Complexity and the integrating disciplines

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Abstract. There are a number of important national problems, such as security, which also span multiple systems levels and cannot be addressed by a single integrating discipline, such as systems engineering. Such problems are complex and as one moves up the systems hierarchy towards the international levels, there is increasing anarchy with no shared purpose between actors or in the extreme case, conflicting purposes. Dealing with complexity requires multiple simultaneous interventions at multiple levels in the systems hierarchy. This paper has outlined how this integration could be approached both vertically through technology management, systems engineering, enterprise engineering and whole-of-society levels, each level with increasing decision stakes, conflicting purpose and uncertainty. A whole-of-society approach is introduced which is more than just the application of systems thinking at a higher level in the systems hierarchy. This paper argues that complexity requires governance at multiple levels for problem solving in conjunction with longer term vision based on future studies approaches that surface underlying assumptions for deep transformation. Just as enterprise engineering emerged from enterprise architecture to deal with complexity, so whole-of-society is emerging from inter-sectoral approaches to deal with complexity.

Introduction

Several years ago, Sparrius (2008), expressed the idea that the economy is not a toaster and that systems engineering could not be used at all levels of the systems hierarchy. There are a number of important national problems, such as security, which also span multiple systems levels and cannot be addressed by a single integrating discipline, such as systems engineering. Such problems are complex and as one moves up the systems hierarchy towards the international levels, there is increasing anarchy with no shared purpose between actors or in the extreme case, conflicting purposes.

This paper will investigate aspects of complexity driving the requirement for integration, a whole-of-society approach and the integration required to deal with complexity.

Complexity as driver of integration

The first aspect diving complexity is the large number of stakeholders with different worldviews and interests. Wildlife crime and rhino poaching as one example that will be used in the rest of this paper, involves and affects multiple states or governments, each having a multiplicity of interests and agendas. Each state has its own, different legislation for wildlife crime. Wildlife crime spans beyond the mandate of at least ten government departments in South Africa. But each department sees the problem(s) through the *lens of their mandate*. Furthermore, for any problem the public is either directly involved or has some interest in the

problem along with non-governmental organisations (NGOs), private sector and communities. In the case of rhino poaching, specific communities around the park (as a subset of the public) are affected by or involved in poaching. In South Africa, there are additional organisational interfaces arising from the national, provincial and local levels of government. In total over 100 stakeholders have interests in wildlife crime (Gonçalves & Schmitz, 2016, p. Appendix B). The interventions required for a complex problem lie outside the mandate of a single department and beyond any single stakeholder. There is no single person in charge of the set of stakeholders required for an intervention. Different worldviews and values of actors contribute to complexity (simplified for illustration):

- Medicinal and status use in South-east Asia;
- The conservationists (parks and NGOs) are waging "war to save biodiversity" (Duffy, 2014);
- The state determines what is legal and illegal and various government departments are responsible for enforcing the law regarding wildlife and related crimes;
- Poachers and traffickers do not see killing rhino and trafficking as illegal referred to as "contested illegality" (Hubschle-Finch, 2016). For traffickers, rhino horn is a way to make money.
- Communities want access to the parks to hunt, earn a living and access to cultural sites (graves, ancestral grounds) (Duncker, 2016); and
- Some private rhino owners see rhino as an investment that should yield "returns".

From a security perspective, McDonald has argued that states tend to define security narrowly, primarily the designation of threats, with the focus on the *moment* of intervention (2008). The truck driven through the crowd in Nice, France illustrates the difficulty authorities have of intercepting the *moment* in time and space.[1] Efforts and spending tend to focus on responding to incidents. A human centric approach to security requires sensitivity to the particular needs of societies, communities and individuals, considering not just political and military issues, but economic and social needs, and the environment (Buzan, 2009). The broadening human dimension of security and the asymmetric nature of security threats has resulted in external and internal security becoming closely interlinked. This phenomenon, along with a trend in the last fifty years for governments to become larger with more specialised knowledge and capabilities, has resulted in security-related knowledge, information and capability becoming extremely "stove-piped" (Caudle & de Spiegeleire, 2010).

