On Teaching Sustainable Development at Universities –

Drawing from the Systems Thinking Approach

E. Alaphia Wright
Former Director, UNESCO Liaison Office to African Union and UNECA
alawright@gmail.com
+260 972672833
79 Chibwe Crescent, Kansenshi, Ndola, Zambia

ABSTRACT

There is increased awareness among leaders, in both the public and private sectors, that a major reason for poor performance of entities is primarily the weak consideration of the interrelationships between the various components making up given entities. The entities include projects, enterprises, institutions, organizations, and even nation states. The weaknesses stem from inadequate attention given to the systemic nature of entities. These weaknesses often lead to policy incoherence, contradictory or negating actions and the consequent poor achievement of results. Hence the urgent need for a more holistic, dynamic and integrated thinking, covering the 'whole', in addition to the 'parts'. This is systems thinking - developed from the growing awareness that our systemic world could be better understood and managed with a more systemic thinking.

It is impossible to imagine achieving the sustainable development goals without successfully accommodating the interrelationships between the goals and the processes needed to achieve them. It makes sense, therefore, for every university graduate to have studied at least a course module in systems thinking. Such a module should assist students in developing adequate systems thinking competencies for use in their various disciplines. Close to two decades ago a compulsory course module: *Systems Thinking and Problem Analysis,* was introduced for all students in the Southern African WaterNet Collaborative M.Sc. course in *Integrated Water Resources Management (IWRM)*. This course is still offered in several universities in Southern Africa. Overall, the module in systems thinking helps graduates to successfully contribute their knowledge and skills from various disciplines (= parts) to addressing issues in the entities (= the whole) in which they are engaged.

The systems thinking body of knowledge is the cornerstone of a methodology that has since been applied to the design, planning, implementation, monitoring and evaluation of development in general, in addition to IWRM. In particular, the methodology has been applied to job creation and tracking the delivery of the SDGs at various societal levels. This paper highlights the relevance of systems thinking in addressing the multi-disciplinary (and systemic) nature of sustainable development. It illustrates how the methodology has been used to improve understanding of the interdisciplinary requirements for the achievements of the SDGs from the viewpoint of an African state. An important aspect of the methodology is that it helps graduates appreciate that the ultimate goal of their professional endeavors is that of achieving sustainable development. It also helps sharpen their problem solving and innovation skills.

INTRODUCTION – SOME BACKGROUND

This paper is yet another 'output' based on research and development work which started in the early 1980's with a fascination with Operations Research (OR), modelling, optimization, simulation and *Systems Thinking*[1]. Brief historical aspects of the R&D work highlighting the migration from the mining industry to development projects and programmes were flagged in 2019[2]. Several useful tools, techniques and procedures have been developed from the work, covering strategic planning, implementation, and monitoring and evaluation. A major finding/confirmation from the work was that 'development initiatives' are primarily systemic in nature. Hence the requirement for the use of a more holistic, dynamic and integrated thinking for achieving results. Of necessity the thinking has to cover the 'whole', in addition to the 'parts'. This is systems thinking.

The foregoing realization was instrumental for the introduction of a compulsory course module: *Systems Thinking and Problem Analysis,* for all students in the Southern African WaterNet Collaborative M.Sc. course in *Integrated Water Resources Management (IWRM)*[3]. This was close to two decades ago. This course is still offered in several universities in Southern Africa.

An evident research question emanating from the various projects, programmes, and indeed from the IWRM case, was: can systems thinking be applied to national development? The answer is yes, and this paper illustrates how it has been done. The presentation is in three parts. The first part briefly reports on the positioning of systems thinking in the *IWRM* course. It highlights how the module contributes to the 'integration' of the various disciplines in tackling water issues. The second part answers the question raised above. It shows how systems thinking has been used to model 'national development' of a synthesized African State – Africania. Part 3 highlights the links of development in Africania to sustainable development.

