (2004: 295) the term “environmental” is prominent. This is pervasive in considering and recognizing what Cashmore *et al.* (2004: 296) refer to as “the inherent limitations of ‘state-of-the-art’ EIA”. In this regard the inherent limitations that Cashmore *et al.* (2004: 296) are noting is that unless the role of EIA within the concept of sustainability is defined within its theoretical foundations it is not reasonable to expect its performance in that role. Currently the legal mandate that is given to sustainability in the South African legislation is not adequate to enforce the concept and ensure that SD receives the attention it deserves in the EA process. The point of departure here is one where a methodology must be prescribed so that all assessments are undertaken from the same, or very similar, bases to make the outcomes comparable.

As has been established by legislation, the EIA is the ‘master process’ used for assessment purposes and it makes sense to consider the detail of the EIA process and define where a SA process will fit in. Following the detail given by Aucamp (2009) the process required for the EIA is as follows (in chronological order):

- “Screening”: this process is undertaken to determine the need for an assessment and what type of assessment is required. In terms of the legislation currently applicable the need may be for a Basic Assessment (“BA”) or a full EIA. The BA process does not

require the full scoping report activity as defined below where a separate report is required in the assessment process but the scoping activity is included in the BA.

- “Scoping”: If a full EIA is required the scoping process defines, among other things, the extent of the impact study. Aucamp (2009: 33) refers to “define the boundaries of the EIA in time, space and subject matter” as the activities of scoping. Scoping is arguably the most important (Middle & Middle, 2010: 164) and decisive phase in the entire EA process but it very often degenerates into an “uncreative exercise” (Mulvihill & Jacobs, 1998: 351). Middle and Middle (2010: 165) also note that by rushing scoping there is a risk of not giving enough attention to all the potentially significant impacts. It is important in respect of reflecting reality and whether the scoping process is being effectively undertaken is a process that can be investigated by using one of the standard measures available. With the SA activities being undertaken in conjunction with scoping, definition will be obtained in respect of the sustainability effects of the impacts identified. In terms of the sustainability issues, it is important to define the following in the scoping process:
 - The contextual nature of each impact, whether it is ecological, social or economic (Hansen & Wood, 2016: 3);
 - The reach of the impact, i.e. is it immediate, is it local, is it regional, or is it national? There may also be transboundary implications here. Certain types of issues, principally ecological, do not respect international boundaries (the impact does not have to be global in nature (Sands & Peel, 2012: 610)). Here International Environmental Cooperation (“IEC”) can raise some international democratic issues (Carter, 2007: 267);
 - The temporal aspect of the impact so that the generational issues can be addressed; and
 - The economic issues surrounding the project. These economic ramifications will be very similar in terms of reach of the impacts. The economic measure will largely define where, who, and how will entities be affected. The view of Morrison-Saunders and Fischer (2006: 226) that economic considerations are implicit in the EIA is not entirely correct in view of what is required in terms of sustainability where the economic aspects may be local, regional, or global.

The points addressed above are in line with the comment by Mulvihill and Jacobs (1998: 352) that scoping must be broad enough to accommodate the diverse issues that are encountered. On the other hand, care must be taken so as not to ‘over scope’ the EIA where excessive resources are expended on minor impacts (Middle & Middle, 2010: 159). The potential of ‘over scoping’ the EIA can be countered by applying the correct skills in the scoping process and making sure that the boundaries of the assessment

system are optimally defined. In this respect Kågström (2016: 171) notes the need to “scope in relevant issues” and to “scope out irrelevant ones”. It is evident that scoping is the principal data gathering activity in the EIA and the validity and relevance of the data collected is of paramount importance. It can be noted that, particularly in respect of sustainability assessment, the quality of the data collected will directly influence any final decision made.

- “Impact Assessment”: Here the significance of the impacts defined in the scoping phase is defined for the alternatives to the development identified. An important activity here is the Risk Assessment (“RA”) and the associated activities. It is also here that the subject-matter specialists undertake their studies.
- “Draft Environmental Management Plan”: The outcome of the impact assessment is a draft Environmental Management Plan (“EMP”) which is a documentation of the actions identified in the Impact Assessment.
- “EIA report”: this is the final document upon which the authorisation is given, and if so what conditions are applicable, or whether authorisation is refused. This is an extremely important document that should serve as ‘road map’ of the manner in which the project should be approached and developed. The quality of the scoping activity will have a direct impact on the EIA report and this is one of the reasons for including a SA in the scoping phase.
- “Post decision”: An important activity, that is often overlooked, is the one of post-decision monitoring. Within the realm of SA it will be important that the promises made in the EA are followed up continually to ensure the continued optimality of the solutions implemented. This is one of the important functions to be fulfilled by the application of the indicators in the operational phase of the project authorized.

The EIA application is very rigorously governed in respect of the process that is to be followed. Retief (2013: 187, 188) refers to this as the “procedural” element of EIA which in South Africa has become “overly complex and inefficient” causing it to move away from the need for “flexibility and the issue-driven approaches typical during the early years of EIA”.

2.2.2.3 Systems approach to sustainability assessment

Utilizing the SA during scoping will provide the flexibility and make use of an issue-driven approach referred to by Retief (2013). The applicability of this approach to SA should become evident with consideration of the systems approach to sustainability. The systems approach to sustainability should, to a lesser extent, address the unambiguous mandate requirement and to, a greater extent, the value-judgement requirement by forcing integration and rationality in the decision-making process. By forcing integration it should ensure a ‘cross-pollination’ of EA inputs and results and the value-judgement aspect will be addressed

by the scientific rationality. The application of a system based approach judiciously will potentially allow an extensive view of a development thereby allowing a comprehensive and uncompromising analysis to be undertaken.

2.2.3 Sustainability

The United Nations (“UN”) definition of development speaks of a multidimensional undertaking that attempts to achieve a higher quality of life for all and that economic development, social development and environmental protection are mutually dependent and reinforcing components of sustainable development (“SD”) (Bond *et al.*, 2001: 1011). In this definition of sustainability there are three terms that are pervasive. They are the terms

- Multidimensional;
- Interdependent; and
- Reinforcing.

Sustainability is a concept that has an “intrinsic fuzziness” about it (Sala *et al.*, 2015: 314) and this makes it a difficult concept to define and measure (Phillis & Andriantiatsaholainaina, 2001: 436). Reference is made to sustainability being something that has to be achieved but as a concept, it is open to abuse by fanatics (Mitcham, 1995: 311).

In general terms sustainability can be considered as achieving a balance between the ecological concerns whilst maintaining mankind’s socio-economic activities (McDonach & Yaneske, 2002: 218). It must be reinforced that the balance is contextual, both spatial and temporal, giving rise to an ecological requirement that may change and a socio-economic regime that is based in the anthropocentric requirements prevailing at the particular point in time. The sustainability situation is a dynamic one and all these conditions have to be met in the assessment process. The idea of having to achieve a balance, as noted by McDonach and Yaneske (2002: 218) will be discussed later when consideration is given to the concept of trade-offs.

In the years of the mid 2000s much attention was placed on the perceived unviability in the long term of the then existing state of ecological degradation and development. A shortcoming of this perception ignored the possibility of some change, a technological breakthrough for example, making the perceived “current conditions” viable (Gibson, 2006a: 171).

This possibility of technological breakthroughs is one reason why it is important that assessment is considered as a holistic system based process that relies heavily on accepted scientific principles that can be explained scientifically. The rationality of decision making in

the presence of scientific principles, specifically in the field of EA, has been discussed previously where it was noted that the application of science can potentially expand the boundaries thereby making innovation, i.e. the presence of breakthroughs, increasingly accessible to the EA process.

2.2.4 Sustainable development

The term Sustainable Development (“SD”) is a much contested one, which is not surprising given its predisposition to sustainability and the general ambiguity that is associated with the term sustainable. The ambiguity of the term sustainability is confirmed by a number of authors (Langhelle, 1999: 129; Bond *et al.*, 2001: 1011; Phillis & Andriantiatsaholainaina, 2001: 436; Williams & Millington, 2004: 99; Hermans & Knippenberg, 2006: 302; Carter, 2007: 208, 211; Pesqueux, 2009: 231; Hansen, 2010: 274; Bourgeois, 2014: 259) with it being noted as being a concept that is “value laden” and having a number of different dimensions (Sala *et al.*, 2015: 314).

Consideration of the reported ambiguity aspect of SD as given indicates that the notion of SD has been on the radar screen since the late-1990s. In 1997 it was claimed that sustainability may have been contrary to development as the concept was driven by the social aspect, on the one hand, and the ecological aspect on the other (Bebbington, 1997: 374). As a result Bebbington (1997: 374) claimed that an attempt to combine the two concepts without modifying them was, potentially, problematic.

Even taking note of all the various opinions being vocalized about how ambiguous the sustainability concept is, and whether the idea of sustainable development is problematic, the reality of it being a requirement should be accepted whatever the perceived shortcomings may be. The fact is that sustainability as a requirement, in whatever form it is discussed, is a concept that should be embraced in an attempt to fulfil the generic responsibility of human kind to be stewards of the planet and to ensure the continuation of the planet’s optimal functioning for future generations. By including SA in the EIA function the important sustainability issues will potentially be addressed at the project level thereby ensuring the consideration of the SD requirements in project level EA.

2.2.4.1 The policy mandate for sustainable development

It was noted early in the 2000s that global trends in nature and society would determine the direction that could be taken to a sustainable society (Kates & Parris, 2003: 8062). Sustainable Development (“SD”) is still an international issue that is becoming more and more important as time goes on. As a result of the identification of the public recognition of the inefficient use of natural resources and the attention that has been directed to the

environmental issues and sustainability as a result of the Brundtland Report, published in 1987, identification of the 'needs' of and the 'limitations' imposed on society (Sands & Peel, 2012: 9) gained wider acceptance. Accordingly, SD is an important policy articulation of most, if not all, governments (Bond & Morrison-Saunders, 2011: 1) and the concept of SD is present in a number of international treaties (Sands & Peel, 2012: 9).

Unfortunately, SD is a concept that has different meanings to different people (Carter, 2007: 217) but the ambiguity (Carter, 2007: 208) and complexity of the concept may also be, as referred to by Carter (2007: 217), a "political strength". It may be that the vagueness of the concept of sustainability is an advantage in that the concept is a difficult one to 'pin' down (Hanson, 2010: 275). Although the vagueness of the concept may be seen as a political strength, the concept of sustainability should still be driven by guidelines, or standards, providing a foundation for a legal imperative for sustainability appraisal to be included in the EA regime.

Referring also to the 'Policy Principle' given in Table 2.2 where it is evident that there is very often no voluntary move on the part of some citizens and organizations (particularly in South Africa) in the direction of 'Modern Environmental Protection' from one of 'Traditional Environmental Protection', a legal imperative has to be used. Also, giving consideration to the South African context, the operation of the business community does not always seemingly allow a move away from the 'command and control' method of sustainability enforcement so the policy has to be translated into a legal requirement which is discussed in the next section.

Prior to the year 2005, there was increasing pressure that the accountability of companies, and industry, be broadened from pure economic performance to one of sustainability (Labuschagne *et al.*, 2005: 373). In the year 2012, Gond *et al.* (2012: 205) noted harshly that "Although many organizations have embraced the sustainability rhetoric in their external reporting and their mission statements, these reports may serve as 'veils' hiding activities whose sole purpose is the reconstruction of an eroded legitimacy". This statement may, or may not, be a true reflection of reality but what cannot be disputed is that the policy requirements of SD eventually filter down to the organizations functioning in the economy.

This process of the policy filtering down is confirmed by the statement by Maas *et al.* (2016: 237) that "a compelling majority of 93% of CEOs (Chief Executive Officers) sees sustainability as important to the future success of their business, while only 38% believe they can accurately quantify the value of their sustainability initiatives". It has also been recognized that the aspect of sustainability, and so by default SD, has developed as an important item on corporate, or organizational, agendas (Kiewiet & Vos, 2007: 371).

Unfortunately recognition does not equate to implementation thereof. A possible reason for this is that a link between the environmental strategies of an organization and the business performance of that organization has not been forthcoming (Darnall *et al.*, 2008: 364) although the impact of environmental management on firm performance received attention by Klassen and McLaughlin (1996). This is indicative of the length of time that the sustainability issue, albeit in a different form, has been on the agenda.

Having now confirmed the existence of a policy mandate for SD, the existence of the legal mandate is now addressed.

2.2.4.2 The South African legal mandate for sustainable development

The Constitution of the Republic of South Africa ("RSA") (South Africa, 1996) is the supreme legislation that governs the country. This Constitution regulates all activities, both public and private; taking place in the country, but the most important clause in the vein of the subject matter of this mini-dissertation is section 24 which provides that everyone has the right to an environment that is not detrimental to his or her health or well-being. This, according to Du Plessis (2011: 291), also refers indirectly to the basic services that are associated with this environmental entitlement. Retief (2013: 185) notes that this right "explicitly includes the concepts of intra- and inter-generational equity as well as sustainable development". The inclusion of the intra- and inter-generational equity issues into section 24 is explicit but it is not an "absolute right" but one that has to be balanced by other rights contained in the Constitution of the RSA (Morrison-Saunders & Retief, 2012: 35; South Africa, 1996).

It is not the aim of this mini-dissertation to evaluate the performance of the state in respect of the provision of the basic services but consideration will be given to the inclusion of the environmental entitlement in the activities that promote development. This section, section 24, of the Constitution of the Republic of South Africa (South Africa, 1996) also ".... compels the government inter alia to engage actively in sustainable development, which is universally understood to require the balancing of social, economic and environmental factors" (du Plessis, 2011: 282). The nature of the balancing of the social, economic and environmental factors is discussed later.

This statutory mandate for SD is operationalized by the environmental management legislation, the National Environmental Management Act, Act 107 of 1998 ("NEMA") (South Africa, 1998). The SD imperative of the legislation is contained in chapter 1 of NEMA where section 2(4)(b)(i) of this legislation reads "The social, economic and environmental impacts of activities, including disadvantages and benefits, must be considered, assessed and evaluated, and decisions must be appropriate in the light of such consideration and

assessment". When consideration is given to legislation, a factor that cannot be ignored is the one of compliance. Environmental legislation is particularly difficult in this regard as rules are not usually broken 'in the open' so by its very nature the level of compliance to environmental legislation does not make itself conducive to exhaustive analysis (Sobotta, 2012: 92). The level of compliance can be improved by moving from a 'command and control' policy to a 'self-regulation' policy principle, as is indicated in Table 2.2. This would entail moving from a 'traditional environmental protection' policy to a 'modern environmental protection' policy. The inclusion of the SA into the EIA process of gaining EAU is a manner in which this can be accomplished.

Within the South African requirement, the EIA is the tool that is used for the assessment of the conditions of achieving the EAU for a development or project. There are a number of definitions contained in the literature for an EIA (Cashmore *et al.*, 2004: 295; Asafu-Adjaye, 2005: 191; Sandham *et al.*, 2008a: 155; Aucamp, 2009: 5; Phillips, 2011: 971; Sands & Peel, 2012: 601). Many of these definitions differ slightly in the detail that they contain, but they all note a "systematic process" together with the use of the words "potential" or "proposed". As a general observation, a systematic process aligns itself with a structured solution with well-defined recommendations while potential or proposed infers a forward-looking solution and a prediction.

The directive contained in NEMA in respect of sustainability, which is a term that is commonly used to indicate sustainable development, is that there should be a balance between three core aspects which are normally represented by three circles depicting sustainability by the space where the three circles intersect. These core aspects are i) environment, ii) social, and iii) economic issues surrounding a development or project. In terms of this description, if a balance between the three core issues noted above is not maintained the concept of the sustainability is skewed unnaturally. There is also a view that the pillar based approach, which this represents, to the sustainability situation is politically favoured because it fits with existing expertise and institutional structures (Gibson, 2006b: 264). A shortcoming of the pillar approach is that, in the interpretation of sustainability, it places equal importance on the environmental, social and economic aspects of decision making (Pope *et al.*, 2004: 597). This creates a problem with integration on the one hand and trade-offs on the other. The issues surrounding trade-offs are discussed later.

Sustainability is essentially an integrative concept that is usually associated with interaction between a complex human system and an ecological system Gibson (2006b: 390). Gibson (2006b: 390) refers to "multiple interacting systems" which adds further importance to the systems based representation of sustainability where the interaction between the systems is

accounted for in the EA process. Application of the three-pillar representation of sustainability causes the integrative concept of sustainability to be lost (Sheate, 2005: 20).

Although the detail surrounding trade-offs will be dealt with later, it is expedient to note a couple of pertinent issues now. Firstly, the main problem with the pillar method of SA is that trade-offs are unavoidable and compromises inevitably result (Gibson, 2006a: 173). Secondly, and probably as a result of the first problem, is that not all sustainability factors can be maintained all the time (Morrison-Saunders & Fischer, 2006: 235) and all choices will result in some compromise having to be made. Having to make the trade-offs could result in one, or more, aspects associated with one pillar overriding certain aspects of another pillar(s). This state of affairs could result in overall unsustainability of a development.

The shortcoming identified with the pillar method has resulted in the definitive model of the three intersecting circles being superseded by the systems approach to sustainability represented by the following Figure 2.2.

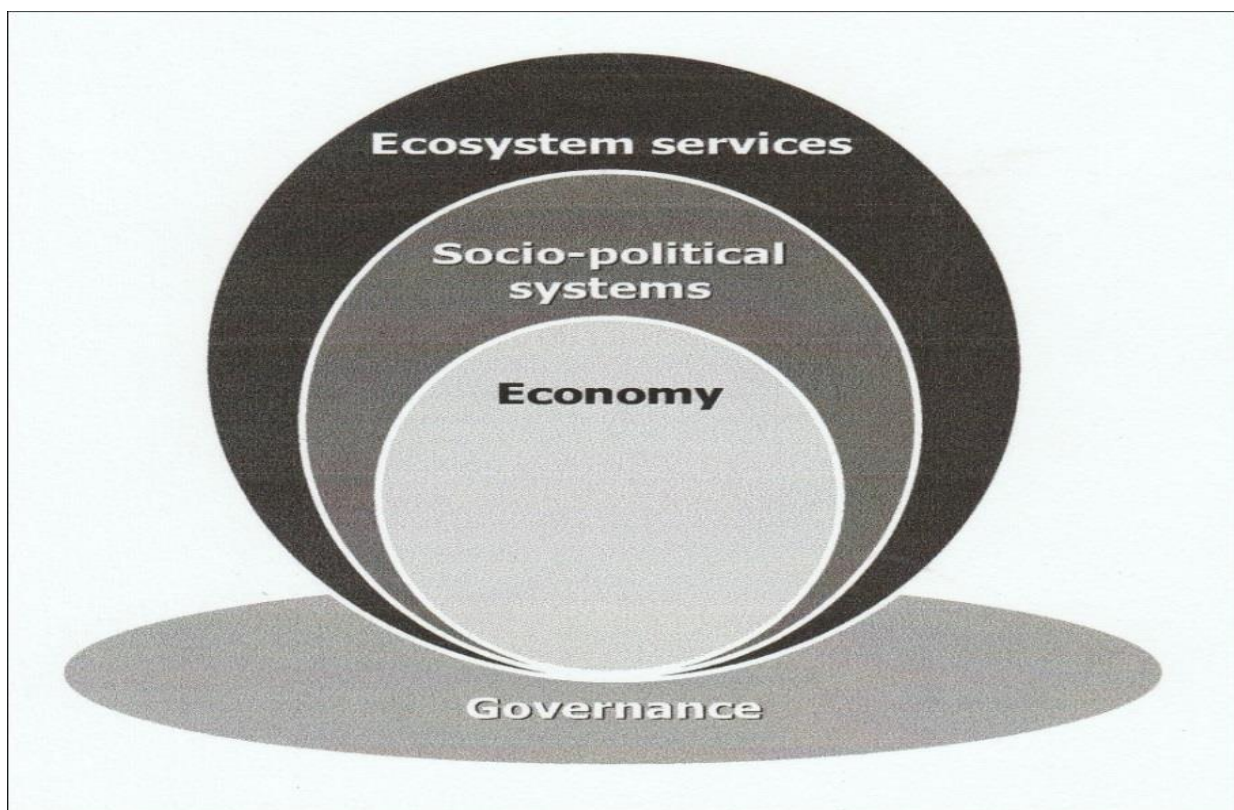


Figure 2.2: Systems depiction of sustainability (South Africa, 2008: 15; Retief, 2013: 187)

It can be seen that sustainability, in terms of the depiction given in Figure 2.2, is a system based function depicting the Ecosystem services containing the sub-systems of i) socio-political systems, and ii) an economic system. The governance requirement that keeps the systems together is assumed to be present in its entirety although it may be prudent for research to be undertaken in this regard, as without the governance support the sub-

systems of the systems concept of sustainability, as illustrated in Figure 2.2, will fall apart. In this respect the National Framework for Sustainable Development (“NFSD”) (South Africa, 2008: 15) sees the governance system as the integrator of the sustainability sub-systems. The governance issues will not be considered further here although without good governance the sustainability system is perilously close to destruction.

A final comment on this is that the depiction illustrated in Figure 2.2 is consistent with the “ecological sustainability model” as described by Pope *et al.* (2004: 598). After an extensive discussion, Pope *et al.* (2004: 600) reduce the options for environmental assessment (“EA”) to two, viz. i) an ‘EIA-driven integrated assessment’, and ii) an ‘objectives-led integrated assessment’ which is derived from an objectives-led SEA. The term SA is then described as an assessment which takes the environmental, economic and social dimensions into account and this definition applies equally to EIA-driven integrated assessment as well as objectives-led integrated assessment (Pope *et al.*, 2004: 600). As illustrated in Figure 2.1 the EIA lies below the SEA where the SEA is used to assess programs etc. and the EIA is development based. In this respect Pope *et al.* (2004: 600) make an extremely important statement that “Ideally, environmental assessments conducted at higher levels of the planning hierarchy would establish appropriate objectives for decision-making processes at the lower levels, although it is recognized that processes are rarely so streamlined in practice”. This is the reasoning behind the proposal that a SA should be undertaken at the EIA level so that there can be assurance that the sustainability aspects are included in the EAu application.