Internationally there has been a trend to reconsider the security chain, consisting of four generic tasks, namely: analysis, prevention, response and evaluation (de Spiegeleire, 2011). Efforts and spending tend to focus on responding to incidents. An international shift to prevention and analysis and requires more focus on systemic approaches to security. There are similar trends in crime prevention based on a whole-of-society approach (Berg & Shearing, 2011; Inayatullah, 2013). It is critical to note that the security chain must run faster than the problems are changing. The consequence of this is that the ability of organisations to respond to changes in the environment (dynamics or uncertainty) requires high levels of integration (Hoogervorst, 2009).

It is now the case that "many of the world's institutions and decision-making processes are inefficient, slow, and ill informed. Today's challenges cannot be addressed by governments, corporations, NGOs, universities, and intergovernmental bodies acting alone; hence, trans-institutional decision-making has to be developed, and common platforms have to be

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[1] Nice attack: What we know about the Bastille Day killings, *BBC*, 19 August 2016, http://www.bbc.com/news/world-europe-36801671 (accessed 07 May 2017).

created for trans-institutional strategic decision-making and implementation." (The Millennium Project, 2012).

South Africa is not except from the earlier quote. Since none of the complex security problems facing South Africa today can be solved by any single organisation or actor, integration of the tasks performed by the various organisations is essential. But with this many organisations it is common to hear people talk about "silos" and "silo behaviour". A silo, from the Greek "*siros*", is a structure for storing grain. In modern organisations knowledge is stored in these "silos", which attempt to "apprehend" meaning as a way of making sense of the world (Brown & Duguid, 2002). An organisation produces and accumulates specialised knowledge which has an isolating effect because shared meaning decreases and coordination must be addressed. The types of organisations employed by the state in the context of security are typically bureaucracies and coordination focuses on control through direct supervision, standardisation and regulation (Mintzberg, 1989). This is in sharp contrast to agile, networked (peer-to-peer) criminal organisations (Williams & Godson, 2002). This issue is further compounded by the need for security clearances and secrecy by personnel. The inter-organisational perception of corruption and low levels of capability leads to low levels of trust (Hardy, et al., 1998). Research conducted by the author (2015) shows that shared understanding of wildlife crime in an area between two organisations was 21% of total issues raised during two separate workshops. Part of the reason for this is that the two organisations have different mandates, and therefore focus on different issues and gather different information. Despite this, the shared understanding was lower than expected. Finally, successful implementation of strategies can be as low as 10% for a single organisation (Mintzberg, 1994).

With the prevalence of technology and in particular information technology, there is a tendency to argue that all that is required is sharing information so that it can be integrated and only authorised people have access to the information (Figure 1). Once this is achieved, according to this line of thinking, everyone will collaborate and then common goals are not required. Collaboration does not automatically create a harmonised approach and different organisations may still work against each other – known as the "accidental adversaries", a systems thinking archetype (Mella, 2012). Furthermore, if such collaboration can be achieved, tactical and operational level situations may be improved but it cannot address problems which require strategic interventions and deep change. Furthermore, collaboration ignores power which could disrupt, stall or undermine any effort. Based on insights from the international community, sharing information is necessary but not sufficient - a cross-organization strategy is required (International Federation of Red Cross and Red Crescent Societies, 2000).

Figure 1.   Spectrum of coordination activities

Complexity arises from fragmentation which, according to David Bohm (2002), "… is now very widespread, not only throughout society, but also in each individual; and this is leading to a kind of general confusion of the mind, which creates an endless series of problems and interferes with our clarity of perception so seriously as to prevent us from being able to solve most of them." Complex problems cannot be reduced and various aspects need to be addressed simultaneously (Morin, 2007). The other factors driving complexity that are discussed are: i) high stakes, ii) the number of simultaneous aspects of intervention, and iii) the problem

dynamics and the huge number of interactions in the rhino poaching problem. The rhino poaching problem is used for illustration, although these factors manifest in other problems.

