

Journal of Economic and Social Policy

Volume 13

Issue 2 *Desert Knowledge CRC, Sustainable Desert
Settlements Research*

Article 2

1-1-2010

Desert Settlements: Towards Understanding the Mutuality of Influence and Scale-free Network Concepts

Kurt Seemann

Southern Cross University, kurt.seemann@scu.edu.au

Dora Marinova

Curtin University, D.Marinova@curtin.edu.au

Recommended Citation

Seemann, Kurt and Marinova, Dora (2010) "Desert Settlements: Towards Understanding the Mutuality of Influence and Scale-free Network Concepts," *Journal of Economic and Social Policy*: Vol. 13: Iss. 2, Article 2.

Available at: <http://epubs.scu.edu.au/jesp/vol13/iss2/2>

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Desert Settlements: Towards Understanding the Mutuality of Influence and Scale-free Network Concepts

Abstract

While most Australian human settlements are large, densely networked urban systems located on the east-south-eastern seaboard and the coastal footholds of Perth and Adelaide, a particular class of settlements have long maintained occupancy in the interior of the country enduring the arid and semi-arid localities that make up the vast majority of the continent's land mass. How this interior class of settlements is perceived plays a significant role in policy formulation processes, including constructing assumptions about their value. This paper brings together two bodies of literature that influence the understanding of the role of remote desert settlements in Australia, namely the 'mutuality of influence' and "scale-free networks", arguing for the need for policy transformation. The first part introduces the proposition of mutual influence between community, ecology and built system pressures; the second explores how the systemic view of human settlements evolved as a viable framework for modelling cities, and describes the scale-free nature of desert settlements. Policy implications from the two theoretical frameworks include the need for new understanding of the complexities surrounding desert settlements as well as alternative approaches to the ones currently adopted by government.

Keywords

sustainability, Australia, policy

Cover Page Footnote

ACKNOWLEDGMENT: The authors wish to acknowledge the financial support of the Australian Cooperative Research Centre (CRC) Desert Knowledge for supporting the conceptualisation of this research. The views expressed here however do not necessarily represent those of CRC Desert Knowledge or its participants. Sincere thanks to the anonymous referees for their good insights and helpful comments

Introduction

In Australia's arid zone, a total of 365 localities of less than 200 people have been identified (Hugo and Champion, 2003). While much information and patterns of structural similarity exist for settlements across Australia above approximately 3000 people (mostly in more rural, peri-urban or urban economies), the same cannot be said for people living in smaller and widely dispersed desert settlements (Maru, Chewings, Jones, and Breen, 2006). Large desert settlements appear to establish mutual dependencies with their smaller outer and more remote settlements. At the same time, these smaller remote settlements appear to form a network of strong and weak bonds among themselves in their attempts to optimise their own local regional inter-settlement dependencies (Moran, Wright, Renehan, Szava, Beard, and Rich, 2007; Seemann, K, 1997a; Seemann, K, Parnell, McFallan, and Tucker, 2008; Stafford-Smith, Moran, and Seemann, 2008). Accordingly, there remains a dearth of information for effectively conceptualising the sparsely distributed settlements in the interior of Australia, to which we refer as desert settlements.

Background views of settlement and communities

Sustainable settlements are ideally places where people want to live and work, now and in the future. They should meet the diverse needs of current and future residents, be sensitive to their natural environment and contribute to rich cultural expressions. Sustainable settlements should be safe and inclusive, well-planned, built and run, and offer opportunity and amenity for all. However in early June 2006, *The Australian* newspaper reported that the Australian Government's plan to wind back key services could have a devastating impact on small and remote Aboriginal communities whereby the effects of the change may not be fully understood for years after its implementation (Higgins, 2006). The article quoted the Western Australian Minister for Indigenous Affairs who said that responsibility for settlements was being shifted to state governments without recognition of this through additional funding from the Commonwealth. The Minister further noted that very small settlements are not considered sustainable in the long term and that possible closure of these settlements should be discussed with community members. Aboriginal leaders at the time however felt that the debate had already occurred without their involvement. They were also concerned that moving people out of their small communities and into larger centres, could place unsustainable pressures upon existing communities within those larger centres through the influx of people (Higgins, 2006).

In 2010 the future of many Aboriginal communities in Western Australia remains bleak with the State Premier and the Department of Indigenous Affairs considering withdrawing services to remote settlements, such as Oombulgurri in the Kimberley, home to the Balangarra people (Bridges, 2010). The concerns of Aboriginal people for their settlements and the fact that they are not genuinely participating in future planning are echoed all around Australia:

That is what the Government is not doing... they don't come and sit down with us. That is where it is wrong. They should have come and sat down with us and set up a program, set up a big plan ... of what the problem is, they sit down with us and then we can work it out together... (Concerned Australians, 2010, p. 18)

Events such as those reported above have highlighted problems associated with poor communication, consultation and collaboration between Australian government departments and the settlements. Failure to understand the needs of remote Aboriginal communities and the establishment of sub-optimal interventions have introduced 'perverse' incentives with limited potential for capacity building, leading to high levels of welfare dependence, substance abuse and overall social dysfunction (Moran, 2004). In more recent times governments have questioned the viability of remote Aboriginal communities and introduced fears that communities might be cut-off or shut down. If this occurred, research indicates that these problems may continue (Biddle and Hunter, 2005, p. 15) or be exacerbated (The World Today, 2006-June-9). Despite the social and economic problems occurring within some desert communities, people still choose to live there as the settlements offer value to them. Graeme Neate, President of the National Native Title Tribunal, noted in an address to the National Indigenous Council that recognition of a group's connection to the land as the people for that area, provides profound social and psychological benefits to them, irrespective of any potential economic benefits (Neate, 2006).

Human settlements evolve to serve a range of social, economic and ecological functions for the people living within, maintaining a link with, or travelling through them. However, as people have shaped nature by creating built environments and networks, these same built environments and networks also induce localised micro climates (Stabler, Martin, and Brazel, 2004). These micro climates create, amongst their inhabitants, expectations that the environment and socio-economic values (or community assets) will be maintained. A key challenge for the occupying communities of settlements is the degree of timely and informed governance they can exert *locally* over the choice and designs of their built systems. If technologies and systems are chosen wisely to fit in with local ecological, socio-economic, and technical constraints, the demands upon the

community will be manageable and sustainable. When chosen poorly (when choices are based on flawed localised assumptions), such systems directly or indirectly tend to dominate local governance agenda items. For example, agenda items to address rental recovery, managing essential services and maintenance, housing upkeep, skill demands, social and family demands on living arrangements, roads, and traffic management, night lighting, tourism facility maintenance, water supply, sanitation, leisure and communication systems, and so on.

The feedback effect from chosen technologies, and the design and layout of spaces and networks is fundamental to the work of architects, town planners and other technical occupations. However, an emerging difficulty with this feedback view is that the effect of changes to technologies and structures installed into settlements both accumulate in their maintenance demands and often interact systemically with previous installations over time, or even changes in available skills. This process of interaction can generate complex systemic behaviours that affect a community's established social-cultural priorities, as well as their local ecological and technical assets making governing settlement systems more difficult than it may initially appear (Seemann, K, 1997b; Seemann, K, et al., 2008). With human communities, and their local natural and built environments changing in response to each other, a pattern of co-evolution can be hypothesised. This co-evolution thesis between the built and the social systems of the human settlement environment underpins the 'mutuality of influence' concept presented in this paper.