2.2.5 Sustainability assessment

Sustainability Assessment (“SA”) is a process whereby the principles of SD are used to ensure that integrated impact assessment is the result of the assessment process that leads to a decision on whether a development may proceed and what conditions have to be met to ensure authorization. SD is a new way of considering environmental decision making by moving beyond the focus on the immediate effects of individual issues and taking a future oriented perspective (van der Vorst, *et al.*, 1999: 2). Many environmental concerns highlight the system based nature of the global environment and the need to focus on sustainability (van der Vorst *et al.*, 1999: 2).

This has reinforced the need for the provision of multi-disciplinary information for decision making (van der Vorst, *et al.*, 1999: 2). The ‘multi-disciplinary information’ referred to above is all of the information supporting sustainable development – this information is not only environmentally oriented but contains a range of aspects that are required to ensure the contribution of the development to sustainability.

Figure 2.3 illustrates the assessment approach of the EIA-driven integrated assessment as proposed where SA is included in the EA (Pope *et al.*, 2004: 602). The EIA-driven integrated assessment aims to keep the negative economic, environmental and social impacts within acceptable limits (Morrison-Saunders *et al.*, 2014: 39).

What is important here in Figure 2.3 is that the exact position of the sustainable state (the end state), which is the target, is unknown. The final state is a moving 'goalpost' which defines the sustainable state defined at the time the SA is undertaken. This sustainable state would be defined based on a 'view' of the future using scenario analysis or any other appropriate tool at the time the assessment is undertaken.

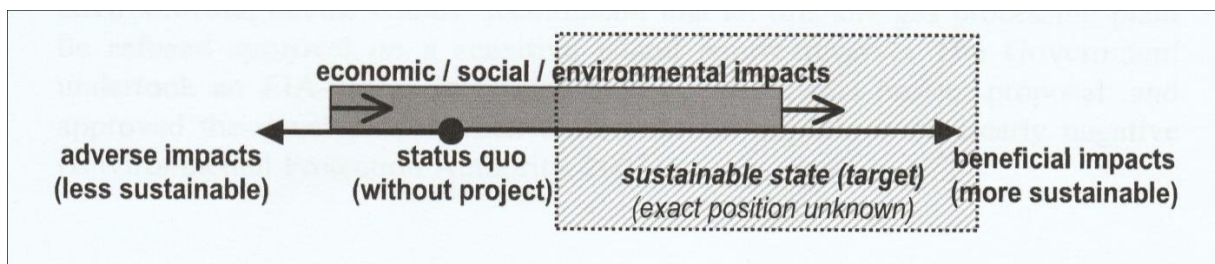


Figure 2.3: EIA-driven integrated assessment process (Pope *et al.*, 2004: 602)

It has been recognized that some trade-offs may be inevitable in EIA-driven integrated assessment (Pope *et al.*, 2004: 603) with Morrison-Saunders and Fischer (2006: 225) asserting that environmental impacts are becoming increasingly traded-off for social and economic gains. This situation is going to prevail indefinitely as SD is situational (both in the spatial dimension and the temporal dimension) so there are going to be instances where social/economic factors may dominate and others where environmental issues will dominate. There will also be situations where the relative importance of one aspect will change as a result of changes affecting the other and it is here that the system based model of sustainability as given in Figure 2.2 makes sense. The changes in the individual aspects could be caused by technological advancements, changes in business strategy or such things. The fit between EIA and SA is well represented in Figure 2.4.

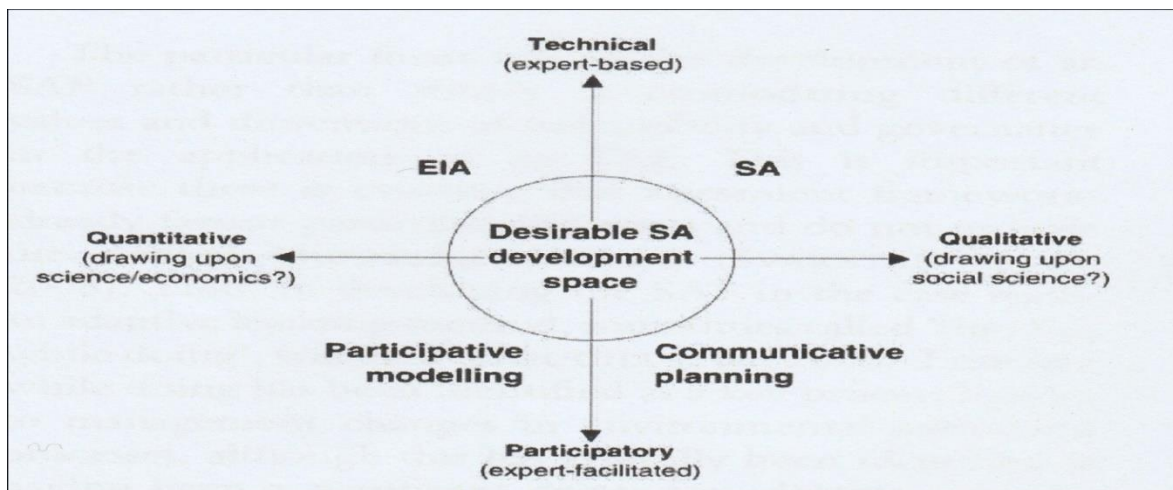


Figure 2.4: The SA space for development (Bond *et al.*, 2011: 1162)

Note that, in terms of the representation in Figure 2.4, EIA is more scientific dependent but that SA leans towards the social science aspect. The objective of the assessment process should be to blur the line between them so that there is a seamless interaction between the EIA and SA.

2.2.5.1 Introduction to the sustainability assessment process

The activity of Sustainability Assessment (“SA”) is epitomized by a statement made by Professor Lotfi Zadeh stating that “As complexity rises, precise statements lose meaning and meaningful statements lose precision” (Tsoulakas & Uhrig, 1997: 1). Complexity, both in the way we as humans are interacting with the world and the effect we are having on the universe is on the increase and will continue to be so. This places an increasing requirement on EA to remain flexible. It is under these conditions that the activity of SA must include ‘as much’ relevant information with as ‘much precision and reach’ as possible to maximize the effectiveness of the decision emanating from the assessment. The fact that SA is primarily a decision support tool is confirmed by the statement made by Bond and Morrison-Saunders (2011: 1) reading as “Sustainability Assessment (“SA”) is a process that directs decision-making towards sustainability”.

This statement above by Bond and Morrison-Saunders (2011) must, however, be seen in the context of the following statement made by Retief (2013) when discussing the substantive effectiveness (of environmental authorisation), in respect of the situation surrounding SA in South Africa. Retief (2013: 189) notes that “..... practitioners still struggle to give effect to or operationalize sustainability thinking towards more sustainable outcomes”. This “struggle” is as a result of the human fear of the unknown and the situation is not going to change until something is done to make the process of SA simpler. It must be made simpler, not less

relevant, and by starting 'small', as proposed the system based view of SA included in the EIA process will not be overwhelming.

This "struggle" will only be overcome by mobilizing the optimal resources to operationalize sustainability thinking in the EA process. This point will receive further attention in the discussion later around the 'role of science in sustainability assessment'.

Consideration of the literature with specific attention being directed towards a process that will facilitate the system based assessment of the sustainability requirements has yielded two principal proposals directly noting items for assessment of sustainability. Prior to proposing a system based model, cursory attention will be given to each with the objective of choosing one to take forward in respect of making a proposal in respect of what a system should entail. The two proposals are i) one proposed by Gibson (2006a), and ii) one proposed by Phillips (2011). The objective is then to arrive at a single tabulation of criteria that have to be considered in applying them to a SA using the system based principles discussed later.

Firstly, the proposal by Gibson (2006a), referred to as the Gibson model, is governed by the following:

Gibson (2006a: 172) gives eight points that "... are safe assertions about the basic insights for the purposes of sustainability assessment". These eight points are

1. "Sustainability considerations are comprehensive;
2. Precaution is required;
3. The minimization of negative effects is not enough;
4. Corrective actions must be woven together to serve multiple objectives and to seek positive feedback in complex systems;
5. Sustainability requires recognition of inviolable limits;
6. Sustainability is not about balancing (this is a reference to trade-offs which will receive attention later);
7. The notion and pursuit of sustainability are both universal and context-dependent; and
8. The process is open-ended and there is no end state to be achieved".

An interpretation of these eight requirements of Gibson (2006a) results in the following comments which direct the decision making in respect of the systems based model that is to be proposed in Chapter 3;

- Comprehensive sustainability considerations imply a multi-disciplinary approach which encompasses all available scientific tools;
- The weaving together of corrective actions to obtain positive feedback in complex systems presupposes a system based approach to the assessment;
- Application of the uncertainty aspects can be very easily modelled in the system based environment;
- Implementing a system based study minimizes the trade-off problem as the evaluation is undertaken on a holistic basis;
- The notion and pursuit of sustainability being both universal and context dependent suggest that there are issues common to all situations but sight must not be lost of unique issues surrounding the situation that is being assessed; and
- The open-ended attribute with no end state being applicable imply that the sustainability issues in the operating phase must also be considered. This would be operational monitoring.

According to Gibson (2006a) this gives rise to a set of decision criteria for the assessment of sustainability. These decision criteria are contained in Table 2.4.

Table 2.4: Sustainability assessment decision criteria (adapted from Gibson, 2006a: 174)

CRITERION No.	CORE DECISION CRITERION	DETAIL
1	Socio-ecological system integrity.	Maintain or build the human-ecological relations to maintain the long-term integrity of such systems. Understand the complex system based interactions and reduce (or remove) the threats to system integrity.
2	Livelihood sufficiency and opportunity.	Ensure that all have enough for a decent existence and that all have the opportunity to improve.
3	Intra-generational equity.	Ensure that sufficiency and effective choices are pursued to reduce gaps in sufficiency and opportunity between rich and poor.
4	Inter-generational equity.	Favour options that will allow future generations to live sustainably.
5	Resource maintenance and efficiency.	Optimize resource use that results in over-extraction (reduce resource use per benefit and eliminate waste).
6	Socio-ecological civility and democratic governance.	Build the capacity of society to maintain sustainability.
7	Precaution and adaption.	Respect uncertainty and continually apply the precautionary principle.
8	Immediate and long-term integration.	Apply all the principles of sustainability at once and do not obviate co-existence. Seek mutually supportive benefits.

These are then the SA aspects that must be addressed in the assessment phase (by the EIA process) to consider the aspect of sustainability in the development being assessed.

Secondly, the proposal by Phillips (2011) is based on the concept of geocybernetics reported on by Schellnhuber and Kropp (1998). Geocybernetics is defined as “the art of adequately controlling the complex dynamic earth system under uncertainties of all kinds” (Schellnhuber & Kropp, 1998: 411). As motivation for this concept, the authors refer to i) the process of globalization driven by the forces of economy, technology and lifestyle, and ii) the global environmental policy attempting to repair or prevent the side effects of global change (Schellnhuber & Kropp, 1998: 411). This initiative comes from 1998, almost 20 years previously, that has only now been gaining practical acceptance which is evident by the discussion in Phillips (2016). The basis of this theory is the co-evolutionary relationship between the “ecosphere”, denoted by ‘N’ representing the environment and the “anthroposphere” denoted by ‘A’ representing human society and its activities (Phillips, 2016: 89). This co-evolutionary relationship between N and A exists at all spatial and temporal scales. Figure 2.5 illustrates this co-evolution where the paths of societal development and environmental collapse are represented by reversions in the current status.

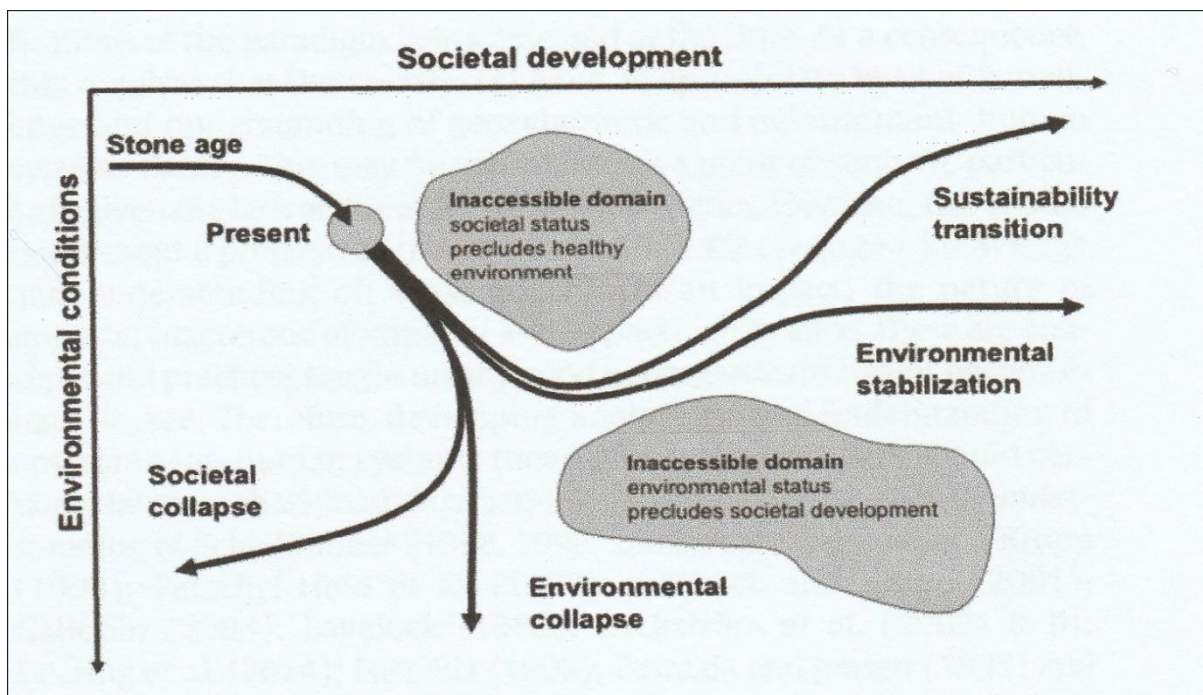


Figure 2.5: Geocybernetic sustainability paths (Phillips, 2016: 89)

A cursory explanation of the diagram contained in Figure 2.5 will not be misplaced. The two dimensions under consideration are the societal development, **A**, on the horizontal axis moving from a point of zero development and to the right. The situation of environmental collapse, **N**, is measured on the vertical axis from a point of zero collapse at the upper left

point and movement down the axis indicating conditions of increasing environmental collapse. The areas shaded in grey indicate inaccessibility (areas that may not be violated) as a result of i) the societal status, and ii) the environmental status precluding further environmental deterioration or the state of the environment precluding additional societal development. The SD pathways are then arranged to circumvent these no-go areas. The mathematical workings surrounding the 'N' and 'A' parameters will not add further value to this discussion. The important aspect here is the representation of the process as system based.

Within the methods aspect of SA, influencing the identification of the methodologies used, Phillips (2011: 969) refers to the application of “five fundamental geocybernetic paradigms of sustainable development in respect of the role and use of impact identification methodologies”. Table 2.5 indicates detail surrounding the paradigms of the representation of SD by geocybernetic principles. These paradigms are used in the geocybernetic Sustainability Assessment (“SA”) process.

Table 2.5: Geocybernetic paradigms (adapted from Phillips, 2011: 971 & Phillips, 2016: 89)

PARADIGM No.	PARADIGM	EXPLANATION	PHASE
1	Standardization	Standardization in respect of instruments that are used in the assessment of the impacts. This aspect is concerned with controlling the human-ecosystem so as to maintain a state of co-evolution. In respect of the SA process this will be definition of the scientific methods that are used in the assessment process so as to ensure the minimal damage to the environment.	Assessment.
2	Optimization	Here the best design for the human-ecological system is sought. This must be undertaken within the spatial determinants of the development being studied and is conceivably an issue that has to be continually monitored so that changes in direction of development can be made. In existing terminology this would largely be a monitoring function.	Assessment and operational.
3	Pessimization	This is an application of the 'precautionary principle'. The principle here would be 'minimum environmental damage for maximum development gain'. Here the solutions proposed to any mitigation must fulfil the precautionary principle. It is important that the trade-off decision-rules noted in Table 2.6 be considered here.	Assessment.
4	Equitization	Here consideration is given to inter-generational equity. The aspect of inter-generational equity is not a trivial one and the equity issue should be continuously monitored and evaluated. It may be that situations change (technological progress) that allows a change and yet still maintains inter-generational equity. The use of non-renewable resources together with waste recycling would be a case in point here.	Assessment and operational.
5	Stabilization	This aspect is associated with bringing the human-ecosystem into equilibrium in a state of co-existence. This would be the situation of monitoring performance in respect of the applicable indicators chosen.	Operational.

This depiction, as given in the table above, encompasses all the aspects of SD that have to be controlled to ensure "... operationalization of the sweeping sustainable development ideal through a set of concise paradigms to be achieved" (Schellnhuber & Kropp, 1998: 411). The authors also note the concept of geocybernetics is feasible on the basis of earth system modelling and fuzzy-control techniques.

Although the detail of the fuzzy logic theory will not be pursued here as it is a specialized engineering discipline that is beyond the scope of this study, there are a number of relevant articles and study texts on the subject by Russel and Norvig (1995), Harris *et al.* (1993), Enea and Salemi (2001), Phillis and Andriantiatsaholainaina (2001), Mohammadian *et al.* (2003), Prato (2005), Weron (2006) and Peche and Rodríguez (2011). An important aspect of SA is the one of forecasting so as to assess the future impacts involved. In this regard the publication by Weron (2006) is a useful source as the involvement of artificial intelligence methods in general, and fuzzy-logic in particular, in the process of forecasting is discussed in detail.

Table 2.5 illustrates the decomposition of a fuzzy SD theory into a set of crisp independent paradigms that can be utilized in the assessment of sustainability (Schellnhuber & Kropp, 1998: 418)

In the application of fuzzy logic principles a system that is based on fuzzy logic has degrees of belief in a state and it also allows "degrees of truth" (Russel & Norvig, 1995: 166). A statement can then be transformed from a 'crisp' binary status, as in 0 or 1 (known as Boolean logic), into logic with a 'fuzzy' set containing a statement with a variation from 0 to 1. The fuzzy set is then made up of 'characteristic functions' (Harris *et al.*, 1993:37). Such a process is called 'fuzzification' which is frequently used in control systems and is generally very useful in representing states that are not crisp (Harris *et al.*, 1993: 97). The application of the fuzzy-logic methods is very good in dealing with uncertainty which is an inherent aspect of predicting the future in SA.

The final outcome is that the theory presented in Table 2.5 is suited for a system based definition in the assessment process by allowing variables that are being studied and assessed to change either gradually or rapidly, in both the temporal and spatial regime. The first requirement that must be fulfilled is that the aspect being assessed must be described as a membership function that can be contained in a set. This description of the aspect being assessed must then be subjected to the 'fuzzification' process by making use of the fuzzy logic principle. The 'fuzzified' set then forms part of a system that is being assessed and the system can then be disaggregated into sub-systems representing each variable on its own.

The application of the geocybernetic method, together with fuzzy logic, within a system based representation of the assessment process is the preferred basis upon which system based SA would be performed. There are both advantages and disadvantages to applying the geocybernetic method as given. This aspect will receive further attention in chapter 3 with the presentation of the system based model that is being proposed.

2.2.5.2 System based sustainability assessment

The first step in controlling a system is to understand, or “securing knowledge of”, the dynamics of the process occurring within the system (Tsoukalas & Uhrig, 1997: 363). Seiffert and Loch (2005: 1198) note that “Systemic (system based) reasoning is more crucial now than ever before, because of the complexity that rules our world”. The use of a ‘systems approach’ to problem solving (which is essentially what a EA is) enables the identification of the interacting components in the problem, especially complex problems, and then separation and simplification of the interactions for solution. Retief *et al.* (2016: 56) refer to the “avoidance” of linear-thinking in favour of a systems concept and that systems thinking will indicate interactions between impacts that may not be evident when thinking linearly.

Each system (or sub-system) can then be analyzed using its own set of unique methods and tools (Seiffert & Loch, 2005: 1197). The individual system (or sub-system) is subjected to its own “function-oriented assessment” that considers up- and downstream impacts (Bidstrup, 2015: 73).

There are a number of methods of describing the processes within a system but these depend on the type of interaction of the components of the process. The processes within the systems depend on the type of impact under consideration and this is where the application of science in impact assessment plays a pivotal role. The role of science in impact assessment will be discussed later. In spite of the importance of the correct application of scientific principles, the correct interpretation of the results obtained within the boundaries of the system definition is important. This places further emphasis on the importance of correct identification and definition of the system. In this case it is important that system based concepts are applied so as to correctly, and as comprehensively as possible, describe the system based nature of the sustainability issues. The comprehensive, and complete, system based description will allow the results of the proposed development to be identified and assessed (Pope *et al.*, 2017: 206).

Arguably, the most important activity involved in the system based study of an aspect is the setting of the boundaries of the system. The principles discussed are equally as applicable to the setting of the boundaries for the sub-systems except that when the sub-systems are

aggregated their sum must add up to the whole system. The process of setting the boundaries for the system and sub-systems is considered in detail later.

The achievement of efficient and effective modelling depends on the choice of sustainability indicators which is discussed in the next section.