PART 1: POSITIONING SYSTEMS THINKING IN IWRM

Systems thinking was included in the module: Principles of Integrated Water Resources Management (*IWRM* 0.1). The structure of the course is shown in **Box-1**. The module consisted of the following:

- Define IWRM, its basic principles, and the key concepts associated with it,
- Define the water concepts relevant to, and consistent with IWRM (based on the hydrological cycle),
- Put IWRM into context
    - In space (global, continental, regional, basin, watershed),
    - In time (historical developments leading to IWRM),
    - By sector (see next point),
- Overview of water demand per sector (domestic water, water for agricultural production, virtual water),
- Introduction to systems thinking and problem analysis; problem tree of a case study, and
- Role play.

[1] Senge, P. M., *The Fifth Discipline: The Art and Practice of the Learning Organization*, London: Random House Business Books, 1990.

[2] Wright, E.A., *Tracking the SDGs at Whole-of-Society Levels: A Systems Thinking Approach*, ICSD 2019, New York: Columbia University, 2019.

[3] Wright, E. A., Savenije, H. G., van der Zaag, P., *The Development of a Collaborative Master Degree Programme in Integrated Water resources management in Southern and Eastern Africa*, International Conference on Engineering Education, Oslo: 2001, 7D7-13 to 7D7-18.

PREPARATORY MODULE

00: English for Water Managers

CORE

01: Principles of IWRM
02: Principles of Hydrology
03: Socio-Econ. Of Water and Environmental Resources
04: Principles of Agricultural Eng. and Environmental Management
05: Policies, Laws and Institutions
06: Project

SPECIALIZED PROGRAMMES

A: Water Resources Management
B: Water and Environment
C: Hydrology
D: Water and Land
E: Water for People

ELECTIVES

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Box 1: Structure of M.Sc. in IWRM

Elements of systems thinking covered include the following:

- Definition of systems,
- Examples of systems,
- Some historical aspects of systems
- Systems terminologies
- Basic systems models
- The concept of systems-ware
- The performance of systems
- Systems, strategic planning and policy development.

Each of the above are richly illustrated with examples from the water sector and its interrelationships with other sectors/disciplines. Apart from lectures, readings, exercises, discussions, and laboratory sessions, students actively participated in 'role plays' and simulation sessions. Initially, students were not very enthusiastic about subjects/sectors that were not their 'specialization'. This low enthusiasm however speedily developed into an appreciation that the success of their specializations depends also on the successful contributions from other relevant professionals/specialists. This is a vivid application of the Principles of Systems Performance[4]. Overall, the module in systems thinking helps graduates to successfully contribute their knowledge and skills from various disciplines (= parts) to addressing issues in the entities (= the whole) in which they are engaged.

[4] Wright, E.A., *The Rule-of-3 in Results-Based Performance Management – A Systems Thinking Approach*, Wandsbeck: Reach Publishers, 2015.

PART 2: APPLYING SYSTEMS THINKING TO DEVELOMENT

For the sake of completeness and convenience, we start by introducing some elements of systems thinking instrumental in this part of the work. These are the principles of systems performance, and two basic systems models - the systems-ware model and the input-output model.

The Principles of Systems Performance

The systems thinking approach is underpinned by the *Principles of Systems Performance*. There are three principles of systems performance covering the whole system, the 'best' member[5], and the 'worst' member, namely:

Principle #1: 'Optimum' performance of a system depends on ALL its members (components and linkages) functioning satisfactorily.

Principle #2: 'Optimum' performance of a system DOES NOT depend on the performance of the BEST member ALONE, but (as noted above) on ALL the members functioning satisfactorily.

Principle #3: However, 'Sub-Optimum' performance can be caused by poor performance of just one member in the system.

The Systems-Ware Model

Every issue, aspect or element dealt with on earth will belong to one or more of ONLY three types of 'wares', namely:

- Hardware, and/or
- Software, and/or
- Human-ware.

Hardware covers plant and machinery, equipment such as computers, tools, infrastructure, etc. In short, hardware covers all physical items, excluding humans, but including animals, or what in primary school was introduced as matter. A prime characteristic of hardware in addition to being matter is that it gets used up with the passage of time.

Software covers aspects such as policies, rules, regulations, procedures, and of course, computer programmes. This author is fond of using the expression: 'the rules of engagement' when referring to software. The concept of money as a medium of exchange or store of value is clearly software. Further, such concepts as costs, profit and loss, and time are also clearly software. However, hard cash in currency notes and coins are hardware. Time is a special software in that it is the reference for occurrences. We are all consciously or unconsciously aware of whether given occurrences are early, timely, or late.