The 'mutuality of influence' thesis for human settlements

In 1943 when Sir Winston Churchill was considering the architectural design of the House of Commons he was concerned that a flawed form may determine the political life of the country. He favoured the rectangular shape that he felt promoted the two-party democracy rather than the 'group system' that was facilitated by a semi-circular chamber. Churchill was thought to have asserted that "we shape our buildings, and afterwards our buildings shape us" (The Churchill Centre and Museum, 2011). In many ways this idea – that our linked up made world, just like our natural and social worlds, transforms our identity in some way, even if done subliminally – underpins the thesis of this paper. The acceptance of the co-evolution effect or 'mutuality of influence' of our choices to transform the natural world into a designed one, is not only evident across archaeological and climate change literature, but indeed is a fundamental aspect to humanity's capacity to innovate and develop its identity (Taylor, 2010). Recent examples also cover the skills we develop to be able to transform the human-made

world (Rushkoff, 2010). This co-evolution relationship extends to scales of human settlement design and choices, as much as it does across cultural, economic and geographic domains.

In the course of the study of human settlements a dialectic can be proposed. On the one hand, we see a view that human settlements are physical structures benign in their influence to shape human community wellbeing and so are seen as inert physical 'shells' subject to absolute subordination to human will. These structures and their means of construction and maintenance play a passive role in the human community. On the other hand, is the view that human settlements, as they grow, link up and develop housing, roads, information and service technologies, begin to pose higher demands upon their human communities and natural environments. For example, higher expectations to manage and administrate their physical and digital assets in order to retain their functional value. The physical structures and systems play an active role in the functionality of, and demands placed upon, the human community using the settlement and its natural surrounds. This latter proposition can be extended to a more complex level. At complex levels the degree of connection and systemic interaction between services, housing and communications is so interdependent that it begins to induce demands of its own accord, of its own rhythms, on human communities as well as the ecology near and far that the settlement relies upon for energy and refurbishment. As a consequence, at some stage the cost to its community to stop or change the support to these systemic demands is perceived as greater than the cost to keep responding to them. In other words, a community may feel inclined to continue the burden of supporting expensive and socially difficult to manage technological systems and design choices, than to plan and divert to a new set of technologies and systems because those new systems require new skills, knowledge and organisation that may seem insurmountable to establish, even if rationally more desirable in the longer term (Archer and Asian Institute of Technology. Urban Land Program., 1994; Barabási, Albert-László, 2003; Cao, Li, Li, and Chen, 2006; Otto, 2009; Seemann, K, et al., 2008). In some respects, the accumulation of built systems and choices can easily entangle the community, where they find it simpler to endure expensive unsustainable environments, than to switch to more innovative technologies, designs and systems that are far better matched to the local constraints of the settlement. Technology choice and transfer presents one set of challenges, but technology switching raises a whole new problem even when a sound rational case is made to switch. The made world has introduced its own systemic maintenance expectations (i.e. demand rhythms) to which many human communities have submitted themselves to endure.

The choice of, or switch to, a technology, based on its design or systemic demands need not be a burden if carefully done to fit into the social-organisation, economic and ecological strengths of the local beneficiary community. This view holds some merit even as a seeding influence on small human settlement governance. For example, the simple act of building a community office can raise the frequency and development of local governance meetings (Sanders, 2009; Sanders, William and Holcombe, 2010). Sanders (2009) observed that the simple provision of an office building raised the frequency and expectations for local groups to hold governance meetings compared to groups that did not have such structures available to them. The technology of an office located in the right context, helped induce a meeting rhythm through the year. Contrariwise, the mutuality of influence may be described in a community development scenario where an upgrade of a dirt road thoroughfare to a basic graded road often leads ontologically to the aspiration for a sealed road followed by a guttered road. Such constructions often raise the need to further manage water run-off or seek advice (at cost) for a more sophisticated system of drains. In this scenario the development of sealed roads may witness a need to enhance council administration and community skills around managing higher vehicle speeds, and maintenance costs of sealed and curbed roads, drains, speed signs, lighting and so on. New technologies can require new demands on governance and alter community lifestyles. How this is managed is one part of the process, but equally, how the technologies were chosen or whether a community finds it easy to switch to an alternative system presents other equally valid problems, which are often overlooked.

Our built environment is rarely benign. We design and create such environments in anticipation that they will provide a new experience and context in our lives. New social and ecological system changes are usually induced as a direct response to the introduction of new technologies in communities (Pacey, 1983; 1999). The position here is not one of technological determinism that suggests communities have little choice in the way technologies affect them. Rather the idea is one of partial determinism based on ontology choice: that is, choosing settlement transformations (technologies and systems) in a direction where they are more compatible with the local socio-economic and ecological constraints of the settlement itself. When technologies are transferred from centrally managed processes into remote settlements, the interpretation of equity tends to be normative and based on sameness of house type and design 'input' rather than their 'outcome' effect as the driving measure of equity for the beneficiary community (Australian Race Discrimination Commissioner, 2001; Federal Race Commissioner: Human Rights and Equal Opportunities Commission, 1994).

In response to the above context of issues, this paper advances the proposition that human settlements are best perceived ontologically as adaptive systems that usually seek to adjust to their local external pressures while simultaneously developing internally induced structures and systems as a response to their internal and external pressures (Australia. Dept. of the Environment Sport and Territories. and State of the Environment Advisory Council (Australia), 1996; Newton, 2006). Accordingly, the ontology of remote desert settlements may not be well accommodated in cases where government policy seeks to constrain local development in line with normative assumptions grounded largely in urban socio-economic, lifestyle, ecological and resource access ideals. Urban centric government policy can prohibit small remote communities from choosing necessary, though locally managed, trade-offs taken on their own informed terms in order to achieve locally sustainable benefits. Where normative government policies do not facilitate localised capabilities and innovations to manage trade-off choices and adapt, then in such situations policy may well be working against the national interest of Australia's vast interior. Further, humble settlements otherwise managing their viability through localised innovations and locally acceptable trade-offs in lifestyles, may be directed towards unviable forms of development under policies that raise expectations to emulate urban based assumptions of access to resources, markets and skills. In situations where remote communities have been long managed by centralised, urban centric policies it may be possible for such communities to present the veil of adequate governance in accordance with urban benchmarks (while being government supported) but which are not in fact sustainable within local conditions. Consequently, choices made that appear to be self-determined, through complying with normative design solutions that emulate urban service and lifestyle patterns, may not be sustainable.

The core policy issue for how remote settlements ought to be enabled appears to be centred on the interpretation of equity of services. The seminal works of both the 'Water Report' (Australian Race Discrimination Commissioner, 1994) and its Review in 2001 (Australian Race Discrimination Commissioner, 2001) are worth noting. The 2001 report recommended to the Australian Race Discrimination Commissioner that,

“Government at all levels actively promote a broader community understanding of equity and equality based on recognition of differences between cultures. Evaluation should be on the basis of equitable outcomes, not similarity of inputs” (Australian Race Discrimination Commissioner, 1994, p.123).

Enabling remote communities to make locally informed choices that at times divert from the higher resource requirements otherwise seen as conventional in urban settings, are policy areas that are likely to enhance the sustainability of many interior human settlements.

Hence a key idea often excluded in the delivery of services and policy for remote human settlements – but which has been consistently posited in the research literature for some time now – is that the created entity we know as the human settlement imposes both overt and subliminal influence upon its human community and natural ecology. This occurs in a mutual relationship where the human community and natural ecology at the same time respond to and influence the summative transformations of the settlement. Human settlements present as complex and self-organising open systems that ontologically seek to adjust to their external and internal pressures, and so must be enabled to innovate locally to achieve sustainability (Newman, Marinova, Armstrong, Marley, McGrath, Raven, and Spring, 2008; Seemann, 1997a; Seemann et al., 2008). While this effect is argued to be most significant as the settlement grows in scale and resource structures, small remote isolated settlements also display emergent feedback effects on any one department of their services or community groups (Otto, 2009; Srinivasa, 2006; Wang, Tseng, Tai, Lai, Wu, Chen, and Li, 2008; White and Kiester, 2008). The historical tendency of policy to ignore the principle of ‘mutuality of influence’ between the whole and the departments of human settlements, was raised as a keystone opportunity for decisive change in grand policy directions in the ‘Housing for Livelihoods’ report of the Desert Knowledge Cooperative Research Centre’s core program “Sustainable Desert Settlements Research” (Seemann et al., 2008).