2.2.5.3 Sustainability indicators

Sustainable development (“SD”) is not only a spatial but a temporal concept as well. This then renders the definition of fixed indicators, both for the assessment process and the operational process, very difficult. Confirmation of this is that sustainability is addressed by sub-systems at different levels where the assessment issues and the operational issues have different areas of focus in respect of the sustainability indicators that are applicable (Herva *et al.*, 2011: 1688). It is important that the indicators chosen reflect the business process and then they can then be defined at lower, more detailed, levels combining with sub-systems (Feng *et al.*, 2007: 216).

Ideally, the indicators of SD that are selected should be chosen in such a way that they reflect the sustainability principles of the assessment under consideration together with aspects that are of importance in the operational phase of the project being assessed. It may also be that indicators which are used in the operational phase of a project may have to be adapted, or changed, so as to account for temporally based changes in the process.

The adage “you cannot manage what you do not measure” is applicable here (Morioka & de Carvalho, 2016: 134) and it is not possible to monitor a variable if it is not being measured but the capability to accurately measure and monitor the new and additional variables is a prerequisite for sensible monitoring (Maas *et al.*, 2016: 238). It has been claimed by Herva *et al.* (2011: 1695) that the main driver governing the selection of the variables for monitoring seems to be popularity and not applicability and measurability.

The status of sustainable development within the corporate or business sphere is confirmed by the statement that the SD challenges must be incorporated into business using the operational practices and the business strategy (Morioka & de Carvalho, 2016: 135). This may entail the operational practices and business strategy having to be changed so as to account for the temporal nature of sustainability necessitating a change in the indicators. This is why it is sometimes futile to attempt to define specific indicators beforehand. An attempt has been made by Azapagic and Perdan (2000) to define generic indices for industry but there is such a diversity of processes in industry where the detail is lost by only working with generic indicators. In this vein, it is important that there are some generic indicators to make operations comparable on some reporting level, but the detailed

indicators would be specific to the operation being assessed. These specific indicators, which would be used by internal management, and not necessarily be in the public domain, will not receive further attention as they would be potentially considered confidential.

There is, however, a definite need for certain standard indicators that can be used to gauge the progress towards, or the maintenance of, an industry or economic sector or country towards sustainability. These indicators can then be aggregated to be able to assess the sustainability position of a nation. In this regard, the discussion surrounding the so-called Environmental Sustainability Index (“ESI”) is important. The ESI is only one of many such indicators (Morse & Fraser, 2005).

The generic indicators of the environmental dimension of sustainability proposed by Herva *et al.* (2011: 1689) are indicators of

- Material and energy flows;
- The territorial dimension;
- Life cycle assessment; and
- Environmental Risk Assessment.

Each of these categories can then be sub-divided to cater for a unique environmental situation and it will be evident later that the engineering processes noted as being necessary for the assessment of sustainability are included in the indicators noted above. These indicators noted above do, however, have certain shortcomings.

The shortcomings of generic indicators here are two-fold. Firstly, these indicators address the environmental aspect of sustainability only, although the material and energy flows may be considered in an economic context as well, and secondly there is no generic indicator of the temporal aspect of sustainability given above. Given that sustainability and sustainable development are dynamic of nature, this is a significant problem that can be overcome by a holistic view of the development. The system based assessment process is one way of ensuring a holistic view of the development.

The requirements of Risk Assessment (“RA”) are features that are becoming an increasingly common feature of international law considering the risks to the environment (Sands & Peel, 2012: 616). Not only is it important for the actual business but the importance is increased if there are transboundary effects in the impacts. In cases such as these the Environmental Risk Management (“ERM”) is an important facet in determining the SD indicators. Not only should the ERM issues be included in the assessment process but it should be included into the evaluation of the business operation.

These risks would normally be assessed through a process of Environmental Risk Assessment (“ERA”). Aucamp (2009) devotes a significant amount of attention to the methods of evaluating, and the reporting of, environmental risk. This ERA would normally be undertaken as part of the EIA process, and although there may be strong sustainability issues in the risk assessment, the aspect of environmental risk will not be considered further. It must, however, be noted that the temporal aspect of sustainability has an important role to play in the assessment of environmental risk.

This aspect of indicators is an important one in that it gives a measure of sustainability and with sustainability being a dynamic function and remaining applicable in the operational phase of a project, or development, measurements are necessary to i) ensure sustainability principles are adhered to in the assessment phase, and ii) these sustainability principles are maintained during the operation. It makes no sense to undertake the effort of a SA for a project and then to allow the operation resulting from the project to become unsustainable. A final point in this regard that will be noted is the one of globalization and the Pollution Haven Hypothesis (“PHH”) that complicates the whole issue and affects the sustainability measures and indicators for developing countries (Dardati & Saygili, 2012: 163). The PHH is activated by an organization in a developed jurisdiction relocating production facilities to a developing jurisdiction where the requirements in respect of environmental limits are potentially less stringent. The application of sustainability principles, i.e. a SA, may serve to prevent, or at least limit, the prevalence of the PHH. The system based method should provide a holistic view of both the jurisdiction from where the production facilities are being relocated to the jurisdiction to where they are being relocated.

2.2.5.4 Trade-offs

The final aspect of sustainability that will receive attention prior to the system based issues being addressed is the one of trade-offs. The aspect of trade-offs (“TOs”) is extremely important in the sustainability discussion as TOs will always be present when choices have to be made. With sustainability where very often choices must be made between environmental, social and economic issues, Seiffert and Loch (2005: 1198) note that “.... SD implies the simultaneous fulfillment of three types of aspirations that tend to conflict with each other in the short run”.

It has been recognized that some TOs may be inevitable in EIA-driven integrated assessment (Pope *et al.*, 2004: 603) with Morrison-Saunders and Fischer (2006: 225) asserting that environmental impacts are becoming increasingly traded-off for social and economic gains. This situation is going to prevail as SD is situational (both in the spatial dimension and the temporal dimension) so there are going to be instances where

social/economic factors may dominate and others where environmental issues will dominate and the dynamic nature of SD may cause the domination of one issue over another be time dependent. The time dependence may cause the TOs to be optimal at one point but be non optimal at another. This type of behaviour will cause TO conditions to alternate. Robust analysis of the system based assessment will, by allowing attention to be given to individual sub-systems, allow investigation of such issues.

According to Asafu-Adjaye (2005: 204) the multi-criteria analysis (“MCA”) approach can be used for the multi-objective decision making of TO analysis. MCA is designed for decision making in situations where there are multiple, and potentially conflicting, objectives. The MCA process defines a set of decisions contained in what is referred to as an equi-preference curve that indicate the relationship between the costs of ecological conservation versus development graph. For each potential solution in the MCA, a trade-off curve is generated that represents the developmental ecological loss/cost relationship that is then plotted on the MCA diagram.

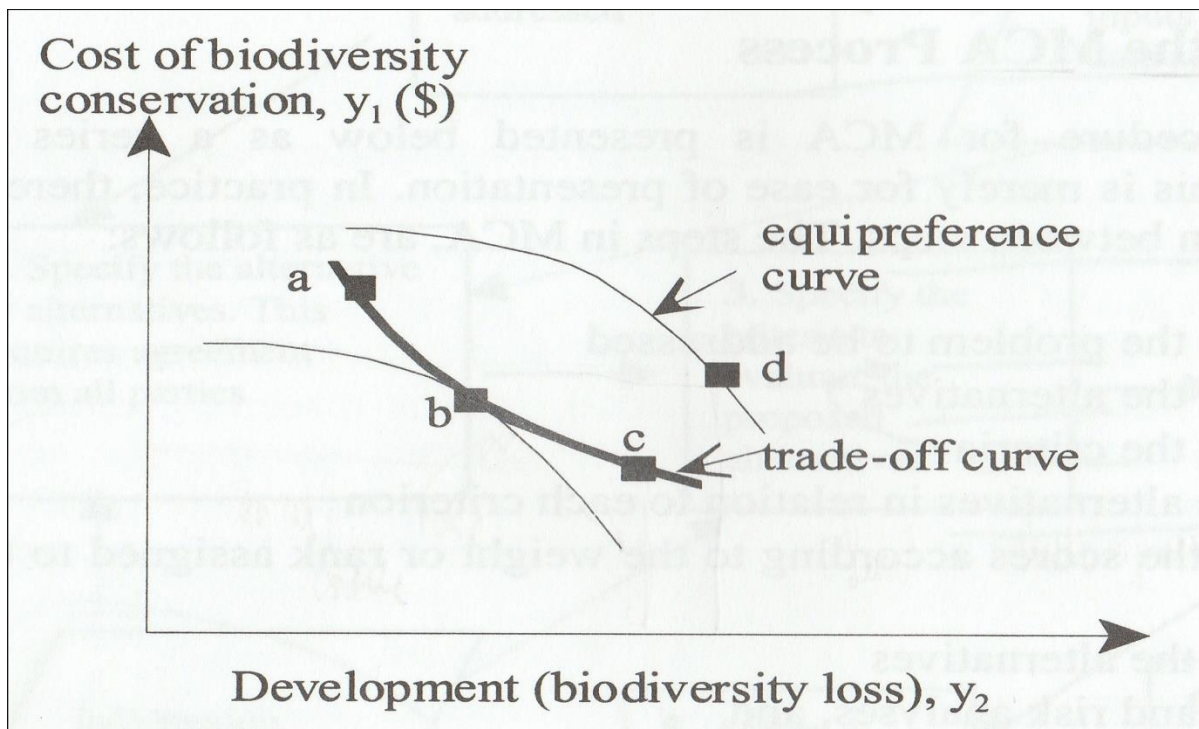


Figure 2.6: Equi-preference curve for evaluating trade-offs (Asafu-Adjaye, 2005: 205)

The equi-preference curve is constructed based on the preferences of a group of stakeholders that equate the points of ecological cost versus amount of development. The relationship developed between the two curves will then define the optimal decision which in this case will be the optimal level of development versus the cost that is to be forgone in the ecology. Figure 2.6 is an example of an equi-preference constructed for the loss of biodiversity in a development versus the cost of protecting the biodiversity. In general, the

optimal point is where the trade-off curve is tangential to the equi-preference curve, i.e. point b in Figure 2.6. There is an assumption here that the biodiversity can be 'replaced' by a cost. This is not always the case with trade-offs and this is then where the trade-off decision rules given in Table 2.6 come to the fore.

Without analyzing the detail of Figure 2.6, the fact that the trade-off points can be represented graphically implies that inclusion of trade-offs as a mathematical function in the system based assessment is feasible but maybe not always practical. The decision rules given in Table 2.6 can be used as defining boundaries for the equi-preference analysis discussed above.

Table 2.6: Trade-off decision rules for SA (Morrison-Saunders & Fischer, 2006: 235)

1. Trade-offs in (all or specified) sustainability related matters are undesirable unless proven otherwise; in other words the burden of proof falls on the proponent of the trade-off.
2. No significant trade-offs with adverse sustainability are acceptable. These include:
 - Trade-offs of permanent losses against temporary gains;
 - Trade-offs of nearly certain losses against highly uncertain gains (precautionary principle);
 - Significant compromises to ecological integrity;
 - Significant increases in integrity of opportunity and influence;
 - Significant increases in energy and material flows, except where the gains address serious deprivation and inequity;
 - Trade-offs where the adverse effects are uncertain and the undertaking is not designed for adaptive response; and
 - Trade-offs where more than one aspect of sustainability may suffer adverse effects.
3. Only undertakings that are likely to provide neutral or positive overall effects in each principle category (e.g. no net efficiency losses, no net inequities) can be acceptable.
4. No significant adverse effects in any principle category can be justified by compensation of any other kinds, or in other places (this would preclude cross-principle trade-offs such as ecological rehabilitation compensations for introduction of significantly greater inequities).
5. No displacement of (significant, net, any) negative effects from the present to the future can be justified.
6. No enhancement can be accepted as an acceptable trade-off against incomplete mitigation if stronger mitigation efforts are feasible.
7. Only compromises or trade-offs leading to substantial net positive long term effects are acceptable.
8. No compromises or trade-offs are acceptable if they entail declines or risks of decline in officially recognized areas of concern (set out in specified official national or other sustainability strategies, plans, etc.).

In the light of the system based method of SA where there will inevitably be TOs, these Trade-off decision rules contained in Table 2.6 may not always be achievable but

cognizance must be taken of permanent destruction of the ecology. The preservation of certain ecologically sensitive aspects that will not recover should be costed at a premium so that their relative contribution in an analysis such as MCA will be maintained. The rules given can be viewed as a basis for defining conditions, as used in an MCA analysis, which may not be violated.

In general the principle upon which each rule is based is sound but the application may not always be practical. With sustainability being a dynamic concept the actual TOs will change in importance depending on in which phase of the project the particular TO is relevant.

There will also be situations where the relative importance of one aspect will change as a result of changes affecting the other – it is for this reason that the system based model of sustainability is attractive as the dynamic nature of sustainability is handled more easily by a system based analysis where concrete inviolable principles can be applied.

2.3 ENGINEERING METHODS AND SYSTEM DESIGN

There are engineering processes based on scientific principles that can be applied to ensure that the value judgements that are made in a system based analysis are consequential and defensible, i.e. they are based on sound engineering and plant design principles. This aspect is being considered in a generic situation so that the applicability thereof will not be restricted by a particular scenario.

With engineering practice being grounded on scientific principles and procedures, it is expedient that the role of science in the EA process receive some attention.

2.3.1 The role of science in environmental assessment

The phrase ‘sustainability science’ is referred to as the focus on the dynamic interactions between nature and society (Clark & Dickson, 2003: 8059). This can be seen as the principal role of science in EA. This has given rise to the following four main definitions of sustainability science (Sala *et al.*, 2015: 315)

- An advanced form of complex system analysis that attempts to understand the interaction between nature and society;
- The development of a greater willingness by the research community to find solutions to the issue of interaction;
- The embodiment of the possibility of transcending the reductionist tendency of the sciences to instituting a holistic approach to problem solving by using a systemic (sic) approach; and

- Using a holistic approach to studying the nature and society interactions.

Prior to embarking on the detail surrounding 'the role of science in EA' it must be pertinently noted that the content is not casting any doubt on the role of or aspersion on the natural science aspects, as practiced by subject matter experts in the respective fields, in EA.

By the very nature of EA the specialist studies that are undertaken play an extremely important role in the assessment of the environment in elucidating information that is critical to the assessment process. This aspect is not being tampered with in the discussion that follows although there have been aspersions made by the Department of Environmental Affairs ("DEA") (South Africa, 2002) in connection with certain improvements in the quality of the application of studies by specialists, or subject matter experts. The information contained in Table 2.7 addresses the aspects noted by DEA where an application of a system based analysis of sustainability will improve the situation. The report of a subject matter expert is an important part of the EA process and as such the terms of reference of the study by the subject matter expert must be very clear and unambiguous (Aucamp, 2009: 87). The terms of reference of such a study will be influenced by i) the dynamic nature of any potential impact, and ii) the influence of the impact on other, i.e. different types of, environmental media. For example it may be that in a development the dust deposition may be within limits but a portion of the deposition may result in contamination of water within the development. The systems based definition will elucidate the potential contamination of more than one environmental medium.

More than twenty years ago it was stated by Beattie (1995: 110) that "EIAs are not science". Such a statement, if not explained, can be very easily misconstrued as suggesting that science is not part of the environmental assessment function. Fortunately, the position of science within the EA process was clarified as it being noted that EIA is a process where scientific knowledge is practically applied (Cashmore, 2004: 408). This can be interpreted to mean that EIA cannot function without science so the application of scientific methods by which EA can be made more effective is the correct way of going.

The EIA is not created to test and refine the explanations of the scientific principles but to use them to predict impacts (Beattie, 1995: 110). What is important, however, is what Cashmore (2004) refers to as causal processes. These causal processes are the ones that determine the manner in which identified impacts are to be mitigated and what TOs can be made. It can happen that a causal issue may undergo a status change in the dynamic nature of sustainability in which case the long-term mitigation of such a factor may be under- or over-specified.

For any scientifically based study to be meaningful the causal processes involved must be well understood (Cashmore, 2004: 418). These causal processes are not restricted to ecological or social issues independently but may be as a result of a combination of both issues. They are normally the ones arising from the development that is being assessed as those that are influenced or affected by the development. Addressing these “causal processes” will entail the application of the research challenges as proposed by Sala *et al.* (2015: 316).

These challenges are

- “adopting a holistic approach for understanding the dynamic interactions between nature and society and for assessing the vulnerability and resilience of complex social-ecological systems;
- moving from multidisciplinary towards transdisciplinary;
- having a normative function;
- promoting social learning and mutual feedback; and
- dealing with uncertainties”.

In the context of this mini-dissertation the first challenge is the most important. This is where the application of the engineering and real world principles of sustainability have a role to play. Given the agenda, and application, of the political requirement of sustainable development any development should ensure the sustainability of the situation within which it occurs which is normally defined by taking a holistic view of the ecological-social aspects involved.

The final aspect of the role of science involves the development of the knowledge systems governing the interaction between the sustainability issues and the application of scientific principles. A part of a strategy to promote SD is the use of science and technology (Cash *et al.*, 2003: 8086).

An extremely important aspect in EIA implementation, particularly in the system based concept of SA, is the multidisciplinary nature of the tasks that it encompasses. It is impractical for an individual managing the EA process to be qualified to undertake all the multidisciplinary studies that have to be done in the assessment process and so the task has to be shared. This is the function of the subject matter experts, specialists, who undertake the studies on specific impacts identified by the EIA process and then report on them. Within the SA realm many of these impacts so identified and reported on will have to be considered within the sustainability regime and the functions of these specialists could well become more important.

Within the South African regime there is, in the DEA IEM series on ‘Specialist Studies’ a fair amount of criticism of the reporting undertaken by the various specialists involved in EIA (South Africa, 2002). These issues are noted in Table 2.7 and they will have to receive rectification attention so as not to degrade the status of EA in general and EIA in particular.

The issues then noted in Table 2.7 will have to receive attention so as not to be a stumbling block in what is proposed in this mini-dissertation as one bad, or sub-optimal, link can collapse an entire system. There has got to be a move away from considering different aspects in an isolated fashion to a broader understanding of the indirect influences on the impacts (Bond & Morrison-Saunders, 2011: 2).

Table 2.7: Application of science in EIA – some deficiencies (South Africa, 2002: 7)

AREA of EIA	DEFICIENCY IDENTIFIED	MITIGATION PROPOSED
Baseline studies	Vague generalizations with no indication of the relative importance of a particular component.	Use system based definition to define the boundaries of the study.
Impact prediction and assessment	Failure to consider all impacts, including indirect and cumulative impacts. Failure to consider all phases of the proposed project (construction, operational and decommissioning phases).	System based evaluation of the impact. By having to make use of the system based sustainability concept all phases of the proposed project will have to be considered.
Impact mitigation	Little indication of the practicality, reliability and potential effectiveness of the mitigation measures.	Ensure application of the most advanced scientific studies. Do not lose sight of the ‘Precautionary Principle’.
Post EIA Impact monitoring	Requirements are generally vague and poorly designed or omitted.	Include requirements in system based monitoring plan.

All the above areas of EIA relate to the technical aspects of the assessment process, but in general, as far as the EIA is concerned, the ‘terms of reference’ of the studies are poorly defined (South Africa, 2002: 7). The optimal definition of and selection of, the boundaries, of the system and sub-systems of the assessment study will address this problem of poor definition of the terms of reference. The other issues that will be addressed by a system based application of SA will be the quality of the ‘impact prediction and assessment’ and the ‘post EIA impact monitoring’.

The system based method of SA has been receiving increasing attention in the literature because of its ability to address the prevalent issues of complexity present when the underlying values and the sub-systems are present (Vildåson *et al.*, 2017: 41). This justifies the aim of this mini-dissertation as it involves a way of looking at the assessment process so as to incorporate the elements influencing the sustainability of a development without detrimentally influencing the quality of the assessment outcomes. The application of the

system based method for a sustainability assessment (“SA”) has been justified by consideration of the literature and the remainder of this mini-dissertation will be devoted to achieving that objective.

2.3.2 Engineering concepts involved in Environmental Assessment

Engineering concepts and methods is a way of applying scientific principles to the design and operability of industrial operations. This was recognized in the last decade of the last century where Turney (2005) authored an article discussing the importance of considering the safety, health and environmental issues in designing chemical plants. The environmental issues noted by Turney (2005) can very easily be extended to include all sustainability related paradigms – in fact the need to make sustainability part of engineering practice has been expressed (Evangelinos *et al.*, 2013: 153).

There are two engineering-based concepts that are applicable to the first phase of the application of the system based concept to EA so as to incorporate the SA concept in the assessment process. When the first phase is complete, as defined by including the identification and delineation of the systems together with the application of basic engineering material balances, then in the second-phase sustainability analysis can be expanded to include more advanced issues such as multi-criteria decision making, fuzzy logic, cost-benefit analysis, etc. The first phase of the implementation of the system based definition and the material balance application is not very difficult, but the implementation of the second phase will require the application of specific skills that may be problematic to access.

2.3.2.1 Systems in sustainability

A system is a collection of objects, or entities, which are bounded in terms of space and time (Asafu-Adjaye, 2005: 13). The systems, and the entities within them, interact in various ‘ways’ with these ‘ways’ generically referred to as processes. This system based concept of the environment can be clearly seen by the model illustrated in Figure 1.1 which is a generic representation of the system based concept illustrating the environment as an open system within the universe. The only output from the environmental system, one in which the complete anthropocentric activity is contained, is waste. The importance of minimizing the waste production as a result of the anthropocentric activity is confirmed as this then reduces the assimilation load on the environment. In the final analysis, the sourcing of resources from the environment have a lesser chance of resulting in total environmental degradation as indicated in Figure 2.5 than the disposal of waste. The waste is then the only ecological destructor that leaves the system. A general illustration of the fit of the system concept into

sustainability is given in Figure 2.7 that illustrates that the large (global) system contained by the ecological system encompasses the entire range of anthropocentric activities.