i. **High stakes**: In the context of rhino poaching there is a loss of biodiversity at stake in the worst case. Since 80% of the world's rhino population is in South Africa (Ferreira, et al., 2013), this is a South African problem with international impact. However, the economic impact is not a simple issue. There is not only a potential loss of income from tourism resulting from a security incident in the Parks, but there is a socio-economic benefit from the illegal activity for communities. For some poachers, poaching might be a survival necessity, but for many others trading in rhino horn is a lucrative activity which they will not readily stop.

ii. **Problems evolve**: Whatever the problem, it has a history. Rhino poaching occurred during the late 1970s through to the mid-1990s (Milliken & Shaw, 2012). It then almost disappeared, resurfacing around 2008 for reasons that are not entirely clear. Poachers are constantly adapting to ranger anti-poaching measures by finding new ways of poaching. Wildlife crime networks and methods are constantly changing. The future must be considered because an intervention takes time with resource constraints. But perceptions of what could happen in the future are different across different organisations. Furthermore, the intervention itself interacts with and changes the "problem".

iii. **The simultaneity of intervention:** Simultaneous interventions are required in addressing wildlife crime which is itself a challenge. Wildlife crime occurs with other crimes and problems. Wildlife crime co-occurs with a variety of crimes such as illegal possession of weapons and drugs, trespassing, money laundering, fraud, corruption, murder and attempted murder, and entrapment. Wildlife co-occurs with other issues such as inequality and poorly managed rural densification (amongst many others) around parks. Without addressing key co-occurring problems (problematique), such as community needs, the issue of poaching cannot be addressed successfully. Thus, multiple levels of simultaneous intervention are necessary. This ranges from the individual (a ranger), groups, organisations, inter-organisational, and internationally. Thus, international demand management happens at the same time as physical security is increased at park level - it is not "either/or", but "and". The challenge here is aligning these interventions so that they do not produce new problems.

Different aspects of complex problems are interconnected, but stakeholders are tempted to address only those parts of the problem within their mandate. For example, while law enforcement is understandably frustrated by its inability to get ahead of wildlife crime, it cannot refer to its efforts as a "war on poaching" or to poachers as "insurgents" and then hope to work with communities[2]. In as much as parks are necessary for conservation, parks fragment land and people as another example. Community interventions offer important alternatives to "militarisation of conservation" (Duffy, 2014). Including stakeholders in the development of interventions increases the chance that these interventions are successful. When stakeholders are excluded, interventions are rejected and do not address important stakeholder issues.

Interventions must occur on multiple time-horizons. The most effective leverage point involves changing perceptions of the status value of rhino horn, and the related status of owning rhino horn products. Effective leverage points (such as changing perceptions) are on a longer time-horizon, but immediate action is required to secure the rhino physically.

Other issues that require attention include:

- Reducing risk and uncertainty. There is an asymmetrical distribution of knowledge, for example, we can know more about rhino and government departments than about transnational organised criminals.

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[2] Based on a number of interviews conducted by the author in 2015/16.

- Building up capabilities (referred to in the policy literature as capacity (Brynard, 2006)) to address wildlife crime in a sustainable way requires multiple disciplines which are normally organized as silos. While natural sciences and technology have played a key role in these capabilities, there is a trend internationally to broaden the scientific base to include social sciences in the area of security (de Spiegeleire, 2011).
- Access to resources. Accessing funding in particular is an issue in terms of governance when working across multiple departments.

There are also epistemological aspects to be considered. Firstly, complexity means there are limits to knowledge (Cilliers, 2005). For example, more can be known about conservation than about transnational organised criminals. Secondly, different ways of knowing must be integrated ranging from natural sciences, social sciences and humanities. In systems engineering the "ilities" refers to a number of disciplines, based on natural sciences, that are integrated into the process. Addressing the epistemological issues between natural sciences, social sciences and humanities is another matter. The structure of the education system and research funding around disciplines perpetuates the problems (Morin, 2007).

The overwhelming nature of the problems can leave stakeholders feeling apathetic, lacking agency, cynical and without hope. An approach that deals with the complexity of security is required which integrates across the systems hierarchy. Firstly, the whole-of-society approach is introduced in the next section with the vertical integration of whole-of-society, enterprise engineering and systems engineering and technology management presented later.