The emergence of a systemic understanding of human settlements

In order to appreciate the grand policy proposition of ‘mutuality of influence’ for understanding human settlement evolution and traits, it becomes necessary to trace key theoretical developments in settlement theory in the literature as it pertains to a systemic frame of reference. The emergence of general systems theories during the 1940s was in response to a management need to improve the performance of industries in the First World (Angyal, 1971; Warner and Low, 1947). The need was based on an increasing recognition of the limits to scientific reductionist models and methods in industrial organisation and management. While research into physical processes could be controlled in a closed environment, social organisational behaviour and living organisms maintain open access to their environment for them to function. Research into the latter posed difficulties for methods that required experimental controls or that could not

accommodate multi-variable complex interactions. Fundamental theoretical principles describing the logical behaviours of systems were not initially developed for social organisation and industrial development purposes. General systems theory focused on controlled closed systems in physics before open biological systems theory was developed (Bertalanffy, 1950). The utility of systems theory re-emerged with social organisation studies of industries in both First and Third World countries. A new development to systems theory introduced the notion that social and technical factors influenced the overall performance of functions undertaken in social and industrial organisations.

Pioneering research in socio-technical systems by Emery and Trist of the Tavistock Institute of Human Relations, London focused on coal mining in Britain and textile industries in India (Emery and Trist, 1960). They, as well as others, found that the overall performance of functions within industries depended upon successful interaction between social organisation and values, and the choice and design of technologies and spaces in those industries (Emery, 1971; Herbst, 1974; Rice, 1963).

In more recent years technology development and research in social and physical sciences in industrialised countries have recognised the utility of general systemic models (Hetzel, 1990; Hetzel and Frith, 1978). Metaphysical, physical and empirical methods of analysis that attempt to understand overall patterns and behaviours of naturally occurring and human organisational systems are gaining broad acceptance; they are seen to supplement and sometimes replace reductionist methods, models and theories (Barabási, Albert-László, 2003; Capra, 1981; Gleick, 1987). This is demonstrated in literature that emerged during the late 1980s where the science of complexity and network behaviours attempted to understand multi variable systems that are partly or wholly defined by their immediate environment. Gleick wrote:

“To some physicists chaos is a science of process rather than state, of becoming rather than being ... Chaos breaks across the lines of scientific disciplines. Because it is a science of the global nature of systems, it has brought together thinkers from fields that have been widely separated: “Fifteen years ago science was heading for a crisis of increasing specialisation”. [Advocates of chaos] feel that they are turning back a trend in science toward reductionism, the analysis of systems in terms of their constituent parts: quarks, chromosomes, or neurones. They believe that they are looking for the whole” (Gleick, 1987, p. 5).

The need for a holistic or systemic understanding of social and technical factors in development projects emerged with an increasing interest to understand local and

regional patterns of community capacities and potential, particularly in the areas of appropriate educational strategies and patterns of response to introduced technologies (Schumacher, 1999). More recently the utility of socio-technical systems theory was applied to the management and evaluation of projects donated by the West to developing countries (Butler and Mazur, 2007; Cherni and Hill, 2009; Cusworth and Franks, 1993; Ellis-Jones, 1999; Kibreab, 2003; Tao and Wall, 2009).

The advance of systems theory has started to inform the understanding of human settlements, including the modelling of their behaviour. A particular insight is provided by the scale-free network concept, which has some profound policy implications. The remainder of this section addresses the above developments.

Systems theory

While the expression 'systems' has emerged in much of contemporary settlement development and project literature, research into the principles underpinning complex system behaviour only emerged during the latter stages of the 20th century. Key ideas are summarised here as they offer useful constructs to understanding how human settlement systems may be described and modelled. Systems theory seeks to explain the relationship between the whole and its parts. Such theories complement reductionist theories which build knowledge from system parts and their sub-parts in terms of a cause-effect relationship between parts, rather than replace them (Angyal, 1971).

Isolation and controls are usually prerequisites to reductionist or cause-effect research models. Systemic theories, such as 'Gestalt' and the contemporary concept of scale-free networks (Barabasi and Bonabeau, 2003; Barabási, Albert-Laszló, 2002), seek to explain the general behaviour pattern of systems as a whole in the context of defined surroundings. Research into biological systems increasingly included the application of pattern and network analysis models rather than controlled experimental models as extensively used in reductionist theories (Clarke, 1993). The research goal is typically to identify key factors or response patterns that explain how or why a 'self-organising system' behaves in a particular environment or in relation to other 'self-organising' systems in this environment.

The applicability of systems theory in research and development is broad; it is utilised in a variety of disciplines and fields. In natural sciences similar theoretical models include chaos, scale-free network and fractal theory while in education and the social and health sciences, holism and social network theory are utilised.

In psychology, Gestalt theory of human perception and pattern recognition has been extensively documented while in biology and social psychology, systemic models are used to aid explanation of organisms and organisational behaviour (Kast and Rosenzweig, 1979). There are few contemporary fields which remain largely untouched by systems theories, including engineering and the science of human settlements (Doxiadis, 1970; Johns, Munro, Redknapp, and Ricketts, 2001; Madanipour, 2010; Seemann, 1997a).

The broad application of systems theory has led to the development of general systems theory as a model for describing and understanding the behaviour of complex operations and organisation. Complex organisations often incorporate self-organising systems. A characteristic of complex systems is that they display patterns of adaptive behaviour to environmental influences, and without this freedom to self-adapt to local conditions, they tend to fail to thrive. Such systems require conceptualisation not adequately accommodated in traditional reductionist analysis models: complex systems generally interact with their environment (external) to maintain themselves, and to do so they form and/or rely on functional subsystems within their control. Research methods that require controlled environments, such as experimental analysis procedures, are therefore limited in the extent of understanding they yield about self-organising complex systems.

Self-organising systems require constant dynamic interaction with their immediate environment. 'Living' and 'social organisational' systems draw energy and resources from their environment to function and maintain themselves. As a result they produce a product back into their environment as either an amenity or waste (for example, unprocessed value or residual value which at the time is unable to be realised). Such systems generally function within ecological constraints (Newton, 2008; Port Adelaide Enfield (SA) Council, 2007). Systems that draw on, are influenced by, or produce products back into their environment are classed as open systems.

General systems theory principles

Living systems metabolise inputs such as food, energy and water to produce outputs such as movement, heat and so on. The efficiency of this metabolism is a measure of the component of the output amenity and by-product or waste against the system input. Storage however is not usually elaborated in general systems theory and this would affect efficiency formulas. It might be defined as received inputs that await processing; as a processed or transformed input implies the production of an output (Kast and Rosenzweig, 1979). Social organisation and

living systems display development or evolutionary characteristics towards greater differentiation and order.

Closed systems or systems whose internal dynamics are dysfunctional, move towards entropy and disorder or death. The systems principle of entropy appears to hold true for both organic living systems and social systems (Kast and Rosenzweig, 1979, p. 101). This suggests that a growing organisation displays a tendency towards greater internal specialisation seen in the creation of departments, control gates and management levels. In management paradigms the extreme state may become dysfunctional due to excessive internal structuring. Where resource input or internal processing fails, social systems move towards disorder, eventually displaying a complete lack of input transformation, adaptation control and potential for maximum random disorganisation. In this extreme state, management systems may become dysfunctional due to excessive internal disorder (Seemann, 1997b; Seemann et al., 2008).

Open systems have a disposition to adapt internal processes in order to reduce the shock of external pressures. This systemic capacity characteristic of adaptive systems is sometimes referred to as homeostasis where the system maintains a 'dynamic equilibrium through the continuous inflow of materials, energy and information' (Kast and Rosenzweig, 1979, p. 102). The mechanism for reaching the condition of homeostasis is through the adequate functioning of its feedback process to regulate the system (Australian Academy of Science, 1994, p. 14). 'Information concerning the outputs or the process of the system is fed back as an input to the system perhaps leading to changes in the transformation process and/or future outputs' (Kast and Rosenzweig, 1979, p. 102). To extend the analogy to human settlements, it is suggested that if human settlements are not enabled to adapt internal functionality (for example, adapt own governance and goals), as required to accommodate the effects of deviations in external pressures (such as the effect of local and regional climate, seasonal economic pressures and imposed policy and programs), the ability of the settlement to thrive as a whole system may be hypothetically compromised.