The diagram contained in Figure 2.7 includes the inner circle described as the 'strategy business dimension' which is the same as the 'economic dimension' shown in Figure 2.2.

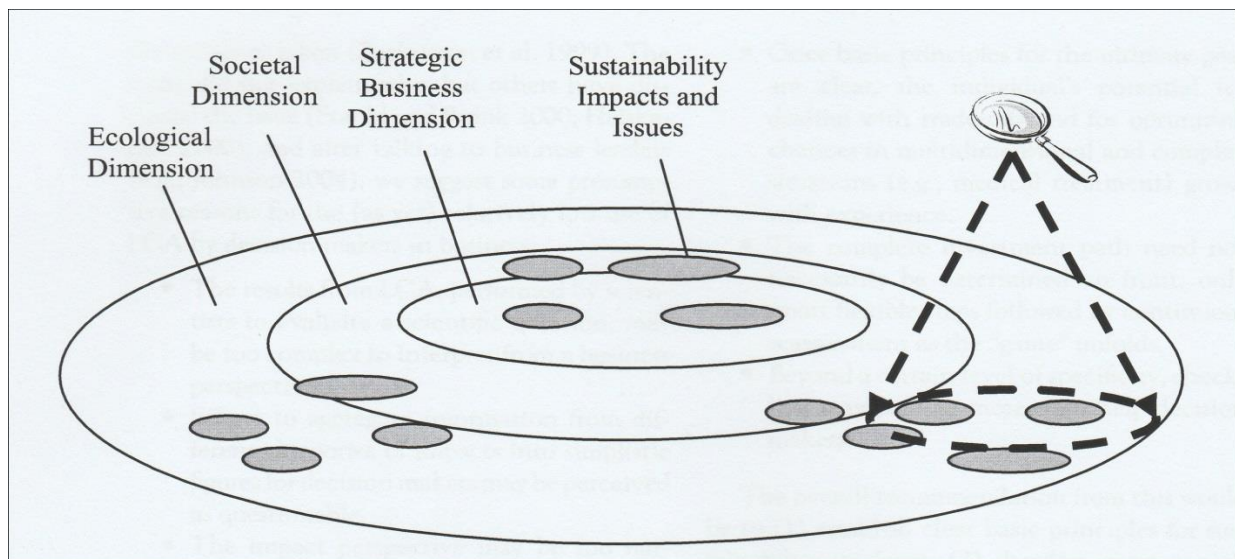


Figure 2.7: System depiction within the circle definition of sustainability (Ny *et al.*, 2006: 68).

Within the depiction of the individual systems, shown by the greyed areas in Figure 2.7, the systems as defined may straddle one or more sustainability issues. The areas depicted by the dashed lines with the magnifying glass illustrate that specific impacts and systems can be focused on to allow for increased lateral analysis that will highlight the interaction of the impact with the different sustainability dimensions. This concept as illustrated in Figure 2.7 may be expanded to include further analysis of each impact (identified by the greyed areas) as discussed while at the same time allowing for the increase in the depth (effect) of the impact. The depth of the impact will be, for example, the inter-generational aspects.

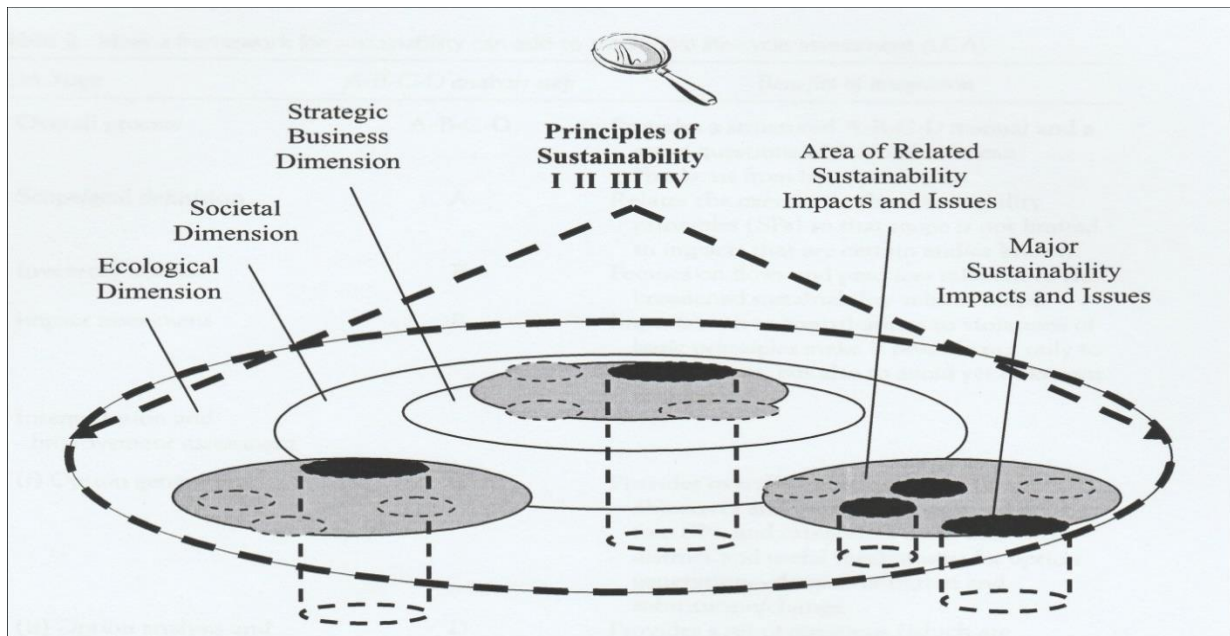


Figure 2.8: Sub-system delineation and criticality (Ny *et al.*, 2006: 71).

In Figure 2.8 the systems being assessed within the sustainability limits of the ecological, societal and economic sub-systems are indicated by the grey areas. It is noticeable that these systems can, and do, transcend the sustainability issue limits. The dotted lines within the grey areas indicate a sub-system that is analyzed as part of the larger system. The smaller sub-systems that are coloured in black are identified as requiring an extended analysis by a subject matter expert. It is evident that designing systems and associated sub-systems allow for differing levels of interaction and analysis within the sustainability definition.

In conclusion, an example of part of a system analysis would look like the contents of the following illustration - (Figure 2.9) where the aggregation of the sub-systems is evident.

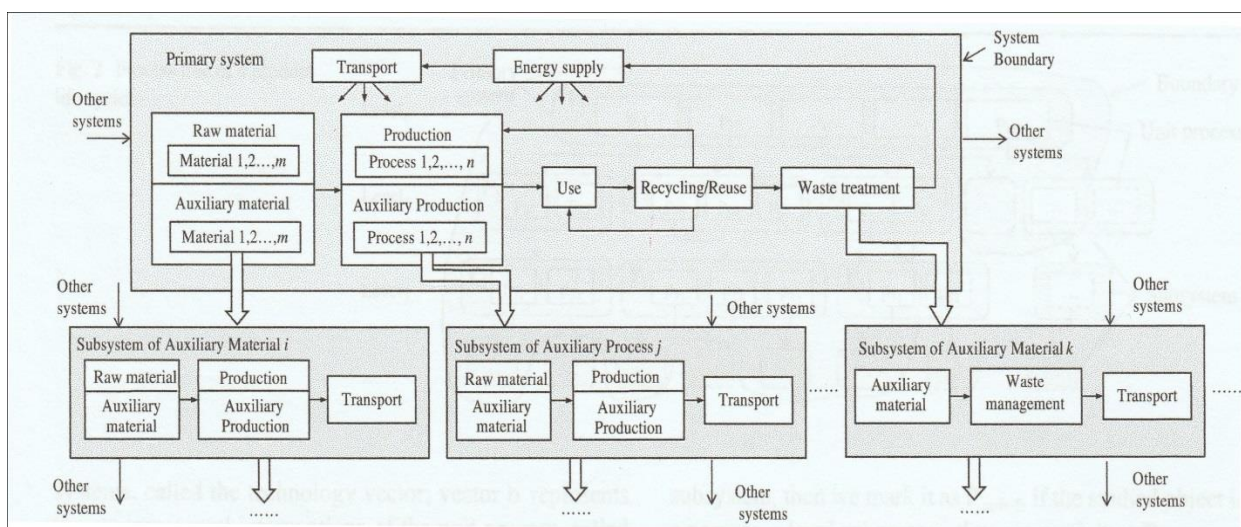


Figure 2.9: A system depiction indicating the sub-systems (Tao *et al.*, 2014: 648).

It can be observed from the detail of Figure 2.9 that a complicated system can be broken down into smaller sub-systems that may be easier to analyze and evaluate. This is consistent with the rationalist approach to impact assessment (Bond & Morrison-Saunders, 2011: 2). This breaking down of the complicated system leads to a debate on too what degree should a reductionist approach be followed? The reductionist approach is basically one where a complex system is reduced to its component parts (Bond & Morrison-Saunders, 2011: 2) where the alternative to reductionism is holism which goes to the opposite extreme of considering systems that, because of certain limitations, cannot be analyzed through sub-components (Bond & Morrison-Saunders, 2011: 2). In reality, this decision – the degree of reductionism applied – should be dictated by the type of system involved and what the attributes of the process that the system is describing are. The degree of reductionism is not a ‘blanket’ decision that can be made about SA but depends on the individual attributes of each unique situation.

A further aspect of paramount importance is whether a system under consideration is an ‘open’ or ‘closed’ one and whether the system operates at steady-state, i.e. equilibrium or is in a transient state. A transient state can be thought of as a system that is moving from one state of equilibrium to another. The distinction between open and closed systems is one of what happens to the material or processes within the system – an open system is one where material crosses the system boundary and a closed system is one where there is no material crossing the system boundaries (Himmelblau & Riggs, 2004: 137). The environmental issue governing such a decision would, for example, be situations regarding waste. A typical situation would be if waste is recycled internally, or if waste produced is handled by an external party.

The final aspect regarding systems that is to be addressed is the one of Scenario Analysis (“SAn”). With SD being a dynamic and future oriented concept the application of SAn is of indispensable importance. The necessity of impact analysts using SA processes engaging in thought processes that deal explicitly with the future is of paramount importance (Duinker & Greig, 2007: 207).

Scenarios normally have a two-fold function that is basically indispensable to the business strategy function and these are i) risk management, and ii) the testing of strategies against possible future states. It is here that SAn will assess the implications of future states which are important in the inter-generational aspect of sustainability assessment (“SA”). Scenario Analysis (“SAn”) is a very powerful approach for considering potential future states that are necessary in EIA where there is SA (Duinker & Greig, 2007: 211). With SA having a very strong future orientation the tools of scenario analysis fulfil an important function of

understanding the possible future developments of complex systems (de Ridder *et al.*, 2007: 131).

An issue upon which the success or failure of a system based analysis will depend is the sensibility of the boundaries that define the system under consideration. This is the most important aspect of the system based analysis. If the systems are not defined properly then the process of SA is doomed to fail.

The next section addresses the determination of the system boundaries together with some methods of defining them.

2.3.2.2 System boundaries

In studying systems and their interaction, it is necessary that the limits of a system are well and logically defined. This is achieved by determining the “system boundaries” (Morvay & Gvozdenac, 2008: 9) which then define the limits of the system (Himmelblau & Riggs, 2004: 137).

In this process of boundary definition, the first things that must be taken into account are what parts of a system are relevant to the aim of the assessment (Ekvall & Weidema, 2004: 161). The critical first step in the application of the system based process is the definition of the system boundary as this will determine the method applied in, and the complexity of, the analysis (Oloman, 2009: 99). The system boundaries as defined are arguably the most variable aspect of the system definition process principally as a result of the value-laden characteristic of sustainability (de Olde *et al.*, 2017: 77). This is particularly true of the temporal aspect.

In giving consideration to the system and the boundaries applicable, a system may consist of many unit processes (Raynolds *et al.*, 2000a: 96). This can increase the complexity of the system exponentially so a good rule of thumb is to select the boundaries to include as few unit processes as possible without reducing the sensibility of the system or the assessment. This may be easier said than done but the application will become easier with experience. In this connection, Raynolds *et al.* (2000b: 38) actually note that “the system describing the entire ‘cradle-to-grave’ life cycle of a product or process is nearly infinite”. To prevent this from occurring, the following criteria will account for a large proportion of cases. The criteria for system boundary identification are

- The boundary between the technological system and nature;
- The geographical area;
- The time horizon;

- The production process; and for more than one product production processes; and
- The boundary between the production process of the product under consideration and the connected system(s) of other products (Raynolds *et al.*, 2000b: 37). This is referred to as open-loop recycling when recycling of material from one product system into another takes place (Ekvall & Weidema, 2004: 164).

In the preceding analysis it was determined that the scoping phase of the EIA process is the most logical for a SA to be undertaken. Given that the definition of the systems, resulting in the determination of the system boundaries, is an indispensable part of the SA process the system boundaries must be determined in the scoping phase. This is confirmed by Raynolds *et al.* (2000b: 37) by noting that scoping is the period in which the criteria for justifying and defining the system boundaries are derived.

The final aspect of importance when referring to system boundaries is the one of the Functional Unit (“FU”). The FU is an important concept in the consideration of systems and the definition of the boundaries, the delineation of unit processes and the use of the material balance procedure. The FU is defined as a measurable and clearly defined reference for normalization in a unit process to make the processes within a system, or between systems, comparable (Plehn *et al.*, 2012: 415). The FU functions as the link between a system and its sub-systems.

It was shown in the preceding section of this mini-dissertation that systems are very flexible and they can be arranged to depict anything that the designer of the system desires – be it interaction with other systems, different degrees of complexity in the analysis of the system or its sub-systems, different scenarios, etc. This demonstrates that a system based depiction is extremely flexible and differing amounts of complexity can be accounted for.

2.3.2.3 Material and energy balances

It is useful to combine input/output diagrams with the flow diagram that depicts the development. The flow diagrams and input/output diagrams assist in understanding the inputs, outputs and wastes that may be associated with the system and sub-systems (Aucamp, 2009: 40). The flow diagram is a block diagram representing the flow streams in a process so as to gain a visual representation of the interaction between the various input and output streams or activities within a unit process.

The flow diagram functions in a manner very similar to the system/sub-system structure indicated in Figure 2.9 where the interaction between the unit processes can also be visualized. An input/output diagram, which is derived from the flow diagram, is basically used as an input to the materials balance function.

The application of material and energy balances is a quantitative account of the distribution of material and energy within a system and is used in the study of equilibrium in systems, modelling and design of industrial processes, the study of industrial ecology, management of resources, and many more. For a materials balance in terms of a system which is defined, the general balance equation is of the form (Oloman, 2009: 98)

$$\text{Accumulation} = (\text{Input} - \text{Output}) + (\text{Generation} - \text{Consumption})$$

This is a generalized balance equation for a closed system which is structured to suit the problem to which it applies. This generalized integral equation can also be applied in differential (rate of change) form by giving consideration to a rate of change of a variable as in a dynamic system. In the ecological, or sustainability, system the materials balance equation is probably more important than the energy balance as a result of its importance in calculating the material loading of a system. The energy balance equation is of the same form as the materials balance equation given above.

The material and energy (“M&E”) balances can be combined and solved simultaneously, in which case they are termed simultaneous M&E balances which can be useful in problems of sustainability assessment (Oloman, 2009: 216). A famous problem that makes use of simultaneous M&E balances is the balance for the hydrogen economy (Oloman, 2009: 230). A further complexity that may arise is the one of steady state versus unsteady state. An unsteady state system is one where the conditions describing the behaviour of the system change over time. This is typical of many SD systems where SA is of interest.

2.4 CONCLUSION

This chapter has given detailed consideration to the literature involved in the aspect of sustainability assessment. Probably the most important information that has evidenced itself in this literature survey is that SA is an IEM process that, if applied, will ensure that the assessment that has been carried out follows the IEM principles. SA has been referred to as one of the new assessment methods that have been the subject of much discussion, and controversy, in the literature. One of the advantages of the controversial nature of sustainability, sustainable development and sustainability assessment together with the discussion that is taking place in the literature is that the opportunity of designing an assessment process from scratch exists.

This is what is being done here. The use of a system based paradigm with the application of engineering principles will provide a method of assessment that addresses the issues

surrounding sustainability that are of paramount importance in ensuring the continued optimal existence of the planet earth.

The discussion in this chapter commenced with the generalized discussion and consideration of literature surrounding the EA process and the corresponding status of SEA and EIA. The EIA is one of the tools of IEM so it makes sense to include the aspect of SA in the EIA process. This will ensure that by undertaking an EIA with the SA included the implementation of IEM is ensured.

The legal mandate for sustainability in South Africa is contained in the legislation governing the EA process via the EIA so it makes sense to include the SA process in the EIA. By giving consideration to the EIA process a fit was decided on by including the SA in the scoping process. This makes sense as a result of a large responsibility in the SA process lies in the identification of the spatial and temporal aspects of SD.

It was noted that there has been a move away from the Triple Bottom Line method of modelling the sustainability criteria to one of representing the criteria in system based form. This then reinforces the use of the system based method of EA.

Detailed consideration was given to the SA process and the literature aspects surrounding the process given by Gibson as against the process of SA presented by Phillips. It was decided that the geocybernetic model proposed by Phillips was more applicable to the system based consideration of SA. This was as a result of the paradigms description of the geocybernetic process together with the mathematical and system based foundation of the geocybernetic process. Application of the geocybernetic principles indicated that the components of importance in ensuring sustainability are the aspects of 'social development' as a function of 'environmental conditions'. Figure 2.5 indicated certain 'no-go' conditions relating to both of these aspects. The sustainability paths shown circumvent these 'no-go' conditions.

Cursory attention was given to the aspect of sustainability indicators and it was noted that the responsibility of ensuring sustainability is being devolved to the participants in the economy. The indicators chosen should reflect this state of affairs. It was also noted that as a result of the uniqueness of the sustainability aspects for each development, the definition of generic sustainability indicators is difficult. In order to compare the performance of different economic sectors in respect of their sustainability some generic indicators are, however, required.

The application of sustainability principles also gives rise to trade-offs which are always going to be present when choices have to be made. Within these choices there are certain

'no-go' areas and issues that must not be accommodated. The discussion of the literature continued with the consideration of the engineering principles that can be applied in SA. Engineering is the practical application of scientific principles and so the role of science in the EA process is important. It was noted that the application of engineering principles in the EA activity will assist with the analysis of complex systems which are seen to be becoming more prevalent in the EA sphere. It was noted that there is still place for the 'specialist studies' that make use of pure natural scientific principles to assess different impacts.

The discussion concluded by giving consideration to various system based issues and the application of the system boundaries and material energy balances to the assessment process.

From the volume of literature referred to it should be evident that SA is a very extensive subject spanning literature involving ecological assessment, economics, societal issues and process operation amongst others. The system based and engineering issues of importance are studies in themselves that could be undertaken in the future. The application of system theory, although complex at times depending on the precise definition of the system, has tremendous potential for the optimal study of SD. The combination of the system procedures with artificial intelligence, specifically fuzzy logic and applicable artificial intelligence processes, will expand the potential of optimally studying SD immensely. It is important to note that the system based procedure can be implemented separately from the artificial intelligence processes. The application of and the definition of the system based procedure is not dependent on the detailed processes used to assess the impacts identified.

The following chapter, Chapter 3, gives specific attention to the definition of the systems by focusing on the definition of the system boundaries. The definition of the boundaries will largely be based on the procedure and definitions given in section 2.3.2.2 but with a limited amount of individuality being applied to cater for unique attributes of each assessment being undertaken.

CHAPTER 3

SUSTAINABILITY ASSESSMENT USING A SYSTEM BASED MODEL

3.1 INTRODUCTION

As has been shown in the previous chapter there is a need for a defined process that will incorporate sustainability assessment (“SA”) with Environmental Authorization (“EA”). In this chapter a model encompassing the system based analysis of sustainable development (“SD”) is proposed so as to achieve the objective of SA in the EA process. A system was defined in Chapter 2 but the description will be repeated here. The Oxford Dictionary (1994) defines a system as “a collection of connected things or parts that form a whole or work together”. A system can be divided into sub-systems that make up sections of the total system. The adding of the sub-systems to form the total system is to be referred to as a process of aggregation of the sub-systems.

It was determined in the previous chapter that there is a very clear policy and legal mandate for the inclusion of a SA process in the environmental evaluation required. The policy mandate arises from the fact that ensuring SD as a policy related issue affects the governance of a jurisdiction such as the Republic of South Africa (“RSA”). The legal mandate for SD in the RSA is very clearly given by the legislation contained in NEMA (South Africa, 1998). Figure 3.1 illustrates the positioning of EIA and SA activities within a structure contained by i) the “strategicness” of the focus and scope, ii) the comprehensiveness of the coverage, and iii) the “integratedness” of the techniques and themes of the activity of EA (Hacking & Guthrie, 2008: 75).