Human-ware refers to all relevant aspects of the human being in relation to the hardware and software in given situations. Hence, under human-ware, we consider such aspects as competence, knowledge, skills, attitudes, culture, political affiliation, motivation, values, etc.
Evidently, systems-ware are to work together for given systems to function satisfactorily. And, what is of utmost importance, is that all three systems-ware are always present in given

[5] Member = component or part…

entities. A major requirement then in systems work is that of identifying the systems-ware involved in given cases. Thereafter, the interaction (existing or desirable) between these should then be examined and specified in the context of systems design, systems control, systems analysis, and systems environmental impact.

The Input-Output Systems Model

Inputs and outputs form the fundamental basis for the functioning of systems, and it is not surprising that an important basic systems model is the input-output systems model. It is a generic construct that brings together inputs, processes (activities), outputs, and the environment within which the system exists. This is illustrated in **Figure 1**.

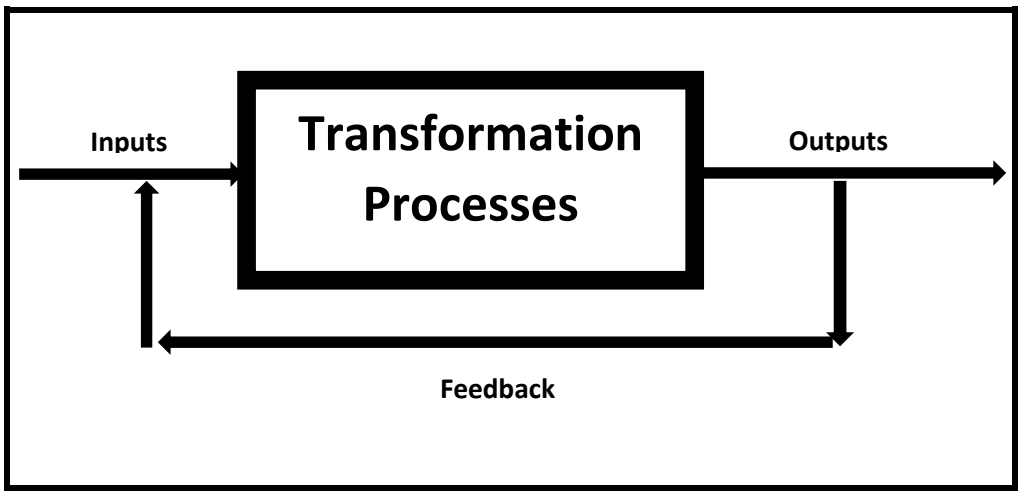

Figure 1: The Input-Output Basic Systems Model

Systems as whole entities are associated with analysis, design, control, and environmental impact. The interplay between inputs, transformation, outputs, and the external environment of a given system is, as would be expected, dynamic. At the systemic level the functioning of every entity – project, programme, organization, enterprise, and even nation states are made up of a series of 'transactions' involving 'givers' and 'receivers'. The input-output basic systems model represents the said transactions perfectly. It is fundamental to systems thinking as the computer bit is fundamental to Information Technology (IT).

Development in an African Country

An ever-present question with the R&D work then was: how does all these fit in with development of an African country? With usually two or three projects over the years in each of some twenty African countries, the country specific data were inadequate to correctly model development of any country. The decision was then taken to use ALL the data to model a 'Synthesized African Country – Africania'. The systems thinking elements used included the input-output basic systems model and the systems-ware model. These were used to develop the Results Based Management Logical ScoreCard (RBM-LSC)©. The tool uses results-chain elements of inputs to activities to outputs to mission and to vision. This depicts the theory of change/intervention logic of projects, programmes, and institutions on just one page.

Fundamentally, how would the intervention logic for development in Africania look? What is the vision? What is the mission? What are the outputs/deliverables? What are the activities/processes? And, what are the inputs/resources? From around the year 2001, it was becoming clearer that the intervention logic/performance profiles for national development has to be relatively 'stable' as the challenges of development in Africa were revolving around basic

needs of food, shelter, health care, employment, etc. The derivation of the RBM-LSC© from first principles is given in several publications [6],[7],[8].