Self-organising complex systems are believed to display 'equifinality' characteristics. This concept describes the ability for open adaptive systems to achieve equity of outcomes despite drawing upon a diversity of inputs and transformation processes (note Walker's proposition previously in this paper). Equifinality suggests that particular results may be achieved with a variety of initial conditions and in different ways (Kast and Rosenzweig, 1979). It is a principle that enables different social systems to achieve common outcomes with different inputs or processes to other systems, or to previous inputs and processes

that may have been used. The reverse however may also apply, namely that self-organising complex systems under clearly different external contextual pressures (remote versus urban for example) may in fact be induced into inequity of outcome as a direct consequence to being forced to comply with similarity of input and governance structures.

Modelling human settlements as systems

In 1996, Australia adopted the Organisation for Economic Co-operation and Development's (OECD) 'pressure-state' model for reporting on the state of the Australian environment (Newman, P., Birrell, Holmes, Mathers, Newton, Oakley, Walker, Spessa, and Tait, 1996). This model (see Diagram 1) was selected for the specific purpose of monitoring and reporting on the flow of energy and materials through human settlements. This flow is acted upon by pressures of population and consumption, to produce either a social (noted below as a Health or Human) amenity or as a by-product of waste (sometimes noted as unrealised value (Seemann and Walker, 1991)). An interpretation of the pressure-state model is the notion that human settlements broadly display the characteristics, from the perspective of environmental analysis, of living biological (open) systems. A key feature of open systems is that they display metabolic characteristics in the way value and unrealised value are produced. Metabolism is a sufficiently general concept for reporting purposes, however it is also specifically oriented to biological and ecological concepts. The concept acknowledges a bias in this direction at the expense of more inclusive frameworks that accommodate technological, socio-cultural or economic considerations (Newman et al., 1996, p. 7).

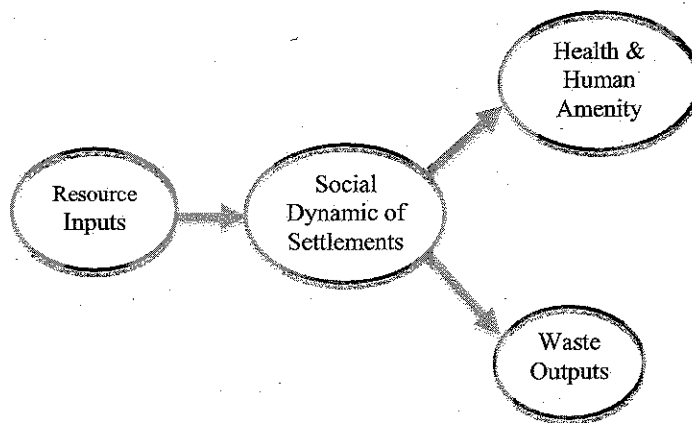


Diagram 1: The metabolism concept of human settlements
Source: (Newman et al., 1996)

A more inclusive model of human settlements was used by Walker (1976) in his ekistic¹ study of a small and remote Indigenous Australian settlement in northern Australia. Diagram 2 shows that the ekistic model incorporates all the essential features of general systems theory: various resource inputs, internal community processes, outputs, feedback information and external controls filtering both future inputs and placing pressures upon internal processes. It was developed at the Athens Centre of Ekistics in 1964 and features inputs that represent the ekistic elements (Walker, 1976, pp. 71-72). The model was developed to assist data collection and classification. In addition to the qualitative analysis of settlements it also provided a basis to explore quantitative measures where appropriate. Another important feature of this model is that it identifies the place of settlement functions within it. Walker observed that 'the inputs basically consist of the ekistic elements with the functions and values of the community acting as the processors' (Walker, 1976, pp. 71-72). Walker's systemic model demonstrates consistency in the hierarchy principles of general systems theory while also opening up the contextual principles of ekistic settlement development theory.

¹ Founded by Doxiadis and Associates during the 1950s, Ekistics is defined as the science of human settlements. See <http://www.ekistics.org/>.

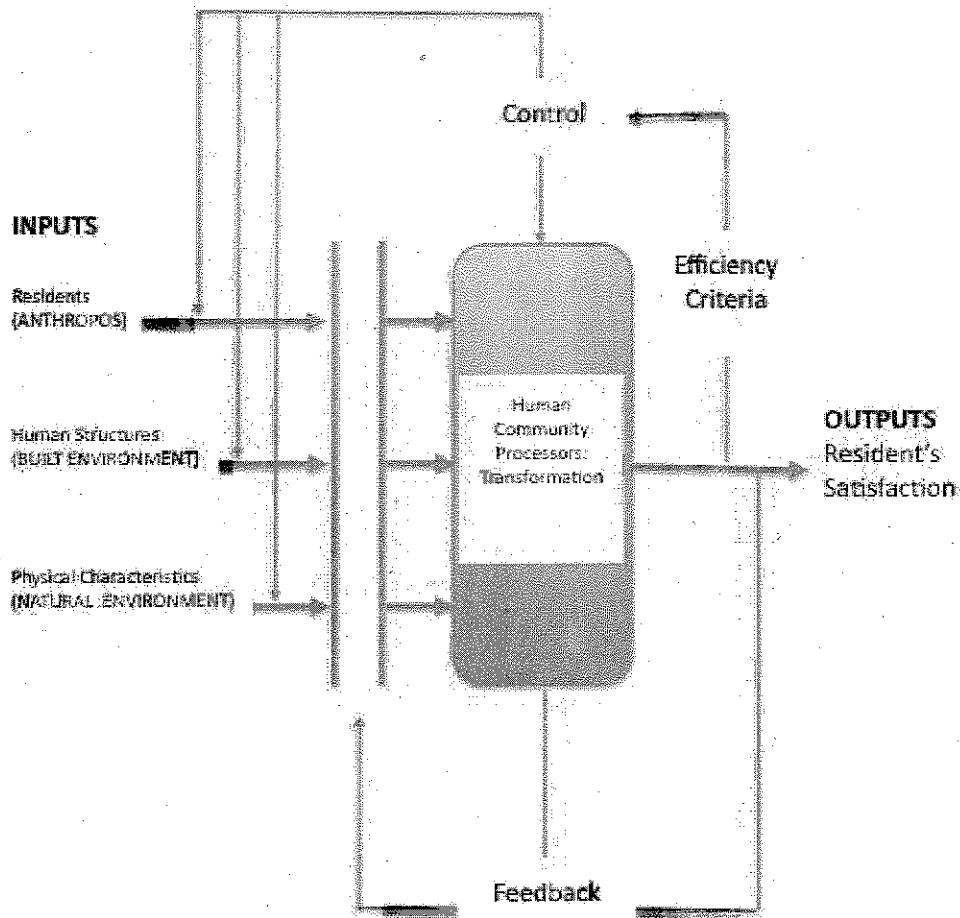


Diagram 2: Walker's systemic model of human settlements showing external supra-system (Controls) that place pressures upon the internal processes of settlements.

Source: (Walker, 1976)

Similar to the ekistic and pressure-state models of settlements, the Department for International Development (1999–2005) developed the Five Capitals or Livelihood Model. Also systemic in design, the Sustainable Livelihoods Model features five key capitals that define both the main classes of inputs and vulnerabilities of settlements. Diagram 3 presents the framework where all viable human settlements process and seek to maximise their key assets of human

capabilities, natural ecological resources, financial wealth, physical and technological assets such as equipment and built facilities, and general social assets such as institutions and governance systems. The idea being these five assets represents both key resilience and vulnerability factors. Accordingly, strong communities grow and maintain these assets well.