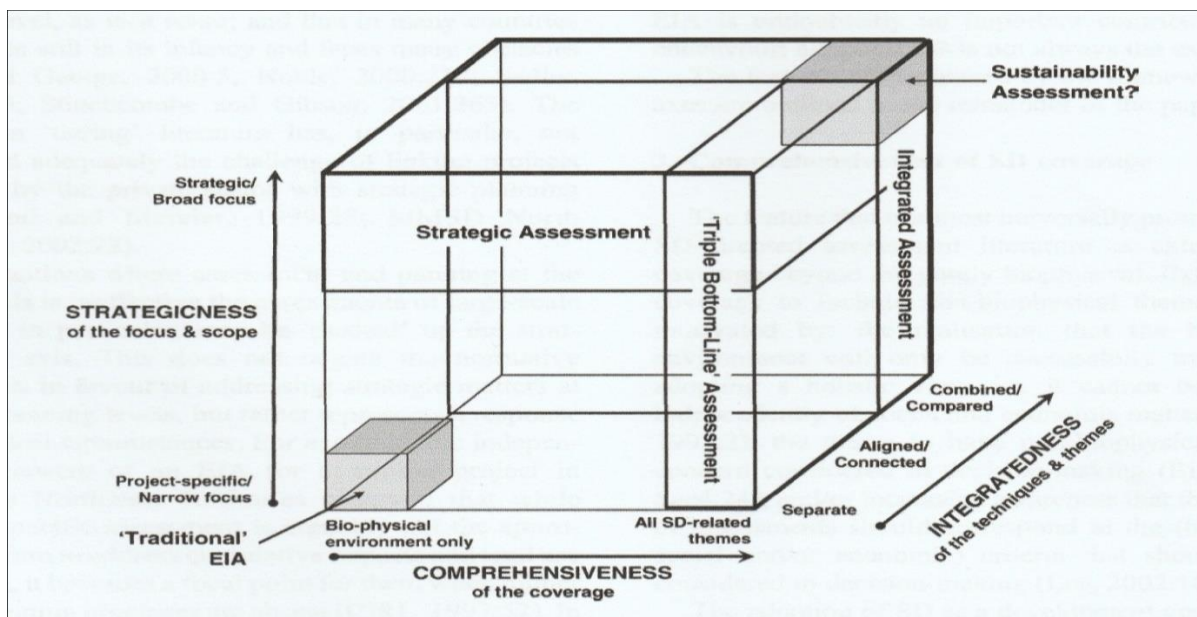


Figure 3.1: Three-axis depiction of assessment processes (Hacking & Guthrie, 2008: 75)

In respect of the positioning of the SA and EIA in Figure 3.1, application of the system based method of SA in the EIA process is going to have the effect of moving the lower boundary of the SA process down on the “strategicness” axis whilst at the same time moving the interior boundary of the EIA depiction towards greater levels of “comprehensiveness”. This will remove the distinction between EIA and SA making SA an integral part of the EIA process. The model proposed later illustrates where in the EA process the SA should be undertaken together with some of the factors that must be taken into account in defining the system used.

Some limiting factors, such as trade-offs, in the evaluation of whether a development is sustainable or not were discussed and noted previously. All these aspects remain valid and will not influence the application of the model. Cognizance must still be given to the decision making aspects of the SA and all the model aims to achieve is to provide a system based depiction of the development under consideration and then to apply the applicable theoretical tools to finalize the assessment.

Application of a system based process will ensure stable and a theoretically substantive evaluation of the factors important in the EA process. It has been noted in Chapter 2 that, not only is the concept of SD a value-laden one but, SD is also situational. The value-laden characteristic of SD actually provides a very wide prospect for deciding how SA should be undertaken and what factors are important in the evaluation. This must all be undertaken in conjunction with considering the situational nature of sustainability.

It was noted in Chapter 2 that ‘engineering science’ must become more involved in the assessment process but the fact that there is still a place, and a definite need, for the application of ‘pure science’ by the subject matter experts in the impact evaluation must not be ignored. It must not be construed that ‘engineering science’ is not pure science’ but ‘engineering science’ is the practical application of scientific principles. The proposal as given is aimed to complement the application of the subject matter experts in the evaluation process.

The remainder of this chapter is devoted to a presentation of a system based model together with the explanation of how it should be applied.

3.2 PRESENTATION OF THE SYSTEM BASED MODEL

Consideration will be given here to where and how the system based model will fit into the assessment process. In Chapter 2, where the literature aspects were discussed in detail, it was noted that the EIA is the only legalized process in the RSA for the assessment of the environment. This implies that the SD issues can only be enforced within the realm of

Environmental Authorization using an EIA. As a result much of the initiative required to progress towards full SA in the EA process should be included in the EIA so a system must be implemented to encourage the progress towards a state within which the SA is an inseparable part of the EIA process. The system based model should achieve that objective. This process can be equated to one of moving from a 'command and control' system of compliance to one of 'self-regulation' as illustrated in Table 2.2 of Chapter 2. The implementation of the system based model should ensure the entrenching of a move towards a system of 'self-regulation'.

3.2.1 Sustainability assessment – position in the EIA process

In Chapter 2 attention was given to the prescribed EIA process required and it was shown that the SA process should be incorporated into the scoping process of the EIA. Inclusion of the SA process into the EIA will have the effect of expanding the reach of the 'sustainability assessment' process shown in Figure 3.1 by increasing its "integratedness" and bringing it closer to, as is shown in Figure 3.1, the "traditional EIA" that only considers the bio-physical aspects.

The SA is not a once-off (or single pass) evaluation but is an interactive and iterative part of the scoping process that should continue, according to the requirements of the Public Participation Process ("PPP"), during the scoping process of the EIA. The interactive activity will take place between the role players in the EA process, while the iterative function will have the objective of ensuring that all the sustainability requirements have been noted. This is illustrated in Figure 3.2 where the SA is shown as an interactive process within the scoping process of the EIA.

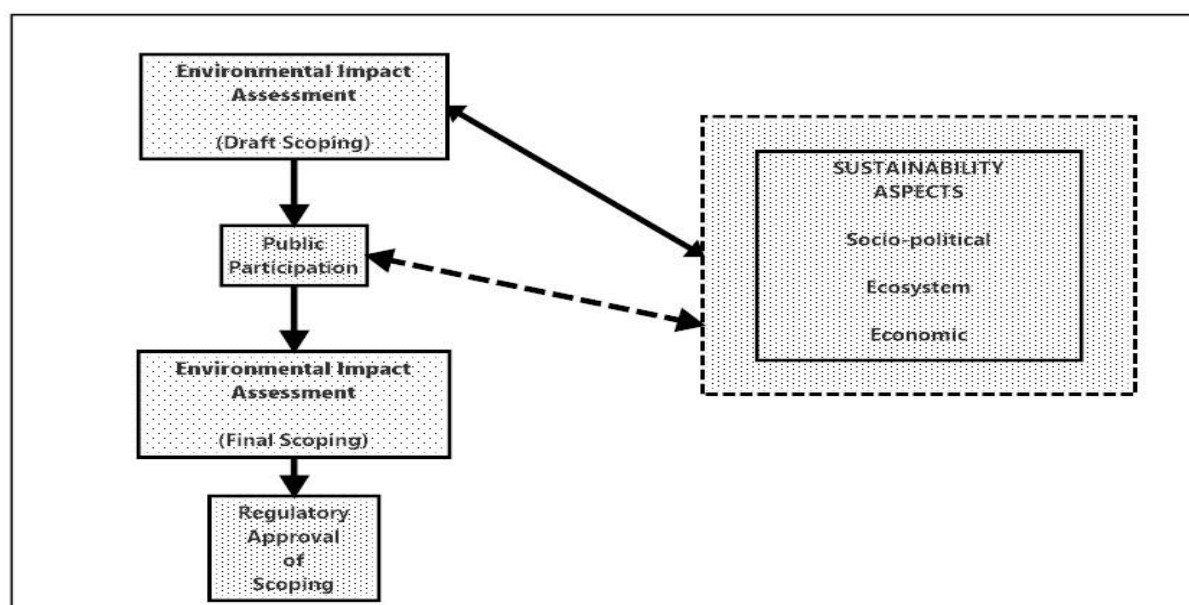


Figure 3.2: Sustainability assessment – positioning in EIA process

The following aspects of the proposal contained in Figure 3.2 are notable:

- The process shown on the left-hand side of Figure 3.2 is the EIA scoping process as currently mandated by NEMA and the associated legislation (South Africa, 1998). Preceding the steps shown, all the aspects of the scoping process, is the 'Screening' process of the EIA and following the Regulatory Approval of Scoping is the Impact Assessment Process. The block on the right-hand side is the Sustainability Appraisal Process which is shown with an interaction to the draft scoping process; and
- The interaction of the SA with the PPP on the Draft Scoping Report ("DSR") is shown by a dotted line because it involves a presentation of the SD aspects in the public participation process where inputs from the public must be noted and should be acted on in cases of deficiencies identified in respect of the sustainability issues.

In order to ensure that aspects of sustainability are addressed for the lifetime of the development, the model of interaction given in Figure 3.2 is based on the fulfilment of the following:

- The SA process being complementary to the EIA scoping process and not being an individual action in the flow of the EIA – the SA process must not replace the EIA scoping process;
- The obtaining of the consensus of all participants in the process of assessment as to what aspects of sustainability are to be evaluated and to ensure that the parameters agreed to by all participants are sensible, measurable and can be assessed;
- To include in the Final Scoping Report ("FSR"), on completion of the PPP, a full description of the development complete with defining the interaction of the development with the environment to describe the spatial impacts of the development together with the temporal ramifications of the development; and
- To interact with the various subject matter experts that will be involved in the assessment in order to ensure identification of the best limits for each scientific study within the sustainability aspects, to ensure a complete and sensible explanation of the requirements and to ensure interaction with each other of the individual scientific studies.

When these issues have received attention and been complied with the definition of the system boundaries must be completed. This must be completed before any material and energy ("M&E") balances can be initiated as the complexity of the calculations in the M&E balances is principally a function of the choice of the system boundaries (Oloman, 2009: 154). It is important that the system boundary definition be considered in conjunction with the M&E balance development so as to ensure synergy between the systems and sub-systems defined.

3.2.2 System based representation of a development

The first step in the process of including SD principles into a EIA would be representing the planned development as a system. The process of this inclusion of the SD principles into the EIA is accomplished by the judicious representation of the system boundaries. The prerequisite is to include all relevant aspects of the development into the system as defined and there are a number of generic issues that can be used as thought starters for defining the boundaries of such a system. These were given in Chapter 2 previously.

In order to attempt to align this proposal with the literature, reference will be made to i) foreground systems, and ii) background systems operating within a total system referred to as the universe environment (Azapagic & Clift, 1999; Nicholas *et al.*, 2000). This concept of the foreground and background system is shown in Figure 3.3 where the similarity with the concept in Figure 1.1 is evident. This model relies on the delineation between i) a foreground system, and ii) a background system within the structure of the environment encompassing the totality of the activities taking place.

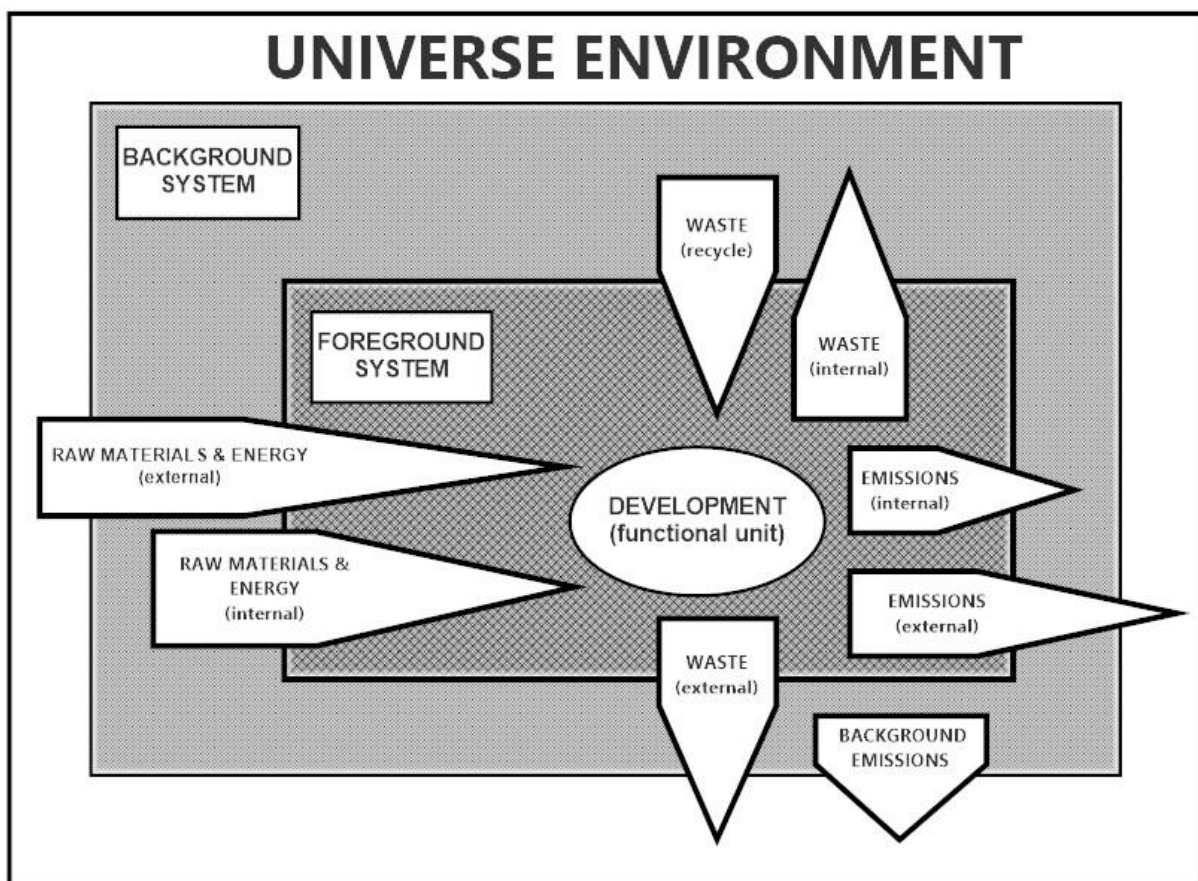


Figure 3.3: System representation for assessment (adapted from Nicholas *et al.*, 2000: 197)

Figure 3.3 provides a comprehensive layout of the system based definition for a development within an environment scenario.

The following points in Figure 3.3 are of note.

- There is a very clear distinction between the foreground and background systems. The unit process, which is the unique activity of the development, is the linkage between the foreground and background systems;
- The reference to 'internal' involves the interaction between the foreground system and the background system whereas the reference to 'external' involves the interaction between the foreground and/or background system with the external universe environment;
- The reference to 'development' in the foreground system is the development under assessment. This development includes any type of installation that requires Environmental Authorisation ("EAu") in terms of the applicable legislation in the RSA;
- The proportion of the wastes developed by the process not being recycled within the process being assessed is shown to leave the foreground system. They are then subjected to an off-site (or out of the development) discard process. This discard process may be the supply of the waste to external parties for further processing or the discard of the waste to a landfill;
- The material recovered from the waste that is moved out of the development and supplied to third parties for further processing may be returned to the development as a raw material. The waste is then recycled back into the development and it can be combined with the raw materials that enter the development; and
- All inputs and outputs (both internal and/or external) must be related to a functional unit ("FU"). The FU, as defined in Chapter 2, is a measurable and clearly defined reference for normalization in a unit process to make the processes within a system, or between systems, comparable (Plehn *et al.*, 2012: 415). The FU functions as the link between a system and its sub-systems.

The implication of the system boundary definition shown in Figure 3.3 is that the foreground system is the actual development that is being assessed so as to gain the EAu. The definition of the boundaries for such a system is potentially very much in line with what the EIA considers presently.

The background system is important in that the boundary definition of the system must reflect the far-reaching impacts that the development has in terms of i) spatial consequences, and ii) temporal consequences which may include all cumulative impacts. For example, the social implications of the development may be an extensive sub-system of the background system.

The two types of system will now receive individual consideration.

3.2.2.1 The foreground system

The foreground system is the system that analyzes the development itself and is very much akin to the EIA as it is presently. The foreground system can be broken down into sub-systems each representing a portion of the total development.

Figure 3.4 is a depiction of the foreground system where the actual physical and chemical operation of the development is considered in detail using the standard engineering methods of unit process M&E balances. These M&E balances can be performed on total masses of components, different types of chemical species, and/or at a molecular (or molar) scale depending on the type and quantity of information the assessment requires. The processes enclosed by the dotted line represent the entire development.

Normally, and only if applicable, a scenario analysis would be undertaken on the foreground system and sub-systems so as to quantify parameters for the impact assessment based on different operating conditions of the development being assessed. The usual standpoint here is that the installation is in a state of equilibrium and scenario analysis would disturb the equilibrium so as to model the different impacts that the system may have. Scenario analysis is an important aspect in modelling disturbances in an industrial process (Turney, 2005: 13).

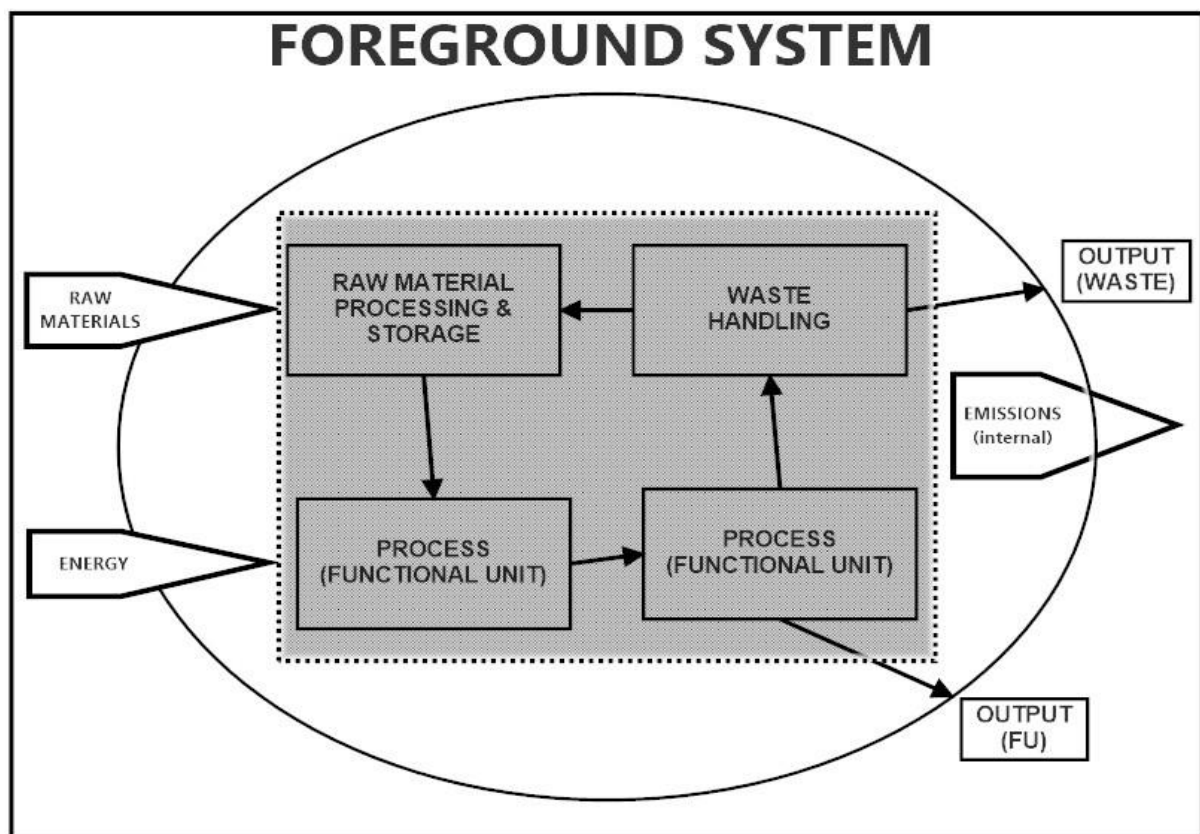


Figure 3.4: Unit process – foreground system (adapted from Azapagic & Clift, 1999: 1510)

It may be necessary, in Figure 3.4, that each unit process be considered separately and then aggregated for the full impact. The manner in which the analysis is undertaken is a procedural issue that need not be discussed further. The aspect of importance here is the determination of the system boundaries so as to be able to complete a full and meaningful analysis.

The method of analysis that will be followed in this case will be determined by the type and format of answer that is required but it will normally start by completing an M&E balance analysis as discussed previously. The analysis would commence with a breakdown of the foreground system into sub-systems that can be analyzed individually. Figure 2.9 was presented in Chapter 2 in order to illustrate the manner in which the foreground system can be broken down into smaller sub-systems that can be aggregated to assess the impact of the overall system. The shaded area in Figure 3.4 is an example of the breaking down of a system into sub-systems where the output of the sub-systems would be aggregated to give an overall result. In the case of emissions for example, the shaded area represents the individual emissions from each sub-system that would be aggregated to indicate an overall emission of the foreground system. This emission from the foreground system would then have to be broken down into 'internal' and 'external' emissions as illustrated in Figure 3.3. A further example involving emissions will be addressed in the discussion on the background system.

The following aspect of the SA to be addressed is the system based definition of the background system, which will contain the bulk of the sustainability issues, such as the inter-generational and socio-economic aspects, that are to be included in the assessment. This will now be discussed.

3.2.2.2 The background system

The background system is conceivably of greater importance than the foreground system when considering the SD aspects of a development. Figure 3.3 is appropriate in this regard. Previously, a set of generic criteria for system boundary identification were given in Chapter 2 and for the sake of completeness they are reproduced here as follows:

- The boundary between the technological system and nature;
- The geographical area;
- The time horizon; and
- The production process.

It is here that the interaction between the production process (or development), represented by the foreground system, and the surroundings is modelled. In this case, the boundary of

the background system might vary depending on the medium affected, i.e. air pollution or water pollution, the type of pollutant, the reach of the pollution, i.e. whether the effect of the pollutant is only local or is it regional, and many other factors.