After numerous iterations, the 'vision' of development was formulated as: *Africanians enjoying dignity, peace, and prosperity*. This was arrived at from basically from two different angles. The first was that almost all African States with a 'Vision-20-Something' had captured their visions to include 'peace and prosperity'. The second was that from the systems-ware concept found in systems thinking, one would have expected a third element in the vision. However, the visions of African states usually have two - prosperity (hardware) and peace (software) as noted. A third, 'Dignity' (human-ware) was thus introduced into the vision of Africania. Interestingly, the three belong together. We cannot have one without the others (systems!).

A fundamental question was: what should Africanians be doing to be able to enjoy dignity, peace and prosperity – the vision? Intuitively, the search was for the necessary three elements from 'systems-ware' that would constitute the areas of engagement. Understandably, traditional development areas such as poverty eradication, access to clean water, good health care services, and quality education were extensively examined with respect to their systemic characteristics. Finally, seven areas (not three), the so-called 7Ms, were selected. The 7Ms define areas of value-added human engagement necessary for achieving dignity peace and prosperity. These are systemic in nature. The 7Ms are nothing but measures for the 'Mission' of development in Africania, which is given as:

> "*Africanians are responsibly engaged (acting with integrity) economically, socially (politically) and environmentally at personal/household; regional (village, town, province); national and international levels*".

The 7Ms are:

- Disposable income/ Gainful employment (**s/w**),
- Good health (**hu/w**),
- Food security (**h/w**),
- Use of intellect (**hu/w**),
- Viable enterprises (**h/w, s/w, hu/w**),
- Sustainable use of natural and built environment (**h/w, s/w, hu/w**), and
- Governance / Management with integrity (**hu/w, s/w**).

Well-known challenges such as poverty, shortage of energy, poor quality education, inequality between the sexes, etc. are not listed in this set as they are invariably sub-sets (sub-systems) of the above seven. Also, the 7Ms are interconnected and interacting with each other (systems!). For instance, good health depends not only on good health care services, but also on nutritious food, etc. These seven measures are necessary for achieving dignity, peace and prosperity. The (RBM-LSC)© for 'Development in Africania' is shown in **Table 1**.

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[6] Wright, E. A. & Wright, B.S., *Results based management: a systems framework*. In Hussein, J. (ed.), Proceedings of the 14th Southern Africa regional Review and Planning Workshop, SADC/ICRAF Agro-forestry Regional Programme. Harare: 2001. 194-199.

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The RBM Logical ScoreCard©: Development in Africania		
	Results-Chains	**Performance Indicators / Verification**
#	***Impacts (=Vision)***	**From Year…..**
5	Africanians are enjoying **dignity**, **peace** and **prosperity**.	Africanians enjoying **dignity**, **peace** and **prosperity** increased by at least 10% p.a.
	Outcomes (= Mission)	**From Year…**
4	Africanians are responsibly engaged (acting with integrity) economically, socially (politically) and environmentally at personal / household; regional (village, town, province); national and international levels.	Africanians benefiting increased by 10% p.a. **M1:** Gainful employment. **M2:** Good health. **M3:** Food security. **M4:** Utilising intellect. M**5:** Viable enterprises. **M6:** Use of natural/built environment, & **M7:** Governance with integrity.
	Outputs (= Deliverables)	**From Year…**
3	**Out-1**: ***[Hardware]***: Infrastructure for the **Ms**[9] in place and their correct use actively promoted.	**OD1:** Hardware in place increased by at least 10% p.a., say.
	Out-2: ***[Software]***: Enabling laws, regulation, policies, etc. for the **Ms** in place and their correct use actively promoted.	**OD2:** Software in place and considered equitable.
	Out-3: ***[Human-ware]***: Africanians have increased awareness, knowledge & skills in**Ms**.	**OD3:** Africanians with increased awareness knowledge & skills in **Ms** increased by 10% p.a.
	Out-4: ***[Management]***: Africania is efficiently and effectively managed.	**OD4:** Africania managed within budgets and plans.
	Activities (= Processes)	**From Year…**
2	**Act-1**: ***[Hardware]***: Design, plan and build (or facilitate) infrastructures / facilities for the **Ms** and operate and maintain these as necessary.	**PIAt1**: Hardware, etc. used as planned.
	Act-2: ***[Software]***: Review, develop, adopt and operate appropriate policies, rules, and regulations for the **Ms.**	**PIAt2**: Software mobilized and used as planned.
	Act-3: ***[Human-ware]***: Review, design, plan, adopt and operate awareness raising, education and training programmes for the **Ms.**	**PIAt3**: Awareness, education and training programmes undertaken as planned.
	Act-4: ***[Management]***: Undertake planning, HRM, PR, mobilisation of funding, implementation and Monitoring and Evaluation.	**PIAt4**: Management activities undertaken as planned for the Ms.
	Inputs (= Resources)	**From Year…**
1	**In-1**: ***[Hardware]***: Infrastructure, facilities, equipment, etc, provided.	**PIAt1**: Hardware, etc. in place by…
	In-2: ***[Software]***: Funding from national and international sources, …	**PIAt2**: Software mobilized by…
	In-3: ***[Human-ware]***: Appropriate knowledge and skills for the **Ms.**	**PIAt3**: Human-ware mobilized as planned.
	In-4: ***[Management]***: Operational procedures and methods; Laws, policies, etc.	**PIAt4**: Management inputs mobilized as planned.