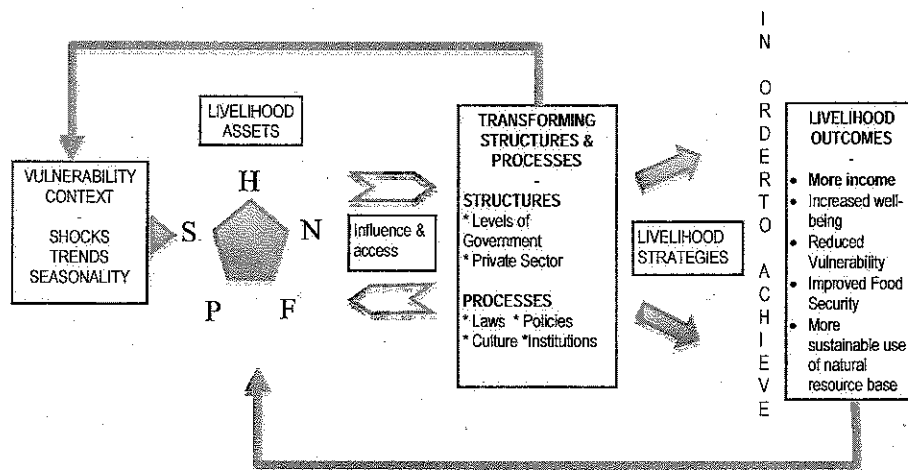


Diagram 3: Sustainable livelihoods model

Source: Department for International Development (1999–2005)

In response to the need for many human settlement projects to act through and monitor more than five aspects of a settlement's functionality, Newman et al. proposed a multi asset model whereby each axis in a 'spider diagram' could be researched and refined to form the basis of a typology analysis of settlement sustainability (Newman et al., 2008). The various axes of the spidergram (see Diagram 4) can also allow communities to monitor their settlement performance.

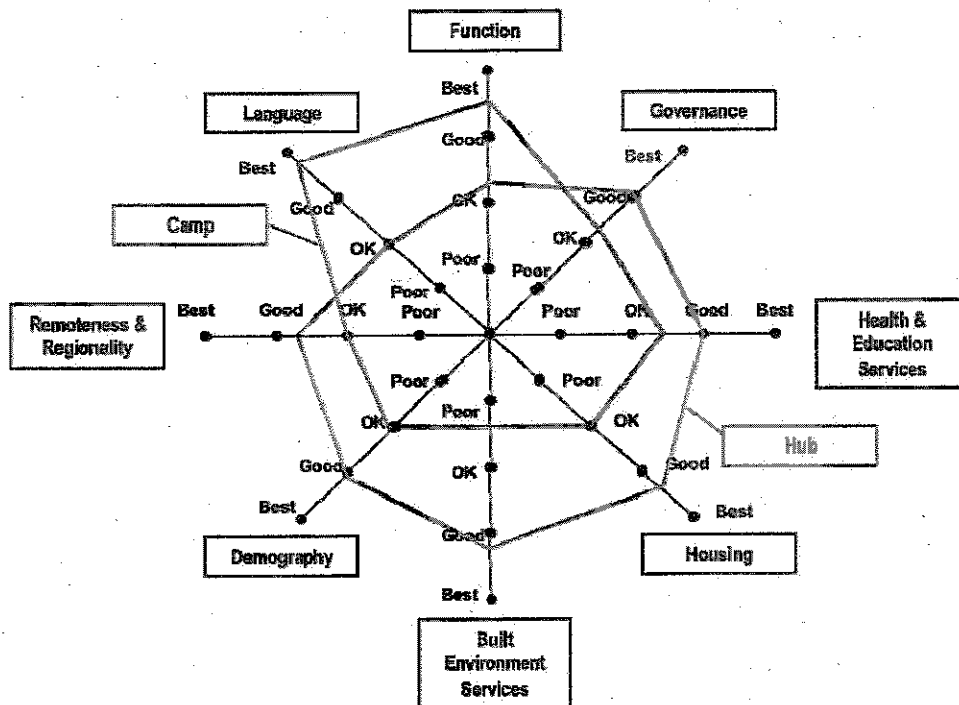


Diagram 4: Sustainability criteria spidergram for Indigenous settlements types

Source: (Newman et al., 2008)

To facilitate strategies of an operational nature within communities, the transformation of resources occurring with settlements have been modelled by Seemann (1997) as sub-systems functioning within the overall human settlement system of concern (Diagram 5). These processes of settlement functions may be described as open socio-technical systems influenced by the general supra-system of their settlement. They are socio-technical in the sense that social organisation and human capital are necessary to transform physical and technical resources into forms of value (such as services or facilities) (Emery and Trist, 1960; Geels, 2005; Herbst, 1974). Contained at a level below settlement functions are basic operations or sub-functions. The ekistic model (Diagram 2) indicates that the input and process of socio-technical systems may include:

- ‘Anthropos’ and societal inputs inclusive of education and social organisation;

- ‘Built Environment’ or shell and network inputs that are inclusive of shelter, tools, technologies and amenities; and
- ‘Natural Environment’ or nature inputs that include ecological assets.

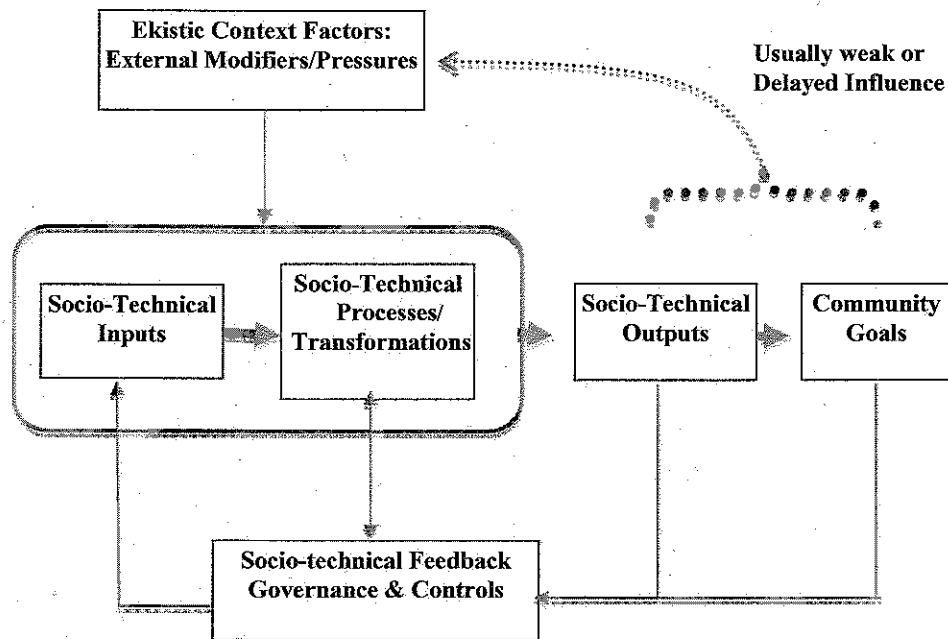


Diagram 5: Model of internal settlement functions: Sub-systems to human settlements.

Source: (Seemann, K, et al., 2008)

The context factors of settlement functions are those consistent with the major axis found in the ekistic framework. They include the influence of settlement population, climatic and geographic location and economic factors. With the above considerations, it is feasible to model settlement functions as socio-technical systems influenced by external factors and incorporating a complex corollary of social, technical and material variables. Seemann (1997, 2008) found that socio-technical systems theory may be used to approximate community functions and that community processes were not driven by their functional purpose of service or product provision alone. They operate ultimately towards implied or aspired goals. Further, while community operations are normally managed or governed with direct controls of future resource use, what they produced also influence indirectly the overall external pressure upon community

life. Materially, the provision of services generated amenity and waste that in turn generated an expectation to manage that accumulation of waste or growth in service aspiration. Equally, community goals may alter as service expectations develop over time. Seemann's model suggests that these outputs tend to have a delayed rather than direct effect upon overall pressure changes to the conduct of internal community functions when compared to the direct effect possible via the internal governance of those functions.