An example will serve to provide clarification on the aspect dealing with the spatial reach of an impact. Table 3.1 gives a characterization of air pollution as to whether the pollutant is primary or secondary. A primary pollutant emanates from the development as an emission and a secondary pollutant would arise as a result of a chemical interaction of the emission emanating from the development with constituents in the atmosphere. In the case of a secondary pollutant there may be a chemical reaction involved which requires an M&E balance to evaluate the extent of the pollution. In terms of the classification between foreground and background systems, primary pollutants will arise in the foreground system and secondary pollution will result from the interaction of the pollution from the foreground system with aspects, e.g. atmospheric, conditions in the background system. This would be the case with large developments that have an extensive impact remote from the site of the development.

Table 3.1: Air pollution constituents (adapted from Nyoka & Brent, 2007: 665, 667).

POLLUTANT	IMPACT	DOMAIN ¹	TYPE
CO ₂ (eq)	Green House Gas ("GHG")	Global	Primary/Secondary
PM ₁₀	Health, Land use, Water resources	Regional, Local	Primary
SO ₂	Health, Mortality, Structures	Regional, Local	Primary
SO _x	Health, Mortality, Structures	Regional, Local	Secondary
NO _x	Health, Mortality, Structures	Local	Primary
NO _x	Health, Mortality, Structures	Regional, Local	Secondary (smog)
NO _x	Land use, Water resources	District, Local	Secondary (nitrates)
VOC ²	Health, Land use, Water resources	District, Local	Primary/Secondary
CO	Health, Mortality	Local	Primary

¹ **DOMAIN** refers to areas of influence (Global – Regional – District – Local in descending order of reach).

² **VOC** is Volatile Organic Compounds.

The definition of the boundaries of the background system would also normally be influenced by the time horizon of the various impacts and it can be used where the impact may change over the time horizon as a result of, *inter alia*, a technological change, either in the installation of technology or pollution mitigation processes. This is similar to the application of cleaner production issues where the change in impact mitigation is as a result of a

development making use of different technologies – the technology can be decided on based on the levels and reach of pollutants and where the development is located. For example, the same type of development located inland versus one located at the coast will have different impacts on the environment as a result of different conditions prevailing.

As a result of the variability in the sustainability concept it is very difficult, and possibly impractical, to specify fixed parameters for the definition of the background system and its associated boundaries to cater for the sustainability aspects of each different scenario that receives consideration. It is an aspect of the SA process that will be unique for each scenario and will have to be approached as such. It could possibly lead to there being different definitions of the boundaries of the background system in each individual scenario. This could, unfortunately, also result in subjective evaluations of sustainability issues arising.

An example relating to the situation in South Africa is the location of the coal-fired power stations on the Mpumalanga province highveld. If sustainability issues had been differently considered prior to the development of a power station, maybe the decision to situate the power station on the coal deposit, or very close to the coal supply, was not the right one. The environmental impact issues surrounding a coal-fired power station are well defined so the study of the foreground system would normally be very straightforward. The impacts, i.e. social, economic and environmental, in the background system would normally not be so simple as a result of the changing social situation over the life of a power station.

3.2.2.3 The system based assessment and the geocybernetic paradigms

In Chapter 2 two potential methods of sustainability assessment (“SA”) were presented. The first was SA decision criteria given by Gibson (2006a) and reproduced in Table 2.4. These were eight criteria that were to be included in the EA process to ensure that sustainability aspects were addressed.

The second method proposed is based on the concept of geocybernetics reported on by Schellnhuber and Kropp (1998). As discussed in detail in Chapter 2 this concept is based on the process of globalization driven by the forces of economy, technology and lifestyle, and the global environmental policy attempting to repair or prevent the side effects of global change. This gave rise to five ‘crisp’ paradigms that are used in the mathematical model for the assessment of sustainability. The reference to a ‘crisp’ paradigm is indicative of the potential use of fuzzy logic principles in the analysis. Table 2.5, in Chapter 2, gives detail on these five paradigms while the process followed based on the concepts of globalization together with global environmental policy is illustrated in Figure 2.5 in Chapter 2.

Table 3.2 identifies each individual geocybernetic paradigm, as given in Table 2.5 in Chapter 2 with the applicable foreground and/or background system as given in the system based model proposed. It is evident in Table 3.2 that all the geocybernetic paradigms are addressed by the system based model consisting of the foreground system encompassed by the background system.

Table 3.2: System based model fulfilment of the geocybernetic paradigms

PARADIGM No.	PARADIGM	REQUIREMENTS to be FULFILLED	SYSTEM APPLICABLE*
1	Standardization	Standardization in respect of instruments that are used in the assessment of the impacts.	F & B
2	Optimization	Seeking the best design for the human-ecological system.	F & B
3	Pessimization	Application of the 'precautionary principle'.	F & B
4	Equitization	Inter-generational equity.	B
5	Stabilization	Bringing the human-ecosystem into equilibrium in a state of co-existence.	B

* F = Foreground system and B = Background system

Although this, the geocybernetic concept, is the preferred model chosen in this mini-dissertation, as a result of it being system based the following additional comments are relevant.

Firstly, there is an advantage in that the geocybernetic process encompasses a systems based methodology, albeit in terms of potentially complicated fuzzy logic principles. Fortunately the application of the fuzzy logic principles and methods can be separated from the system based methodology. The definition of the systems, as illustrated in Figure 3.3, are based on paradigms 1 and 2 in the foreground system and paradigms 1, 2, 4 and 5 in the background system. The application of paradigm 3 will be over-arching in the process of assessment.

Secondly, a further advantage of making full use of the geocybernetic method of SA is that, based on the previous discussion, its complete application can be divorced from the requirement of the skill set of being able to apply fuzzy logic principles to the Environmental Assessment ("EA") process. In order to address this aspect, the proposal made here is to apply the system based assessment as a first phase of the implementation and allow the gradual development of the skill set of artificial intelligence processes.

The application of M&E balances will now receive consideration.

3.3 MATERIAL AND ENERGY BALANCES

The correct application of the M&E concept is an extremely effective method used in the study of situations where there is a transfer of materials and energy. All developments result in situations where there is a transfer of materials and/or energy and as such the application of M&E balances to the study of the development is strongly recommended.

The effective application of the system based procedures presented in the previous sections hinges, to a very large extent, on the effective use of the M&E concept. There are a few pertinent points made by Oloman (2009: 154) that must be considered by the user of the M&E balances. The user of the M&E balances must;

- be able to interpret the “jargon” and possess the ability to resolve the potential ambiguities that may be evident, both in the description of the development and the SD issues;
- have the ability to construct a flowsheet of the development and locate the individual unit processes that can be aggregated;
- have the understanding and ability to define the systems and sub-systems that are relevant;
- have the understanding and ability to construct a set of equations relating to the development stream table matrix containing the known and unknown quantities that are used in the M&E calculations;
- be able to express the mitigation of each impact chemically or in a manner that will enable a materials balance to be completed;
- determine the degrees of freedom (“DoF”) of the system so that the possibility of under- or over- specification of the M&E problem can be avoided; and
- have the understanding that M&E balances are based on the conservation of mass principles and the unambiguous recognition of using ‘conserved’ or ‘non-conserved’ quantities in non-nuclear processes.

Most of the factors described above will have to be undertaken in conjunction with the subject matter experts. The application of the system based SA described above could be undertaken by any person that is familiar with, and knowledgeable of the, process described.

An extremely important aspect in the system analysis procedure, that has an effect on the M&E application, is whether a system is open or closed. An open system is one where there is a transfer of material over the system boundary as this can implicate a transfer of energy by the energy content of material across the system boundary. This is especially relevant when there is a chemical reaction taking place in the system as defined.

When there is a chemical reaction taking place within the system, the M&E balance can be based on individual components that react individually. There are then two issues that must be taken account of in a case such as this. Firstly, there is a heat (energy of reaction) component involved that must be accounted for by doing an energy balance, and secondly, although there is a conservation of mass principle that is inviolable, the change as a result of whether any reaction is molar (or molecular) must also receive consideration.

Referring back to the 'internal' and 'external' issues surrounding the pollutants present in the emissions of a development, Table 3.3 classifies primary and secondary pollutants. The M&E concept enables the quantification of the different types of pollutants based on the 'internal' and 'external' distribution of the emissions from a development. This allows the quantification of effects of the development and studies in respect of the mitigation of impacts far removed, i.e. the background system, from developments.

3.4 CONCLUSION

This chapter has built on the literature study in the previous chapter by providing a method to undertake a SA in the EIA process as practiced in South Africa. The SA model using the system based concept with the M&E balance process has been proposed on the basis that it will provide an EA, and ultimately a SA, that is undertaken using sound engineering principles and procedures. This proposal made is not a criticism of the current methods of EA, but is an attempt to make the assessment of sustainability in large developments with potentially extensive impacts an easily attainable reality by making use of tools that are currently available.

As more advanced procedures, such as Fuzzy Logic ("FL") and Multiple Criteria Analysis ("MCA") etc., are developed to fit in with the assessment activity, the foundation of the system based procedure with M&E balances can easily be adapted and expanded to cater for the developing computational and decision making processes.

By regarding the foreground/background systems using the spatial and temporal boundaries, many of the legacies that exist where sustainability was not considered in detail may not have been initially created. Sustainability Assessment ("SA") in the EIA is not negotiable and it is suggested here that the most expedient manner of approaching it is by making use of robust scientific principles using tried and tested engineering paradigms.

The system based principle, with well executed M&E balances, is the manner of achieving an assessment of sustainability in the EIA process. EA will then be a sustainability toll-gate in the authorisation process. This proposal is the first step in achieving the goals of sustainability by utilizing the "science of engineering" (Evangelinos *et al.*, 2013: 153).

It is also clarified that the process of SA discussed is more applicable to large developments that are of an industrial and mining nature where the potential for significant sustainability impacts is extensive. The implementation of this procedure may not be optimal for smaller developments that may have a very restricted environmental impact.

The application of this type of SA to projects where the EIA process, both Basic Assessment ("BA") and full EIA, was followed will be discussed in the next chapter. The case studies being discussed have been chosen so as to illustrate the potential advantages and permutations of applying a system based sustainability assessment in the EIA process to provide better information for the Environmental Authorization aspect.

CHAPTER 4

ANALYSIS OF CASE STUDIES USING A SYSTEM BASED MODEL

4.1 INTRODUCTION

The literature study in Chapter 2 placed the aspect of Sustainability Assessment (“SA”) in perspective in terms of identifying the need for SA and what the current state of thinking is in respect of the implementation of SA. It was decided that a system based model, as proposed in Chapter 3, was appropriate.

The methodology of building and utilizing a system based model using engineering principles was given in Chapter 3. The model proposed in Chapter 3 is based on a foreground and background system being used. The definition of the system boundaries would be undertaken during the scoping activity of the EIA.

This chapter is the data gathering section of this mini-dissertation. Practical substance is given to Objective 3 of the study by using the case studies to quantify the difference that a sustainability assessment would have made to the authorisation obtained. It must be noted that the role of ‘good’ data in SA is very important and the data should be collected with the objective of the use of the data in mind. The data that has been used in these case studies was not collected with the objective of performing a sustainability assessment but it is the only data that is available.

The case studies selected are:

1. Proposed Panfontein Colliery.
2. Demolition of ferroalloy furnaces.
3. Calcination Plant located in Sasolburg.

Even though the validity of the data in each of these studies may not have been directed towards the assessment of sustainability all of these case studies are considered to be appropriate examples of the necessity of the application of the principles of Sustainable Assessment (“SA”). The case studies presented are, together with the system based model discussed in the previous chapter, used to demonstrate how the application of SA could have provided more comprehensive information that could lead to a better decision for authorisation, i.e. a decision that will go further towards achieving sustainability.

4.2 CASE STUDIES

The detail of each case will now receive attention.

4.2.1 Case 1 - Panfontein Colliery near Vereeniging in Gauteng

The first case study was the application for authorization of a coal mining operation to ensure the uninterrupted supply of coal to the Eskom SOC Lethabo coal-fired power station ("Lethabo"). Lethabo is located in the Free State province adjacent to the Vaal River approximately 10kms downstream from the Vaal Dam. The proposed coal mine was known as the Panfontein Colliery located on the Panfontein Farm.

The proposed coal mine could have resulted in potentially serious water supply ramifications that deserve noting. The position earmarked in the application, known as Panfontein, consists of an area of land located on the northern bank of the Vaal River on the southern side of the Rand Water Zuikerbosch pumping station just outside the town of Vereeniging in Gauteng in South Africa. Panfontein is strategically important in that the canal and underground emergency pipeline carrying water from the Vaal Dam to the Rand Water Zuikerbosch facility runs through the site.

The Vaal River barrage is located approximately 50 km downstream on the Vaal River from Panfontein. According to Tempelhoff *et al.*, (2007: 116), it was evident during the 1980s that there was increasing waste water pollution at the barrage in the Vaal River. The main reasons for this increase in pollution was the proliferation of informal housing settlements in the catchment areas of the Klip River and Suikerbos River which are both tributaries of the Vaal River upstream of the Barrage (Muller, 2015: 47). The Klip River and Suikerbos River both enter the Vaal River in the Vereeniging area. The general implication of the proposed coal mine was that any additional pollution of the Vaal River as a result of the mining activity at the Panfontein site would accentuate the level of pollutants at the Barrage and this would detrimentally affect the quality of the Vaal River water downstream of the Barrage.

It should also be noted that the Anglo American New Vaal Colliery, which is the designated coal supplier to Lethabo, was at the time of the EIA at Panfontein was at the time busy with its own EIA. This EIA, which commenced in 2010, was directed to the expansion of the coal mining facilities at the New Vaal Colliery by extending the life of the mine to extend the period of coal supply to Lethabo to approximately the year 2050. Although there is ambiguity surrounding the start date of the EA for the Panfontein Colliery, the first public complaint in connection with the proposed coal mine was received in 2014 approximately four years after the commencement of the EIA for the extension of the life of the New Vaal Colliery.

Although the process of application for the Panfontein Colliery was never completed, the EIA did progress to the stage of submitting the Final Scoping Report ("FSR") to the CA. By applying the concept of the issues of sustainability in commenting on the Draft Scoping

Report (“DSR”) additional and expanded specialist studies were identified that had to be undertaken.

At the time of commenting on the DSR the desirability of the mining activity earmarked for the area of Panfontein was referred to the political structures in the Parliament of South Africa. The application was subsequently inexplicably suspended by the proponent and it has, to date, seemingly not been resuscitated. The reason for the suspension of the mining right application was never confirmed but that was not the important aspect in respect of this study. The importance of the case study emanates from the fact that the application of a system based view to the EIA application identified serious shortcomings in the scope of the mining operation that was to be assessed.

4.2.1.1 Proposed Panfontein Colliery

The project was an application for a mining right for coal on the Panfontein Farm. The farm is located south-east of the town Vereeniging on the northern bank of the Vaal River. Unless otherwise noted the information provided in this section is taken from the Environmental Scoping Report for project DEA 14/12/16/3/3/2/709, DMR 30/5/1/2/2/10015MR (Makhubedu, 2014).

4.2.1.2 Background to the proposal

The area of the proposed mining development is shown in Figure 4.1 by the area enclosed in the red boundary.

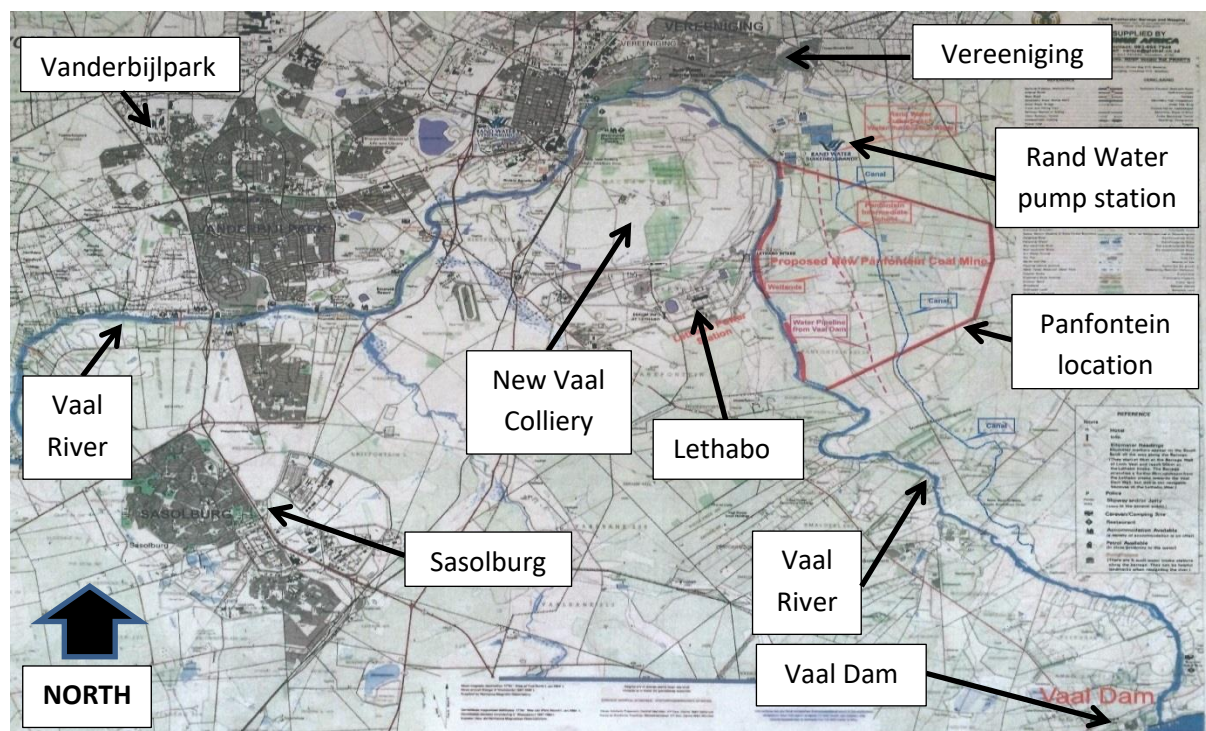


Figure 4.1: Location of proposed Panfontein Colliery (amended from Makhubedu, 2014)

The following is pertinent to the area depicted in the map shown in Figure 4.1 obtained from the EAP. There was no other topographical information available from the EAP but the figure has been annotated to show the positioning of the important detail.

- The direction of flow of the Vaal River is from east to west in Figure 4.1;
- The area of the proposed Panfontein Colliery is shown in the diagram bordered in red and is placed on the northern bank of the Vaal River directly opposite Lethabo;
- The coal seam dips downwards from south to north in the area so the planning for the mining included both opencast and underground mining and the proposal for the mining right application considered both underground and opencast mining operations;
- The Vaal River is shown from the point of the outlet of the Vaal Dam in the lower right-hand corner of Figure 4.1;
- The path of the Vaal River from the Vaal Dam to a point west of the town Vanderbijlpark is shown in Figure 4.1;
- The position of Lethabo is indicated slightly to the right (east) of the centre of the diagram, i.e. on the western bank of the Vaal River. It is notable that the power station is directly adjacent to the Vaal River;
- The area north of Lethabo and south of the town Vereeniging bordered by the southern bank of the Vaal River is occupied by the New Vaal Colliery which currently supplies the entire coal requirement of Lethabo;
- The New Vaal Colliery was given authorization to extend the life of the mine to allow for the supply of coal to Lethabo until about the year 2050;
- The coal deposit in this area (both the deposit for New Vaal and at Panfontein) is of a low grade for which Lethabo has been uniquely configured but the low grade nature of the coal increases the ash (waste) production of Lethabo;
- Directly to the north of the proposed Panfontein Colliery area is the location of the Zuikerbosch Pumping Station of Rand Water SOC;
- This pumping station is the focal point of the potable water supply from the Vaal. The main raw water supply to the pumping station is via an open canal from the point of abstraction of the water from the Vaal River to the Zuikerbosch pumping station through the proposed area of the Panfontein Colliery. The route of this canal is clearly shown on the diagram as a blue broken line running through the proposed Panfontein Colliery area;
- In addition to this canal, Rand Water SOC has an underground pipeline running through the area of the proposed Panfontein Colliery. This is indicated by the red broken line running through the area of the proposed Panfontein Colliery shown in Figure 4.1. This underground pipeline is directed towards an emergency water supply in the event of the canal water supply being interrupted;

- It is noted that the majority of the coal reserve lies on the entire Panfontein Farm with the coal seam to the north (of the farm) consisting of underground reserves and the coal in the centre to the southern portion of the farm consisting of reserves amenable to open-cast methods of mining. The open-cast mining would have influenced the Rand Water canal supplying raw water to the pumping plant. Blasting and the underground mining operation would have influenced the integrity of the underground pipeline and the integrity of the canal; and
- The Zuikerbosch Pumping Station also fulfils a water purification function undertaken prior to the potable water being reticulated to the various offtake points in the areas of supply. Part of this purification function requires sludge settling dams located in an area contained within the area of the proposed Panfontein Colliery. Rand Water SOC was provided with Environmental Authorization for the enlarging of the sludge line capacity;

The system based evaluation process for the Panfontein Colliery will now be presented.

4.2.1.3 System based model for the Panfontein colliery

Figure 4.2 is a block diagram depicting the pertinent sustainability aspects surrounding the proposed Panfontein Colliery.

Figure 4.2 indicates all the external aspects that would potentially have had an economic, social and environmental interaction with the proposed Panfontein Colliery. It is evident that there are many aspects that have a potential influence on the evaluation of such a development and not only the internal aspects that are contained within the area of the proposed Panfontein Colliery.