Table 1: RBM Logical ScoreCard© Development in Africania

[9] **M's**: The **seven** sets of Measures for the Mission / Outcomes of development.

The above realization was a milestone in the R&D work. Dignity is personal wellbeing (human-ware). Peace is inter-personal wellbeing (software). Prosperity is material wellbeing (hardware). Taking the vision to be the highest attainable result in the development results-chain, a test of the Africanian vision has been to search for a result that is higher than dignity, peace and prosperity. None has been found to date. The vision for African development can thus be considered to be dignity, peace and prosperity. Similarly, concerning the mission, the 7Ms cover all the traditional measures (at mission level) met with in practice.

PART 3: LINKING DEVELOPMENT IN AFRICANIA TO SUSTAINABLE DEVELOPMENT

The successful systems modelling of the synthesized African state presented exciting implications. Firstly, the RBM-LSC© on just one page was shown to be valid for entities from single projects up to the nation state. Secondly, the seven M's captured for the outcomes (mission) are a compact presentation of what Africanians mean when they contemplate (sustainable) development. The 'Africania we want' is one in which equitable progress is made in ALL the seven Ms. Failures to progress in some of the Ms will tend to negate gains made in the others (principles of systems performance). The 7Ms are interconnected / interrelated, as Africania is indeed a system.

A fundamental assumption is that the aspirations of the peoples of Africania to enjoy the attainment of the vision of dignity, peace and prosperity has to be the same for the peoples of the world. Agenda 2030 (with the 17 SDGs) provides a functional 'measure' for sustainable development on a worldwide scale. Question: How do the 7Ms relate to the 17 SDGs? A mapping exercise was undertaken to retrofit the 17 SDGs to the 7Ms (**Figure 2**).