While the above systemic models provide a useful framework for studying settlement functions they remain essentially static in time. These 'snap-shot' interpretations of community functions can be placed against the axis of time as suggested by Doxiades:

"A review of the history of human settlements, is an attempt to present a theory of their evolution, an important factor in the life and study of human settlements ... It is therefore useful to explore the problems related to the time dimension in order to understand the situation better" (Doxiades, 1968, p. 219).

When human settlements are modelled as dynamic systems that change and evolve over time, new intra- and inter- settlement network research challenges manifest themselves. Dynamic adaptive systems rarely act in isolation, and are reliant upon an ongoing exchange with the drivers and resources beyond their immediate social and technical boundaries. The next and final section of this paper critiques the emerging conceptual frame of network analysis for how to improve the way we may understand and develop policy for remote human settlements when viewed as systems linked, and adapting, to other settlements and greater regional drivers.

Scale-free network of human settlements

The 'mutuality of influence' thesis asserts that once human settlements are formed, depending on the built systems chosen and created, they provide a set of both expectations and demands upon their governance as singular, unique entities. This section of the paper examines the networked effect of many settlements across a defined region: the remote interior of Australia. In particular, how the social and resource flow networks between and within settlements also play an active role in setting up both constraints and opportunities for communities in the outback. A specific form of network topology that we will refer to is of the scale-free form. A scale-free network is a network whose degree distribution, or the number of connections from each node/hub, follows a power law (Barabasi and

Bonabeau, 2003; Caldarelli, 2007). Mathematicians represent the power law with an exponential equation and networks as graphs with nodes and links (Seemann and Marinova, 2009). The most important feature of a scale-free network (or any network for that matter) is the connectivity between its nodes. With many links, the network can exhibit fault-tolerant behaviour or robustness, which is a property, that allows it to operate in a reliable way even if there is a (limited or randomly distributed) degree of failure. If a particular node is affected and becomes non-functional, the connectedness within the network can be restored through an alternative path, using a different combination of nodes and links. The World Wide Web is an excellent example of this point.

Networks also provide a powerful abstraction for social interactions, including interactions that are dynamic and evolving. Each node can be thought of as a human settlement which has connections with other settlements through people, resources, structures, the natural environment, economic activities and so on. Settlements are also subject to outside forces which can affect the connectivity between nodes, such as natural disasters, war or military conflicts, quarantine protection, political and commercial restrictions.

A scale-free pattern of connectivity between the nodes of a network has a very different nature to a normal distribution of links (see Diagram 6). It essentially makes certain nodes more highly 'favoured' than others as they have a much larger number of connections. If for some reason such a favoured node is taken out, the network will fall apart and the remaining nodes will become isolated, non-connected islands. On the other hand, if the major hubs are functional, the robustness of the network will be maintained through the links from the remaining nodes.

The robustness of the connectedness provided by the scale-free networks is the key to the social and economic aspects of the sustainability of human settlements (Seemann and Marinova, 2009). The underlying power law lends weight to the view that the linked up system being observed emulates scale-free preferential networks with hierarchical tendencies. This pattern suggests an inherent topology of human settlements, namely a long-tail distribution, where there are very few large settlements (high values of x (large size) and low values of y (few of them)) and many small settlements (low values of x (low size) and high values of y (many of them)).

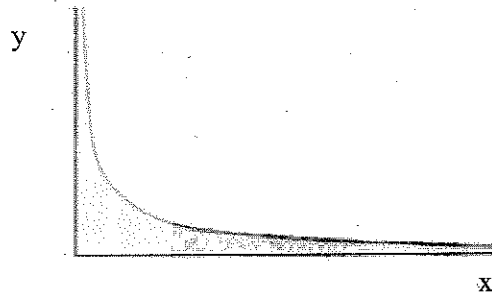


Diagram 6: Power law distribution

x-axis denotes frequency, y-axis denotes the probability of a particular event

Another feature of scale-free networks is that they be constructed “by progressively adding nodes to an existing network and introducing links to existing nodes” (Barabási and Albert, 1999) . This historically explains the emergence of many human settlements through processes, such as breaking up of existing family clans and establishment of new communities.

One of the most interesting properties of the scale-free network form is the connectedness described as ‘small world’, namely that in some networks, nodes may include shortcut links directly to other major hubs via a few degrees of separation. Applied to the level of settlements, the small-world phenomenon alludes to the fact that even the smallest town is easily connected to the big towns or cities. What is important from a sustainability point of view is the nature of these connections. In the majority of the cases they are two-way connections, namely:

- Through such connectedness the small town relies on this extended network of people who do not live there but are loyal to it and constantly connect it to the big world. In other words, the small town is bigger than it looks because of the myriad links it has with other settlements. This translates in information flows, financial remittances, visits by relatives and to familiar places (Guerin and Guerin, 2008).
- The big settlements need the small-world connections for their existence as they justify its big-world importance as a node of multiple links. They provide economic and social services to the small settlements and their resilience is based on the capacity to do so.

In other words, irrespective of their size, settlements need each other for their long-term sustainability. The exchange of services, information, people and finances can only happen if the channels of communication (represented by the

connections between nodes) remain open both ways; that is, if the scale-free network is robust.

The small-world phenomenon defines the nature of social networks of the settlements in desert Australia. These arid zone settlements exist within the context of Australia's settlement system and share many of the broad trends and drivers that affect this country, such as increasing population flows toward capital cities; and the growth and volatility of the resources sector, both challenging environmental conditions (Newman et al., 2008). However, arid zone settlements also exhibit markedly different features that are unique for outback Australia, such as low population density, high Indigenous population, remoteness from markets and high environmental variability. The typology of these remote settlements is rich and well represented by the power curve. Hence, even in dense big cities, small remote towns may have 1-3 degrees of shortcut access to key people in them. Diagram 7 demonstrates the scale-free distribution of hubs to links where typically there are very few large hubs such as hub (a) that attract many people (links) and many more smaller hubs (c,d,f) that attract fewer people people. In such a distribution, pairs of individuals (e,b) often find they link to each other via only one (e-b) to a few links (e-a, a-c, c-b). This topology is critical to how rural and remote communities manage regional flows of information and resources (via road, air or communication networks). The various link options enable better problem-solving possibilities to help manage their resilience and accommodate random events.

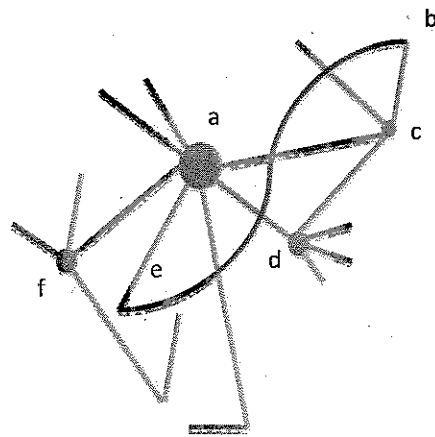


Diagram 7: Schematic of Small-world connectedness with scale-free (typically power law compliant) network topologies: person 'e' can exchange with 'b' via only 1-3 degrees of links.

Policy implications from the ‘mutuality of influence’ and ‘scale-free network’ concepts

The push by the Australian governments to formulate new policies for settlements situated in the interior of the country (or desert settlements) requires reconceptualisation of their importance and role, for current residents as well as for the wider Australian community. With more than two-thirds of Australia’s population living in major cities (Australian Bureau of Statistics, 2008), desert settlements, and particularly the small communities, are viewed as insignificant and in many ways an obstacle to achieving government efficiencies. The situation is further complicated with the terrors of distance and climatic nature of the arid zone.