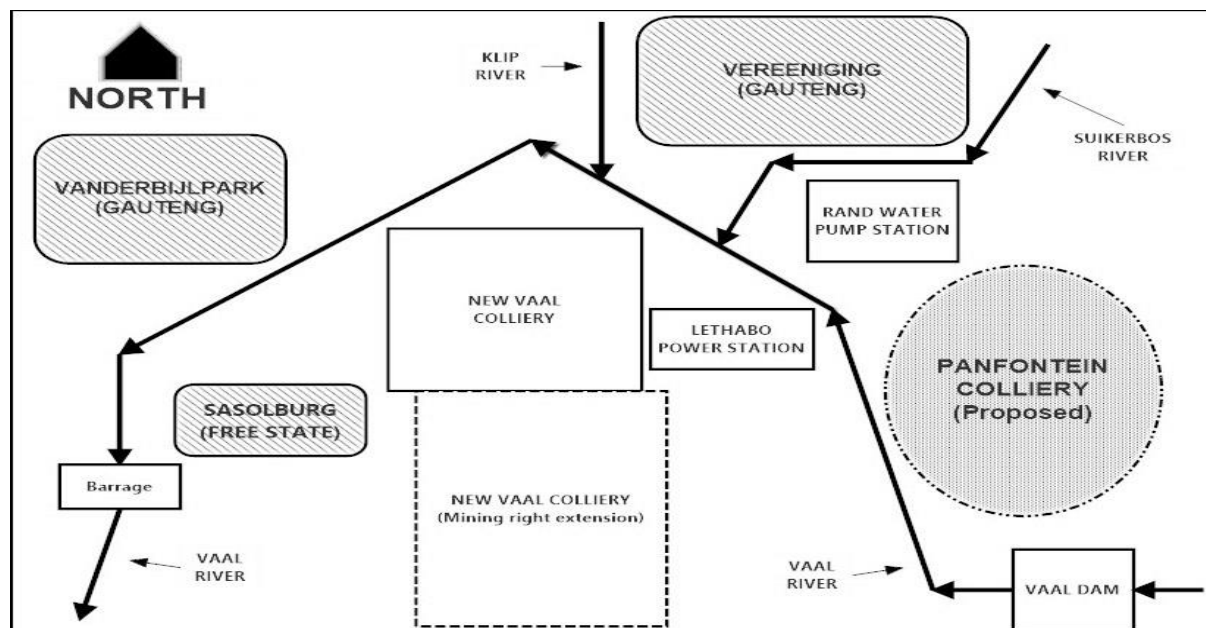


Figure 4.2: Block diagram of the sustainability aspects of the Panfontein Colliery

In terms of the system based definition given in Chapter 3, the proposed Panfontein Colliery would have been delineated as in Figure 4.3.

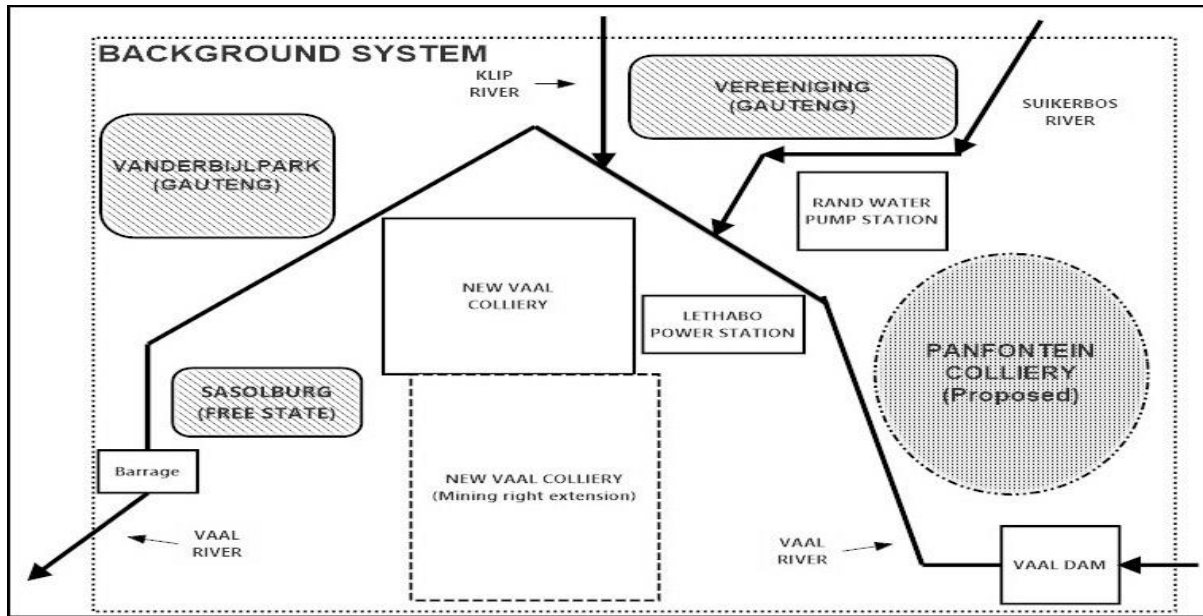


Figure 4.3: System based delineation of the Panfontein Colliery assessment

In Figure 4.3 the foreground system is the hatched area denoted 'Panfontein Colliery (Proposed)' and the background system is the area bounded by the dotted line.

In terms of the system based delineation given in Figure 4.2 above, the foreground system would, *inter alia*, have included,

- The mining licence application undertaken in terms of the regulations;
- The environmental assessment of
 - Coal washing plants;
 - Coal storage;
 - Stormwater;
 - Groundwater;
 - Roads;
 - Social issues;
 - Product transport;
 - Waste; and
 - Air pollution.

The background system would have included,

- The aspects affecting the Rand Water pumping station;
- The effect of the Panfontein Colliery on the water quality at the Barrage and downstream noting that the Suikerbos, Klip and Vaal Rivers flow into the system and that Vaal River flows out ;

- The inter-generational effect of the proposed Panfontein Colliery on the agricultural activities dependent on water from the Vaal River downstream of the Barrage;
- The societal issues of the surrounding towns (both commercial and residential);
- The air pollution interaction in the Vaal Triangle Airshed Priority Area (“VTAPA”);
- The waste issues surrounding the activities at Lethabo if coal was to be supplied from the Panfontein Colliery; and
- The transport of the coal from the Panfontein Colliery to Lethabo noting that they are both situated on opposite sides of the Vaal River.

Each individual aspect within the background system, i.e. the towns, Lethabo, Rand Water pumping station, water quality at the Barrage, etc., would be treated as sub-systems of the background system. Each of these sub-systems would have its own boundaries and then each would be subjected to the applicable type of analysis. The analysis of each will be dictated to by the type of answer that is required. For example, the VTAPA would be subject to a mass balance analysis to comply with the requirement that the additional pollutant loading of the Airshed must be matched by a pollutant loading reduction from some other activity in the Airshed. The secondary air pollution, where both the Sulphur and the potential spontaneous combustion of coal stockpiles is concerned, would also have been an issue that was not included in the original DSR. The system based delineation resulted in their identification.

4.2.1.4 Conclusion of case 1

By undertaking a sustainability assessment (“SA”) of mining coal in the designated area located in the sensitive position that was proposed, the issues impacting the proposition would have been identified and addressed more fully by delineating the process into systems as described. In terms of the definition of the boundaries given in Chapter 3, the SA would have defined the foreground system where the mining development and the associated activities were planned to take place.

The boundaries of the background system would have been defined by the extent of

- The supply of water to Rand Water SOC, together with the issues surrounding the supply of the potable water;
- The potential change in the water quality at the Barrage together with the influence on the water quality of the Vaal River downstream of the Barrage;
- The air pollution issues surrounding requirements in terms of the VTAPA;
- The transport of the coal from the Panfontein Colliery to Lethabo; and
- The waste storage issues at Lethabo.

The background system would also have had to consider the inter-generational aspect of the coal mining activity together with the long-term effects of the development on the local population.

4.2.2 Case 2 - Demolition of ferroalloy furnaces

The following case study involves the Environmental Authorisation (“Eau”) given by the Gauteng Department of Agriculture and Rural Development (“GDARD”) for the demolishing of a BHP Billiton plant located in Meyerton in Gauteng. Prior to discussing the details of the study it will be expedient to define and discuss some applicable concepts. The manganese alloy production facility located in Meyerton is known as the Kookfontein Works, or alternatively as Metalloys, and consists of separate manganese alloy production units making use of the submerged arc furnace (“SAF”) technology. The manganese alloy production units consist of a SAF of a given electrical capacity that is defined by the size, both the primary voltage and current rating, of the primary electrical transformers. In general the smaller SAFs, i.e. those with the lower electrical capacity, have a greater level of tolerance of lower quality raw materials where the lower quality of the raw materials is defined by the physical grain size being smaller and more variable in respect of upper and lower sizing limits.

South Plant consisting of ‘smaller SAFs’, the subject of the EIA for the demolition, was an integral part of the manganese alloy production function of Metalloys. This was because a proportion of the raw material mix to South plant was dedicated to the reduction of manganese containing waste material accumulation in Metalloys.

This case study is one where a system based SA of the proposed project for which authorization was being sought would have undoubtedly highlighted issues in the total waste management scenario that may have caused the proponent’s management, together with the Competent Authority (“CA”), to take a different view of the proposal.

4.2.2.1 Metalloys furnace demolition

The entire environmental authorization application, together with the appeal, is a voluminous study in itself so only the issues pertinent to this study will be considered. In the discussion that follows, reference to the ‘facility’ is based on the description used in the EA documentation and will refer to the entire production facility located at the Metalloys infrastructure whereas reference to a ‘plant’ is to an autonomous structure housing a group of SAFs within Metalloys.

4.2.2.2 Background to the authorization process

The environmental authorization process followed here was a Basic Assessment (“BA”) in which there was very robust participation followed by an appeal of the positive authorization, with all the concomitant processes culminating in the dismissal of the appeal by the Member of the Executive Council (“MEC”) in the Gauteng legislature. The BA process was conducted in line with the 2010 EIA regulations. Scoping is not an individually reported activity in the BA process but there is still an opportunity to consider a holistic view of the project.

In this case it was with the appeal process that a number of expanded business conditions that were not considered in the BA process were discussed and were expanded on in a significant amount of detail (Gauteng Province, 2014). This detail considered the system based delineation in discussing the foreground and background issues of demolishing the plant.

This case study is presented as a result of the contention that a full SA would have identified, and allowed the analysis of, these holistic business imperatives. This analysis would have, potentially, led to different decisions being arrived at by enabling the overall view of the process to be considered.

4.2.2.3 Project Description

As noted in the title of this EA application, the proposal was for the demolition of five electric SAFs at the BHP Billiton manganese alloy smelting facility located in the industrial area of Meyerton in Gauteng. Prior to the demolition of the five SAFs located in South Plant, the manganese alloy smelting facility consisted of three plants, viz. South Plant with five SAFs, North Plant with two SAFs, and West Plant with one SAF and one SAF at West Plant in the process of commissioning. West Plant also housed the refined alloy production facilities. The smelting facility, Metalloys, also houses the entire infrastructure required for the storage, packing and dispatch of the alloys as well as all the infrastructure and facilities for the supply of the utilities and services to fulfill such a smelting operation.

A block diagram layout of Metalloys is provided in Figure 4.4 illustrating the interconnectivity of the pollution control systems of the individual plants. The waste material, dust from the dry pollution control processes and sludge from the wet pollution control processes, was collected for further processing. The collection facility is indicated separately. The plant that was to be demolished is marked in Figure 4.4 as South Plant.

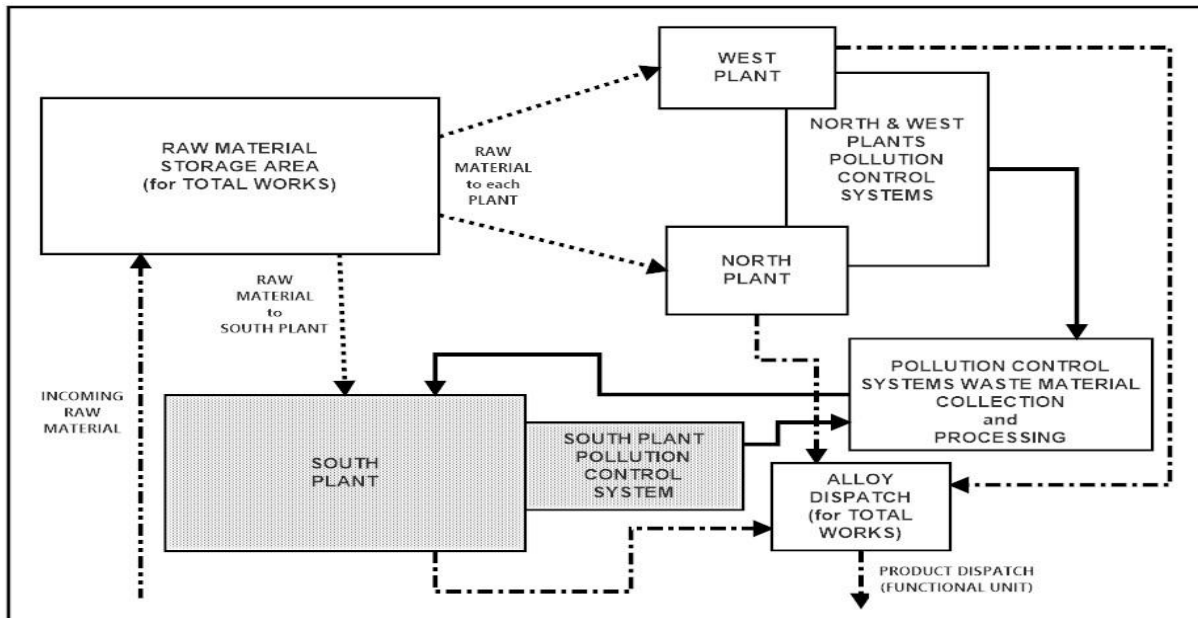


Figure 4.4: Metalloys layout – block diagram

Subsequent to the BA being completed, authorisation was given by GDARD for the demolition of South Plant. This authorization effectively removed a waste processing facility from the manganese alloy production facility, Metalloys. The authorization was appealed according to procedure legislated.

4.2.2.4 Appeal of the environmental authorization

This case study is an example of how a SA will ensure that the principles of Integrated Environmental Management (“IEM”) are achieved. IEM relies on the strategy of Integrated Pollution Control (“IPC”) which is defined by the OECD Council as “taking into account the effects of activities and substances on the **environment as a whole and the whole commercial and environmental life-cycles of substances** when assessing the risks they pose and when developing and implementing controls to limit their release” (Sands & Peel, 2012: 132) (emphasis added).

It is evident in Figure 4.4 that Metalloys was integrated in terms of the overall operation and the removal of one of the sections of operation would break the integrated nature of the operation in terms of the waste processing and recycling. This integration would be lost unless there was a specific initiative to restore the integrated nature of the waste processing and recycling operation at Metalloys. This specific initiative would have formed part of the background system.

The confirmation of the layout of the plant subsequent to the demolition of South Plant is represented by Figure 4.5.

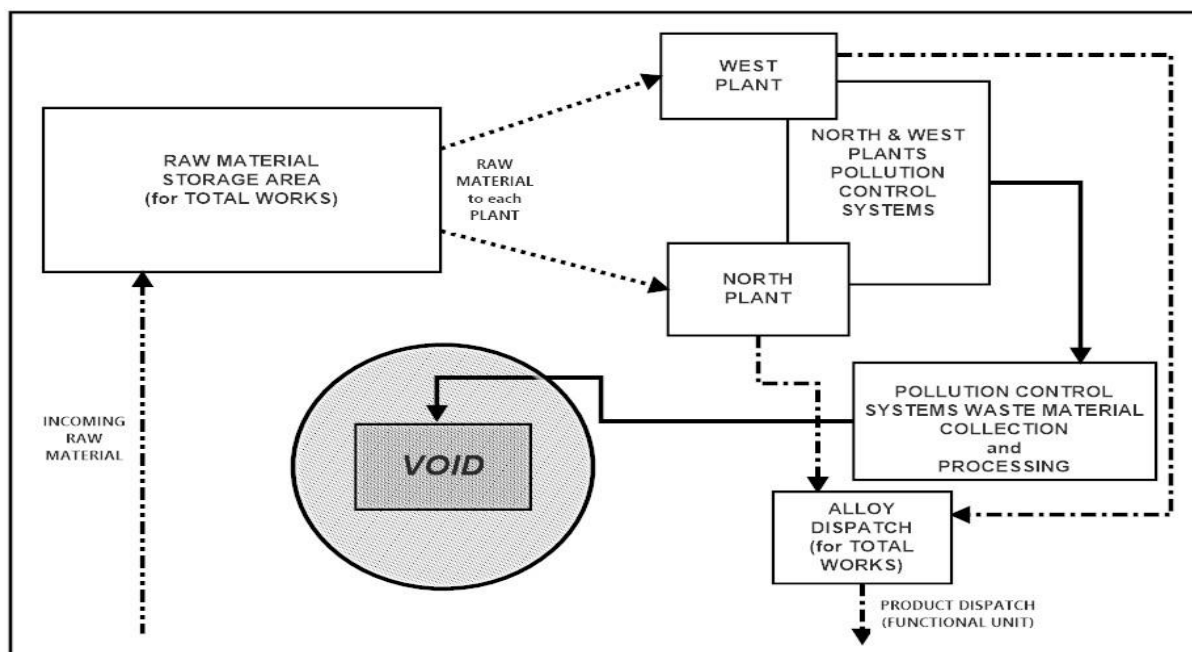


Figure 4.5: Metalloys layout after demolishing South Plant

It is evident that the removal of South Plant created a void and broke the integrated nature of the activities in respect of the manganese containing waste at Metalloys. In order to reconstruct the integrated nature of the operation, this 'void' should be filled to prevent the accumulation of the manganese containing waste on the Metalloys site. There are potentially a number of environmentally acceptable methods that could be implemented in order to prevent the accumulation of waste on the Metalloys site but the possible solutions would form a part of the SA process that should have been followed. A system based analysis, where the background system would have indicated the collection and processing facility for the manganese waste material, would have identified this break in the integration issue and it would have been clear to the CA that there was a potential deficiency in the process of manganese containing waste handling.

In terms of the Materials & Energy ("M&E") principles discussed in Chapter 3, Metalloys moved from a situation of 'material equilibrium' to one of 'material imbalance', which is not sustainable. However, it could have been prevented by a comprehensive system based analysis together with the material balance study of the sustainability issues.

4.2.2.5 Conclusion of case 2

This case study has been considered to illustrate the consequences of a break-down in the application of IEM in particular, and good environmental management principles in general, on the optimum application of multiple aspects of the Environmental Assessment ("EA") function. The EA function would have been improved by the application of the SA principles to the integrated nature of the operations.

By considering the demolition of the plant as ‘part of a larger picture’, which would be the basis of a systems based SA activity, the imbalance in respect of the waste management would have been exposed. Within the ambit of the proposal given, the foreground system would have consisted of the facility proposed to be demolished and the background system would have included the entire Metalloys. By considering each plant within the total Metalloys as a sub-system of the background system the imbalance in respect of waste material production and re-use would have been clear.

4.2.3 Case 3 – The Sasolburg calcination plant

The third and final case study involves the construction and operation of a calcination plant in Sasolburg in the Northern Free State Province of the RSA. The plant is to be located within the SASOL Chemical City Eco Industrial Park (“ChemCity”) site in Sasolburg, located in the Metsimaholo Local Municipality (“MeLM”) (ERM, 2016a: 1). The MeLM is located as part of the Fezile Dabi District Municipality (“FDDM”). This municipality forms part of the northern Free State referred to in Figure 4.6.

The project of the calcination plant arose from the request by SASOL that the company Durrans purchase the waxy oil green coke arising as a co-product of the Coal-to-Liquids process operated by SASOL in Secunda in the Mpumalanga Province. This waxy green coke, after being calcined, was to be sold into industry as a source of carbon.

4.2.3.1 Assessment process

The EA process followed the standard EIA procedure applicable in the RSA and the details will not be discussed here. The Free State Department of Economics, Small Business Development, Tourism and Environmental Affairs (“DESTEA”) was identified as the CA for this project.

In terms of the system based analysis, Figure 4.6 illustrates the position of the calcination plant with respect to its surroundings as well as interaction with the province of Mpumalanga in terms of raw materials. The siting of the project within the Sasolburg area addresses a number of strategic priorities identified by the Integrated Development Plan (“IDP”) of the MeLM. This addressed the single most important priority of the development of the local economy of the northern Free State which is to create additional employment opportunities (ERM, 2016b: 6).

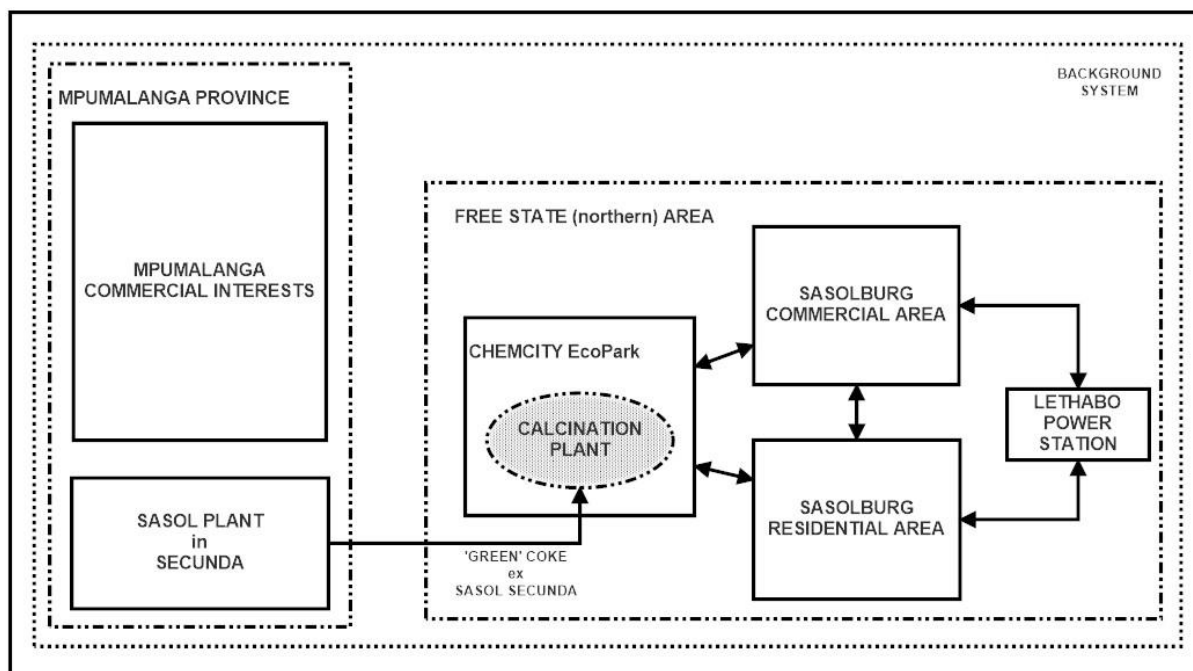


Figure 4.6: Inter-provincial focus of calcination plant in ChemCity

The illustration contained in Figure 4.7 clearly delineates the foreground and background systems where the background system stretches across inter-provincial boundaries. This emphasizes the spatial aspect of sustainability. In this depiction the structure of the foreground system is of note.