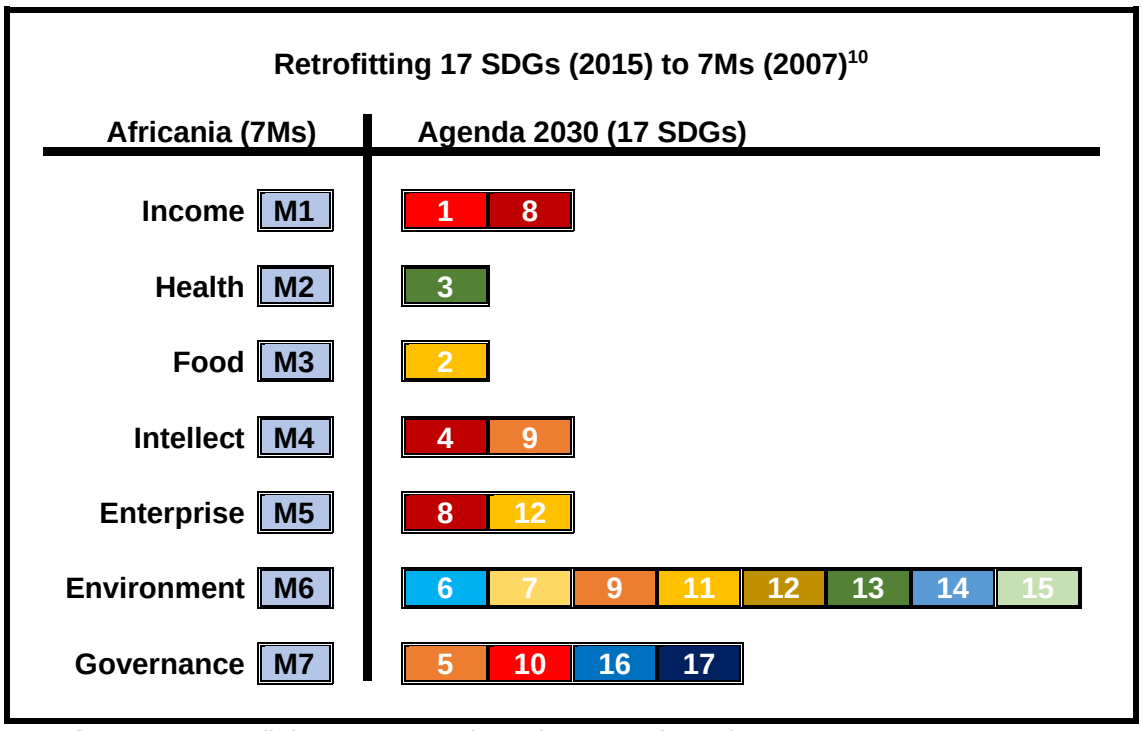

Figure 2: Retrofitting 17 SDGs (2015) to 7Ms (2007)

[10] Wright, E. A., *Geoinformation for Poverty Alleviation*. In: Zeil, P. and Kienberger, S. (Eds) Geoinformation for Development. Heidelberg: Wichmann, 2007.

The alignment shown is spectacular and the implications exciting. Firstly, the 7Ms provide measures for sustainable development 'on the ground'. For instance, these have been used to profile households, primary schools, secondary schools, universities, local authorities, the formal sector, the informal sector, and even the synthesized African State, Africania[11]. The foregoing is in addition to using the methodology in a study on job creation[12]. Secondly, the use of the basic systems models to develop a derived systems model valid for profiling sustainable development contributes to enhanced understanding. This is similar to what was achieved with the *IWRM* course.

DISCUSSIONS – IMPLICATIONS, CONCLUSIONS (AND RECOMMENDATIONS?)

The initial response of students to the systems thinking module of the M.Sc. course in Integrated Water Resources Management (IWRM) was not enthusiastic. This was mainly because they were more interested in their 'specializations'. This low enthusiasm however speedily developed into an appreciation that the various specializations necessary to address water issues in an integrated manner are equally important. This is a vivid application of the *Principles of Systems Performance*. This response, among others, prompted the study on using systems thinking in national development.

Findings from the on-going R&D work have several implications with regards to sustainable development. Firstly, retrofitting the SDGs (of the World) to the 7Ms (of Africania) effectively translated them down to the 'ground level' where the citizen lives his/her day to day life. The 7Ms (and the SDGs) understandably lead to the common vision of dignity (personal wellbeing, a human-ware), peace (interpersonal wellbeing, software) and, prosperity (material wellbeing, hardware). Secondly, what started off as a study of the use of systems thinking for modelling of 'national development' ended up demonstrating that national development can advantageously be considered as 'sustainable development at national level'.

Systems thinking clearly facilitates a better understanding of the of the interconnectedness / interrelations between the various elements characterizing sustainable development. The methodology gives stakeholders the opportunity to appropriately position themselves as 'givers' and 'receivers' in given situations. They thus develop an appreciation for the collaboration necessary for achieving results, including minimizing competition inherent in working in 'silos.

It is impossible to imagine achieving the sustainable development goals without successfully accommodating the interconnectedness/interrelationships between the goals and the processes needed to achieve them. It makes sense, therefore, for every university graduate to have studied at least a module in systems thinking. Such a module should assist students in developing adequate systems thinking competencies for use in/with their various disciplines, as they collaborate for achieving sustainable development.

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