According to Massey (1994), each place is a product of layer upon layer of different linkages, both local and to the wider world. What we argue in this paper is that these small desert settlements have a dual importance for the wider Australian society. Firstly, they are not subjected to the infrastructure and service pressures, and growth requirements as experienced in the large cities. Secondly, they play a vital role in Australia by supporting larger settlements and providing the network’s robustness and connectivity.

The nature of the small desert settlements however is distinctively different and requires a different approach by government than the “one size fits all” policies based on normal distributions (Seemann and Marinova, 2009). As suggested by equifinality particular results, in this instance provision of services and good quality of life can be achieved with a variety of initial conditions and in different ways. In the context of remote human settlement policy, when such settlements are subjected to urban assumption of equity of inputs to achieve similarity of outcome in services, the results would be devastating.

The insights that this research has so far generated in relation to informing policy can be summarised in the following few points:

- The small desert settlements impose fewer governance demands in terms of services provision which need to be met in an innovative way and in collaboration with their communities;
- The robustness of the scale-free network of Australian settlements is built on their connectivity and the ability to provide alternative links. If this is compromised, the networks will become dysfunctional and transform into

isolated sections with little ability to provide a sound operational environment for the economy as well as for the wider Australian society;

- The small-world phenomenon alludes to the importance of the variety of settlement sizes as they mutually reinforce each other. Any decision-making should acknowledge the existence of a large number of smaller settlements (as described by the power law) which are very different in nature to the relatively small number of large cities;
- Maintaining diversity and connectivity is a step towards predicting, evaluating and diagnosing the social, cultural and economic sustainability of settlements.

A comprehensive understanding of settlements and settlement functions therefore requires an evolutionary analysis based on qualitative interpretation of historical records and recent data. Basing policies entirely on quantitative judgements disregards the systemic nature of settlements. While most research so far has taken the traditional route and focuses on one or a few key settlement measures (such as demography, economy, infrastructure provision, ecological footprint, health or education), such an approach is fast becoming dated as methods for settlement research mature. Systems methods which examine human settlements as complex adaptive systems, including the mutuality of influence and scale-free networks, have generated new concepts and entered a new era, one of understanding complexity and connectedness. These approaches are also capable of delivering predictive, evaluative and diagnostic methods for future implications of policy scenarios. This is a new growth area for settlements research, design and policies evaluation worth wider inclusion and examination.

Acknowledgment: The authors wish to acknowledge the financial support of the Australian Cooperative Research Centre (CRC) Desert Knowledge for supporting the conceptualisation of this research. The views expressed here however do not necessarily represent those of CRC Desert Knowledge or its participants.

Sincere thanks to the anonymous referees for their good insights and helpful comments.

References

- Angyal, A. (1971). A Logic Of Systems (1941). In F Emery (Ed.), *Systems Thinking*. Victoria, Australia: Penguin Books.
- Archer, R. W., & Asian Institute of Technology. Urban Land Program. (1994). *Network infrastructure for sustainable urban development : implementing the formula $L+P+F+NI = SUD$* . Bangkok, Thailand: Human Settlements Development Program, Asian Institute of Technology.
- Australia. Dept. of the Environment Sport and Territories., & State of the Environment Advisory Council (Australia). (1996). *Australia, state of the environment 1996*. Collingwood, Vic.: CSIRO Publishing.
- Australian Academy of Science. (1994). *Environmental Science*. Canberra: Australian Academy of Science.
- Australian Bureau of Statistics. (2008). *Australian Social Trends. Catalogue number 4102.0*. Canberra: Australian Bureau of Statistics.
- Australian Race Discrimination Commissioner. (1994). *Water: a report on the provision of water and sanitation in remote Aboriginal and Torres Strait Islander / Federal Race Discrimination Commissioner*. Canberra: AGPS.
- Australian Race Discrimination Commissioner. (2001). *REVIEW OF THE 1994 WATER REPORT*. Canberra: AGPS.
- Barabási, A. L., & Bonabeau, E. (2003). Scale Free Networks. *Scientific American*(May 2003), pp. 50-59.
- Barabási, A-L, & Albert, R. (1999). Emergence of scaling in random networks. *Science*, 286, pp. 509-512.
- Barabási, Albert-Laszló. (2002). *Linked : the new science of networks*. Cambridge, Mass.: Perseus Pub.
- Barabási, Albert-Laszló. (2003). *Linked : how everything is connected to everything else and what it means for business, science, and everyday life*. New York: Plume.
- Bertalanffy, L. (1950). The Theory Of Open Systems In Physics And Biology. In F Emery (Ed.), (1971) *Systems Thinking* (pp. 70-85). Victoria, Australia: Penguin Books,.
- Biddle, N, & Hunter, B (2005). *Factors Associated with Internal Migration: A comparison between Indigenous and non-Indigenous Australians Working Paper No. 32/2005*. Unpublished manuscript, Canberra.
- Bridges, A. (2010, 15 October). Oombulgurri on Borrowed Time. *The West Australian*. from http://parlinfo.aph.gov.au/parlInfo/search/display/display.w3p;page=1;query=MajorSubjectId_Phrase%3A0089G;rec=2.
- Butler, L. M., & Mazur, R. E. (2007). Principles and processes for enhancing sustainable rural livelihoods: Collaborative learning in Uganda. *International Journal of Sustainable Development and World Ecology*, 14(6), pp. 604-617.
- Caldarelli, G. (2007). *Scale-Free Networks: Complex Webs in Nature and Technology*. Oxford: Oxford University Press.

- Cao, B. H., Li, D. Y., Li, B., & Chen, G. S. (2006). Complex network topology mining and community detection. *Dynamics of Continuous Discrete and Impulsive Systems-Series B-Applications & Algorithms*, 13(3-4), pp. 361-370.
- Capra, F. (1981). *The Turning Point: Science, Society And The Rising Culture*. London: Fontana.
- Cherni, J. A., & Hill, Y. (2009). Energy and policy providing for sustainable rural livelihoods in remote locations - The case of Cuba. *Geoforum*, 40(4), pp. 645-654.
- Clarke, K.R. (1993). Non-Parametric Multivariate Analysis Of Changes In Community Structure. *Australian Journal of Ecology*, 18, pp. 117-143.
- Concerned Australians. (2010). *This Is What We Said: Australian Aboriginal People Give Their Views on the Northern Territory Intervention*. Melbourne, Victoria: Concerned Australians.
- Cusworth, J.W., & Franks, T.R. (1993). *Managing Projects In Developing Countries*. NY: Longman Scientific and Technical.
- Doxiades, Konstantinos Apostolou. (1968). *Ekistics: an introduction to the science of human settlements*. London: Hutchinson.
- Doxiadis, Constantinos A. (1970). Ekistics, the Science of Human Settlements. *Science*, 170(3956), pp. 393-404.
- Ellis-Jones, J. (1999). Poverty, land care, and sustainable livelihoods in hillside and mountain regions. *Mountain Research and Development*, 19(3), pp. 179-190.
- Emery, F (Ed.). (1971). *Systems Thinking*. Melbourne: Penguin Books.
- Emery, F, & Trist, E. (1960). Socio-Technical Systems. In C Churchman & M Verhulst (Eds.), *Management Sciences: Models and Techniques* (Vol. 2, pp. 83-97). NY: Pergamon Press.
- Federal Race Commissioner: Human Rights and Equal Opportunities Commission. (1994). *Water: A Report on the Provision of Water and Sanitation in remote Aboriginal and Torres Strait Islander communities*. Canberra: Australian Government Publishing Service.
- Geels, F. (2005). *Technological transitions and system innovations: a co-evolutionary and socio-technical analysis*. Cheltenham, UK: Edward Elgar Publishing.
- Gleick, J. (1987). *Chaos: Making a New Science*. London: Cardinal.
- Guerin, B, & Guerin, P. (2008). Relationships in remote communities: Implications for living in remote Australia. *The Australian Community Psychologist*, 20(2), pp. 74-86.
- Herbst, P. (1974). *Socio-technical Design*. London: Tavistock Publications.
- Hetzel, B.S. (1990). Communication And Health - Health As An Ecosystem. *The Medical Journal Of Australia*, 153(November 5), pp. 548-551.
- Hetzel, B.S., & Frith, H.J. (1978). *The Nutrition Of Aborigines In Relation To The Ecosystem Of Central Australia*. Melbourne: CSIRO.
- Higgins, E. (2006, 5th June). Cutbacks Threaten Outstations. *The Australian*. from <http://www.aussieexpats.com/forum/index.php?topic=406.msg642 - msg642>.
- Hugo, Graeme, & Champion, A. G. (2003). *New forms of urbanization : beyond the urban-rural dichotomy*. Aldershot, Hants, England ; Burlington, VT: Ashgate.