In the foreground system, contrary to the delineation of the foreground systems in the previous case studies, there is more than a single foreground system within the delineation of the background system. Each foreground system is constructed so as to contain an area consisting of a number of coherent activities.

This illustrates a potential advantage in the use of the system based analysis where the systems may be delineated into a foreground system based on their own unique activities and attributes between them but still within the structure of a background system. There is still a clear distinction between the systems where, in terms of the assessment process, one system is a provider of raw materials and the other is the user of the raw materials as is shown in Figure 4.6.

Figure 4.7 illustrates a possible variation on the delineation of foreground and background systems for this case. Figure 4.7 provides a more narrowly focused view of the ChemCity development although the raw materials for the development are still supplied from outside the background system.

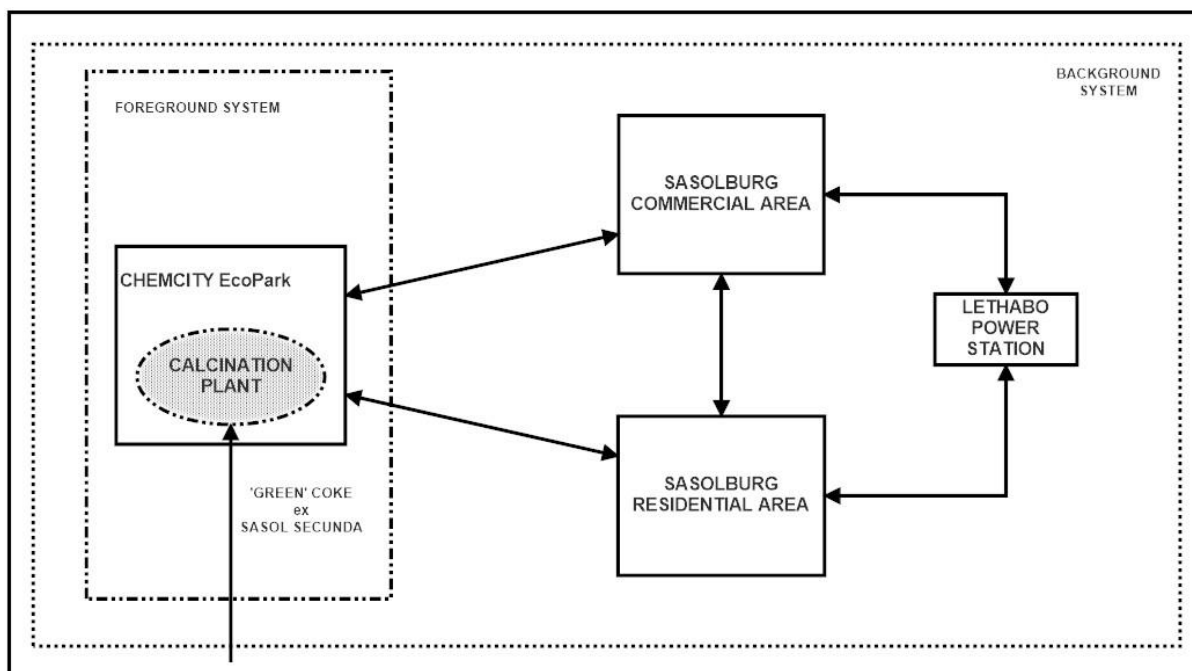


Figure 4.7: Narrower focus of the calcination plant development in ChemCity

The indication here is that the system delineation is a function of the focus that the assessment requires. This procedure of making the delineation of the system a function of the focus required by the assessment would normally be extended to the delineation of the background system.

An important feature identified in this case is the ability of being able to define differing permutations of the systems. In line with the illustration of Figure 2.2 in Chapter 2, where it was shown that governance underpins and supports the system based definition of sustainability, being able to address the governance aspects by differing delineation of the systems is a distinct favourable advantage of the systems based model. Giving consideration to the delineations of the foreground and background systems for this case indicate that it is feasible to give differing amounts of attention to different aspects of the assessment by changing the system delineation. This allows the consideration of the differing aspects of governance.

This advantage of being able to change the system delineation is countered by a potential disadvantage in that, with such a process where there is a large number of permutations in respect of the delineation of the sub-systems, care must be exercised to ensure that the overall assessment remains sensible. With larger degrees and/or areas of integration between individual processes the actual balancing of the Material and Energy (“M&E”) balance becomes more difficult to define because the aggregation of individual processes can result in the over- or under-specification of the individual process M&E balances.

4.2.3.2 Conclusion of case 3

This case study was analyzed in order to illustrate the potential flexibility of the system based delineation for assessment of sustainability. Sustainability encompasses a number of diverse issues that allow creativity in the delineation of the systems so as to maximize the decision making potential of the Sustainability Assessment. Once the systems have been delineated then the application of the engineering based methods comes to the fore and the assessment process continues by applying the concepts of science to the assessment.

4.3 CONCLUSION OF THE CASE STUDIES

The three case studies considered here all illustrate the possibility of being able to address sustainability issues by making use of the system based structure presented in Chapter 3. They all allowed the projects to be structured as a framework of a foreground system within a larger background system. There may be cases of assessment where the systems based method, as described in Chapter 3, is an over-complication in relation to the decision making required but the decision in this regard is one that must be taken on a case by case basis. The full application of this proposal of a system based analysis will not be necessary, or even be desirable, in cases of smaller projects but this analysis of diverse case studies has shown that the method is applicable to most situations. The aspect of data inadequacy, discussed previously, is applicable but it does not impact negatively on the demonstration given.

The first case study of the proposed Panfontein Colliery is a situation where the full suite of potential influencers of sustainable development was not considered in the scoping of the EIA. This was, in effect, one issue that ultimately negatively affected the IEM principle application in particular, and the fulfilment of the sustainable development requirement in general. It was evident that the scope of the proposed project would have influenced a far wider society than was allowed for in the original proposal. A sustainability assessment using the system based model would have allowed all the factors being potentially influenced to have been identified prior to the project being comprehensively initiated by the drafting of the FSR. It is accepted that the definition of the system boundaries, as proposed previously, is not a simplistic exercise as a result of the multiplicity of activities being designed and for which EA was being sought. The SA process would have, in this case, acted as a draft scoping in the approval process and this draft scoping would have identified the individual aspects of the authorisation process that required investigation. The wider ramifications of the impacts would have also been flagged to receive attention and be addressed by mitigation measures. The application of the system based definition for this project would have flagged all the impacts that would have had to receive attention in the assessment.

The second case study considered involved the authorization required for the demolition of a manganese alloy plant within a manganese alloy producing facility. It was noted that this particular plant had a role to play in the overall waste management strategy of the facility but by choosing to restrict the definition of the system to the plant that was proposed to be demolished the proponent actually accentuated the waste management problem within the facility. In this case the application of a system based assessment considering the sustainability aspects would have conceivably resulted in the withholding, or modification, of the authorization given because of the waste issues involved.

The third case study revolved around an authorization for the development and operation of a plant to calcine green coke obtained as a co-product from the Coal-to-Liquid process operated by SASOL in Secunda. It was noted that the structure of the processes of assessment lent themselves to a system based method with very clear delineation being evident between the foreground and background systems. Although the application of the system based method would possibly not have altered the positive authorization obtained, the approach of the system based method would have been potentially more informative and may have allowed better interaction with the IDP.

Table 4.1 gives a summary of the results from the analysis of each case study together with what could be expected to have been the difference that a sustainability assessment would have made to the EIA. It is notable that the application of the sustainability assessment could only have changed the authorization given by the competent authority in one case. The case was the demolishing of the manganese alloy plant where the application of the system based sustainability assessment would have highlighted the destruction of the integrated nature of the operation.

The other definitive case revolved around the calcination plant development in Sasolburg. Although the application of the system based sustainability assessment would probably not change the authorization it would have allowed the application of a comprehensive scenario analysis for dealing with the governance aspects involved.

The case involving the Panfontein Colliery is noted as having an indeterminate result as the assessment was never completed. The application of the system based assessment process would have made a difference because the procedure would have allowed the identification, and inclusion, of sustainability issues that would have arisen remotely from the mining development.

Table 4.1: Summary of results of case study analysis

CASE STUDY	Final Authorization Decision	Would the application of the system based model have changed the authorization decision	What difference would a sustainability assessment have made?
Case 1: Panfontein Colliery	EIA process was not completed.	Indeterminate	Would have noted more potential impacts of the development particularly the long term sustainability issues that should have been included in the original assessment scoping.
Case 2: Alloy plant demolition	Positive	Yes	Increased attention would have been given to the issues surrounding the integration of the activities and the effect of the decision on the long-term aspects of waste storage and handling.
Case 3: Calcination plant	Awaiting but probably positive based on recommendation of EAP	No	The application of the system based model to the entire assessment, i.e. the foreground system and the background system, that included the sourcing of the raw materials, would have allowed attention to be given to the interaction of the process being assessed with the sustainability issues surrounding governance.

This study of the cases has addressed the data gathering aspect of this mini-dissertation and has identified potential deficiencies and aspects that should be addressed in the future.

The following chapter, Chapter 5, consolidates the conclusion of the study together with recommendations for further work.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

The study commenced by noting that sustainable development was a value laden, ambiguous and fuzzy concept that allowed situational interpretations of its meaning. The concept originally had its origins in the realization that the relationship between ecology and the need for development was deteriorating and had to be made less adverse to ensure the continued progressive relationship between society and the universe. The result of this realization was the definition of 'needs' of society versus the 'limitations' arising from the capacity of the environment to satisfy those needs being in conflict with one another. It was from this realization that the requirement for the assessment of sustainability came to the fore. The assessment of sustainability fitted in with the procedure of Environmental Assessment.

Environmental Assessment is a process that is underpinned by various procedures to assess the influence of developmental activities on the environment by considering impacts arising from those developmental activities. All the available procedures, such as SEA and EIA and the associated assessment toolboxes together with the environmental management processes such as EMPs, ISO standards and various industrial initiatives, have their own functions within the procedure of caring for the environment. The problem arises with the efficient addressing of sustainability within the ambits off these processes.

This mini-dissertation had the overall aim of determining whether a sustainability assessment would make a difference to the assessment outcome from EIAs by undertaking a system based process with a holistic application of accepted engineering procedures to the assessment process. The holistic application was seen to be a combination of pure (natural) scientific principles and the application of these principles. The function of applying these principles is the one of engineering.

5.2 RESEARCH PROCEDURE

The research was undertaken to answer the research question by starting with a literature study addressing the aspects surrounding the assessment of sustainability. The debate within the literature and the discussion around the aspects of importance in the sustainability assessment was addressed in Chapter 2 of this mini-dissertation. The results of the debate directed the provision of a system based model in Chapter 3 which would make the

assessment of sustainability within the process followed by EIA possible. The application of this model was tested by considering three case studies in Chapter 4.

The research question was posed as

Environmental Impact Assessment

in South Africa

- what difference can a sustainability assessment make?

Although the assessment of sustainability is a requirement of the legislation governing the use of EIA, the assessment of sustainability is made difficult by the diverse nature of the sustainability requirements in respect of economic, social and ecological factors.

By considering sustainability in terms of the 'pillar' model, where the three issues noted are considered to be separate foundational aspects of sustainability, the issue of trade-offs arises inevitably making the assessment of sustainability process one of 'bargaining'. The 'pillar' model of sustainability has been replaced by a 'system based' model where the ecological system contains the economic and social aspects as nested systems and all is underpinned by a foundation of corporate governance. This is the foundation of the model presented in Chapter 3 of this study.

The final answer to the question was to be attained by fulfilling the objectives of the study. The objectives were

1. To debate the concept of sustainability assessment by giving consideration to the literature aspects of the sustainability issues.
2. Propose a system based model that could be used in applying a practical starting point to include the aspect of sustainability assessment in the assessment of the environment.
3. Decide whether the application of the system based model as given would have resulted in a different authorisation decision for the case studies presented.

The degree to which each of these objectives has been achieved will now be discussed.

5.2.1 Objective 1: Literature debate of the concept of sustainability assessment

This objective was addressed by Chapter 2 of this mini-dissertation. Detailed consideration was given to the literature addressing the issues of environmental assessment, sustainability, sustainable development and sustainability assessment. Attention was also

given to the EIA aspect and where in the EIA process the sustainability assessment should take place. The monitoring of sustainability related progress was also addressed as well as the issues surrounding trade-offs.

The following points itemize the relevant outcomes of the literature study.

- The assessment of sustainability is an indispensable aspect of the environmental authorization process;
- The assessment of sustainability falls within the requirements of EIA as the only legally mandated environmental assessment process in South Africa;
- SEA is driven by the concept of sustainability even though it is not legally mandated but it may be required as a result of other legally mandated processes;
- That EIA is but one of the tools in the Integrated Environmental Management (“IEM”) toolbox and that sustainability assessment guarantees the application of the IEM principles;
- That sustainability assessment is an inherent part of the EIA-driven integrated assessment process;
- Rationality is not always a foundational aspect of decision making as a result of the EIA process but that scientific rationality in the EIA process is assumed;
- That sustainability assessment has an important role in ensuring rationality of the aspects considered in the EIA;
- That the inclusion of the sustainability assessment requirements in the EIA scoping process will ensure comprehensive attention to all impacts be they ecological, social or economic;
- Integration and rationality can be enforced by the use of a system based approach to sustainability assessment;
- That science has a definite role to play in the assessment process;
- That there is still a considerable amount of debate regarding the methods to be used in assessing the sustainability considerations;
- That the geocybernetic method of sustainability assessment has been developed with a system based procedure in mind; and
- That there is a portion of the literature fraternity that advocates the system based assessment process.

The result of the literature study is that there is a definite role for sustainability assessment to play in the environmental authorisation process and that there is a need for the application of engineering science in the assessment methodology.

5.2.2 Objective 2: Proposal of a system based model

The achievement of this objective is contained in Chapter 3 where the methodology of defining a system based model is given. A need in the sustainability assessment process is to make the decision making process of EIA rational and increase the strategic reach of the assessment process by considering the spatial and temporal dimensions of sustainability. The method used for sustainability assessment should not create tension between the three foundational aspects of sustainability but it should create a regime of cooperation. It was evident by consideration of the literature that the geocybernetic model was the most suitable as it is system based and it can be diagrammatically represented in two dimensions, viz. i) a societal development dimension, and ii) an ecological condition dimension. The sustainability requirement of meeting 'needs' while considering 'limitations' fits in well with the two-dimensional geocybernetic model.

The devolution of the geocybernetic model to five sustainability paradigms was noted and it was shown that the model addresses all the paradigms. The geocybernetic sustainability paths, which are described mathematically in a system based context, are based on i) societal development, and ii) environmental condition.

The model proposed in Chapter 3 of this mini-dissertation consists of a foreground system encompassed by a background system that considers the extended, both spatial and temporal, impacts present in the assessment under consideration. The foreground system is more focused in the sense that it describes the impacts of the immediate development. The background system is used to delineate the impacts that are remote from the development being assessed but that still result from the development.

The five paradigms of the geocybernetic model were shown to be covered in their entirety by the system based model consisting of a foreground and a background system. It was also noted that the detail considered by the system based model could be increased by delineating the foreground and background system into interacting sub-systems.

In respect of the delineation of the foreground and background systems, it was noted that the foreground system would often be the direct development. This implies that there would be very little change from the scope of the EIA as it is presently considered. The most significant change would be related to including the sustainability related impacts in the background system. The implication is that the scoping of the Environmental Assessment, as it is presently undertaken for the EIA, will become more extensive.

5.2.3 Objective 3: Decide whether the authorisation decisions would have differed

This objective has been addressed by Chapter 4 of this mini-dissertation where consideration was given to three diverse case studies. Each case study was addressed in order to illustrate differing aspects of the process of system based sustainability assessment. There was, however, a potential deviation identified with the case studies and it involves the collection of data for the assessment being considered. It was noted that for sustainability assessment there is a need for sustainability related data to populate the model proposed. If the data type required is not identified beforehand, as is the case with the case studies here, there will be focus on the incorrect, or irrelevant, data.

The first case study involved the application for a mining right for a coal mine near the town of Vereeniging on the northern bank of the Vaal River. The original motivation for the mine was an economic one based on the requirement of additional coal to operate the Lethabo coal-fired power station up to the year 2050. This motivation was flawed in that the New Vaal Colliery, the current coal supplier to Lethabo power station, was in the process of applying for environmental authorisation to allow the extension of the mining activity at New Vaal Colliery so as to be able to supply coal to Lethabo power station up to the year 2050. The coal mine, if authorized, would have had a detrimental influence on the societal aspects surrounding the security of supply of potable water and the quality of water in the Vaal River downstream of the mining site. Although the process of application for the mining right was terminated prior to the EIA scoping process being completed, it was clear that by undertaking a system based sustainability assessment during the scoping process the society related issues that would have to have been included in the environmental assessment. The execution, and so the quality, of the scoping activity would have improved by the execution of the system based assessment process. It is not known whether the application of sustainability assessment ("SA") would have resulted in a different environmental authorization as the EIA never reached the decision stage. The system based model of the development did, however, provide a coherent view of the effect of the proposed development and thus what impacts had to be assessed in order that a comprehensive study of the impacts be forthcoming.

The second case study involved the evaluation the positive authorisation given for the demolishing of a metallurgical plant within an integrated manganese alloy production operation. It was shown that by applying the system based model structure to the evaluation highlighted the interaction between the various unit processes within the integrated operation. By demolishing the one plant, an imbalance in terms of the waste recycling potential within the integrated operation was created. The use of the system based model highlighted the interaction between the unit processes within the integrated operation

thereby accentuating the break down in the waste recycling process if the one plant was demolished without it being replaced by an alternative to address the accumulation of waste.

In this particular case this all-encompassing view of the integrated operation provided by the utilization of the system based model would have conceivably resulted in an amended authorization. The change in the authorization would have resulted from the improved decision making as a result of the CA being presented with information that would reflect the holistic view of the impact.

The third case study that was considered was based on the positive environmental recommendation given by the EAP for the construction and operation of a calcination plant in Sasolburg. This case study was originally included to illustrate the possibility of altering the scope of the delineation of the systems so as to evaluate different levels of interaction of the development with the environment in which it is to operate. It was shown that it is possible to, within the delineation of the foreground and background systems, integrate other legally mandated structures within the assessment process. This will definitely have the effect of making the EIA process inclusive in the governance structure of South Africa.

5.3 CONCLUSION OF THIS STUDY

On the basis of the discussion in section 5.2 it can be said that the objective of the mini-dissertation has been achieved. An answer of a sustainability assessment based on the application of a system based model and applicable engineering science will make a difference to EIA in South Africa by i) ensuring that the sustainability principles are addressed in the EIA process, and ii) that a holistic interpretation of a development assessed by an EIA is taken.

It is accepted that the application of the system based method may result in an increase in workload during the scoping activity so it may not be either applicable or fully value-adding in all developments of differing extent. This is a decision that would have to be taken by the EAP prior to commencing the assessment. It has been noted that the sustainability assessment should form part of the scoping exercise of the EIA. Where there is no formal separate scoping report in the environmental assessment (as in a Basic Assessment process) the EAP should be responsible to ensure the completion of the sustainability assessment in a complete and logical manner.

The applicability and desirability of undertaking a system based sustainability assessment of a development is a subject that should be discussed and finalized by the EAP with the proponent before the commencement of the Environmental Assessment process. The decision must be taken from a basis that the SA must be undertaken in the assessment. The

decision should then be extended by answering the question 'must the SA be system based or not'. There should be a very strong motivation for not undertaking a system based SA.

In terms of the literature debate, the detail of the model proposed, and the limited case study analysis, it can be said that the inclusion of a sustainability assessment in the EIA process will influence the decision making emanating from the assessment. The application of a system based model will emphasize the synergies that are required to ensure compatibility of the sustainability assessment with the EIA process.

5.4 RECOMMENDATIONS

The following recommendations for further work in this regard are made:

1. That the detailed aspects to be included in a sustainability assessment be published in the form of 'good practice guidelines' and that system based SA be included as an IEM tool;
2. That a similar analysis (as was followed in this mini-dissertation) be undertaken using a wider set of completed EIAs, with applicable sustainability data, where authorizations have been forthcoming; and
3. Investigate other methods of sustainability assessment and their link with the EIA.

Fulfillment of these recommendations should go a long way in entrenching the sustainability assessment process in the EIA in South Africa.

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