- Johns, David, Munro, Ian, Redknapp, Aimee, & Ricketts, Sarah. (2001). *Maungarei O Tamaki: A Town within Auckland in 2050*. Paper presented at the World Society for Ekistics Conference 27th October, 2001.
- Kast, F.E. , & Rosenzweig, J.E. (1979). *Organisation And Management: A Systems And Contingency Approach (Third Edition)*. NY: McGraw-Hill Book Company.
- Kibreab, G. (2003). Displacement, host governments' policies, and constraints on the construction of sustainable livelihoods. *International Social Science Journal*, 55(1), pp. 57-67.
- Madanipour, Ali. (2010). The limits of scientific planning: Doxiadis and the Tehran Action Plan. *Planning Perspectives*, 25(4) pp. 485 - 504.
- Maru, Y, Chewings, V, Jones, M, & Breen, J. (2006). *Mapping Socio-regions in Outback Australia*. Alice Springs: CSIRO and Desert Knowledge CRC.
- Moran, Mark. (2004). The Practice of Participatory Planning as Mapoon Aboriginal Settlements: Towards Community Control, Ownership and Autonomy. *Australian Geographic Studies*, 42(3), p. 339-355.
- Moran, Mark, Wright, Alyson, Renehan, Peter, Szava, Anna, Beard, Nerida, & Rich, Elliat. (2007). *The Transformation of Assets for Sustainable Livelihoods in a Remote Aboriginal Settlement: DKCRC Research Report 28*. Alice Springs: Desert Knowledge CRC.
- Neate, Graeme. (2006). Looking in a mirror dimly: Native Title and broader indigenous policy issues Address to the National Indigenous Council. 2006 (28 February).
- Newman, P, Marinova, D, Armstrong, R, Marley, J, McGrath, N, Raven, M, et al. (2008). *Desert Settlement Typology: Preliminary Literature* (No. 9). Alice Springs: Desert Knowledge CRC.
- Newman, P., Birrell, B., Holmes, D., Mathers, C., Newton, P., Oakley, G., et al. (1996). Human Settlements. In State of the Environment Advisory Council (Ed.), *Australia State of the Environment 1996. An independent report presented to the Commonwealth Minister for the Environment* (Vol. 1996). Collingwood: CSIRO.
- Newton, P. (2006). *Human settlements: theme commentary prepared for the 2006 Australian State of the Environment Committee*. Canberra: Department of the Environment and Heritage.
- Newton, P. (2008). *Transitions : pathways towards sustainable urban development in Australia*. Collingwood, Vic.: CSIRO Pub.
- Otto, Friei. (2009). *Occupying and Connecting: Thoughts on territories and Spheres of Influence with Particular Reference to Human Settlements* (Michael Robinson, Trans. 2009 ed.). Stuttgart: Axel Menges.
- Pacey, Arnold. (1983). *The culture of technology*. Oxford, England: B. Blackwell.
- Pacey, Arnold. (1999). *Meaning in technology*. Cambridge, Mass.: MIT Press.
- Port Adelaide Enfield (SA) Council. (2007). State of environment report, June 2007pp. 1 computer optical disc). Available from [http://www.portenf.sa.gov.au/webdata/resources/files/State of Environment 30 Aug07.pdf](http://www.portenf.sa.gov.au/webdata/resources/files/State_of_Environment_30_Aug07.pdf); <http://www.portenf.sa.gov.au/site/page.cfm?u=293>
- Rice, A. (1963). *The Enterprise And Its Environment*. Lond: Tavistock Publications.
- Rushkoff, D. (2010). *Program or Be Programmed: Ten Commands for a Digital Age*: OR Books.

- Sanders, W. (2009). Core Project 4: Sustainable Desert Settlements - Annual Research Workshop Feb 2009. In K. Seemann (Ed.) (Workshop discussion of the role of an Office in seeding and facilitating local meetings in community management. ed.). Adelaide.
- Sanders, William, & Holcombe, Sarah. (2010). The Role of Local Government in Desert Settlement Sustainability. *Journal of Economic and Social Policy, Winter (pre-publication draft)*(Manuscript 1144).
- Schumacher, E.F. (1999). *Small Is Beautiful: Economics As If People Mattered: 25 Years Later...With Commentaries* (2nd ed.). Berkeley: Hartley & Marks.
- Seemann, K. (1997a). *The Socio-Technical Sustainability of Shelter Systems and Hardware in Remote Indigenous Australian Communities*. Unpublished PhD, University of NSW, Sydney.
- Seemann, K. (1997b). *The socio-technical sustainability of shelter systems and hardware in remote indigenous Australian communities*. Unpublished PhD, University of New South Wales, Sydney.
- Seemann, K., & Marinova, D. (2009). *Understanding Connectivity of Settlements: Implications of the Power Curve*. Paper presented at the MODSIM 2009 International Congress on Modelling and Simulation.
- Seemann, K., Parnell, M., McFallan, S., & Tucker, S. (2008). *Housing for livelihoods : the lifecycle of housing and infrastructure through a whole-of-system approach in remote Aboriginal settlements*. Alice Springs, N.T.: Desert Knowledge CRC.
- Seemann, K., & Walker, B. (1991). *Remote controlled waste : an introduction to waste management and appropriate technology in remote Aboriginal communities*. Alice Springs [N.T.]: Centre for Appropriate Technology Inc., Alice Springs College of TAFE.
- Srinivasa, Srinath. (2006). *The power law of information : life in a connected world*. New Delhi ; Thousand Oaks: Response Books, a division of Sage Pub.
- Stabler, L., Martin, C., & Brazel, A. (2004). Microclimates in a desert city were related to land use and vegetation index. *Urban Forestry and Urban Greening*, 3(3-4), pp. 137-147.
- Stafford-Smith, M, Moran, M, & Seemann, K. (2008). The 'viability' and resilience of communities and settlements in desert Australia. *The Rangeland Journal*, 30(1), pp. 123-135.
- Tao, T. C. H., & Wall, G. (2009). Tourism as a sustainable livelihood strategy. *Tourism Management*, 30(1), pp. 90-98.
- Taylor, Timothy. (2010). *The Artificial Ape: How Technology Changed the Course of Human Evolution*: Palgrave Macmillan.
- The Churchill Centre and Museum. (2011). Famous Quotations and Stories at the Churchill War Rooms, London. Retrieved 16 February, 2011, from <http://www.winstonchurchill.org/learn/speeches/quotations>
- The World Today (Writer). (2006-June-9). Wadeye Residents Left Homeless Following Gang Fighting Australian Broadcasting Commission Local Radio Broadcast. Australia: ABC Local Radio.
- Walker, B. (1976). *Ekistics As A Framework For An Aboriginal Settlement Study*. Unpublished Ph. D, UNSW, Sydney.

- Wang, S. C., Tseng, J. J., Tai, C. C., Lai, K. H., Wu, W. S., Chen, S. H., et al. (2008). Network topology of an experimental futures exchange. *European Physical Journal B*, 62(1), pp. 105-111.
- Warner, W., & Low, J. (1947). *The Social System Of The Modern Factory*. Yale: University Press, GB.
- White, D., & Kiester, A. R. (2008). Topology matters: Network topology affects outcomes from community ecology neutral models. *Computers Environment and Urban Systems*, 32(2), pp. 165-171.