A whole-of-society approach

This section is an overview of a whole-of-society approach developed by the CSIR based on projects in the area of border management and wildlife crime (Gonçalves, 2014; Gonçalves, 2017). A whole-of-society approach is of interest in complex security problems, such as disaster management that require more sustainable, proactive approaches. The first purpose of a whole-of-society approach is to address large, complex national security problems that lie outside the mandate of any single department or agency, private organisations, and individual members of the public. The second purpose is to move from reactive approaches (e.g. anti-poaching operations in the park) to proactive approaches such as (interventions in potential demand states and community interventions). This requires foresight.

Whole-of-society approaches are being called for in international governance frameworks such as the *Sendai Framework for Disaster Risk Reduction 2015-2030* developed by the United Nations Office for Disaster Risk Reduction (referred to there as "all-of-society"). By whole-of-society three things are meant in the context of this paper:
- The actor scope of consideration is multi-sectoral, with actors having differing values and interests;
- The approach to inquiry (problems, opportunities and visions of the future) is participative; and
- A method appropriate to the whole-of-society inquiry under consideration. Such a method must, from a complexity perspective, rest on a transdisciplinary approach (Gonçalves, 2014).

The approach does not require consensus on a common purpose, but it does require harmonizing interventions. A single purpose is not desirable or possible. It is not desirable from a resilience point of view and it is not possible because stakeholders have a range of values and interests. Stakeholder engagement fundamentally underpins the approach and is important for the co-development and assimilation of strategies and technologies.

The process consists of creating a shared understanding of the current situation, foresight, and developing cross-organisational interventions and the implementation of the interventions (establishing capabilities within an enterprise) (Figure 2). The methodology usually applied by departments, beyond just wildlife crime, is a planning approach which deals with the immediate problem solving so that political leaders are seen to be "doing something about the problem". It has a short-term (five years or less) focus on a particular goal, in this case reducing the number of rhino poached. It is the approach to a vast majority of issues. But, as discussed earlier, multiple time horizons must be addressed and as Joseph Tainter notes, "Systems of problem solving develop greater complexity and higher costs over long periods." A longer-term vision, amongst other things, is required to reduce harm to the environment and people.

A planning approach must be complemented by a futures approach. Future studies is the systematic study of possible, probable and preferable futures, and worldviews and the myths and metaphors that underlie each future (Inayatullah, 2005). The shift is from problem solving to creating a preferred future. Futures studies seeks multiple ways of knowing and alternative futures. Different ways of knowing includes: qualitative and quantitative information, text, drawings and images, objective evidence, worldviews and values, and myths and metaphors (discussed again later). In this article reference will be made to observable measures and trends as forecasting and cultural/psychological aspects as transformation. Both forecasting and transformation are important. Familiar approaches to anticipating futures in the context of security include scenarios and risks analysis. The assumption underlying planning in general is that the future will be like the past. This assumption is characterised by extensive data analysis. It is therefore important to remember that the future may contain things that have never existed before.

Futures are developed through a facilitated, participative and inclusive process. Including different stakeholders ensures that the impact of different interests, actions and various issues on others becomes part of the shared understanding. A number of artefacts have been developed to support different ways of knowing and shared understanding. One such example is spatially modelling community vulnerability to involvement in poaching, which would determine the geography of the community intervention (Schmitz, et al., 2017). Before new problems arise, such as new countries becoming consumers of illicit wildlife products, there will be trends underpinned by data, and these trends are preceded by emerging trends or weak signals of a new problem (Molitor, 2003). Such vulnerabilities have the potential for exploitation by criminals.

Futures are important in escaping short-term focus by challenging assumptions and particular interests. The simple issue of measures such as number of arrests and number of convictions, as particular ways of assessing effectiveness in law enforcement serves the interest of particular stakeholders. If law enforcement is to be used to disrupt wildlife crime, then the rate at which law enforcement arrests traffickers and disrupts their activities must exceed the rate at which traffickers (middle men up to the kingpins) are being replaced (Gonçalves & Schmitz, 2016). This is a different goal and would require a new measure.
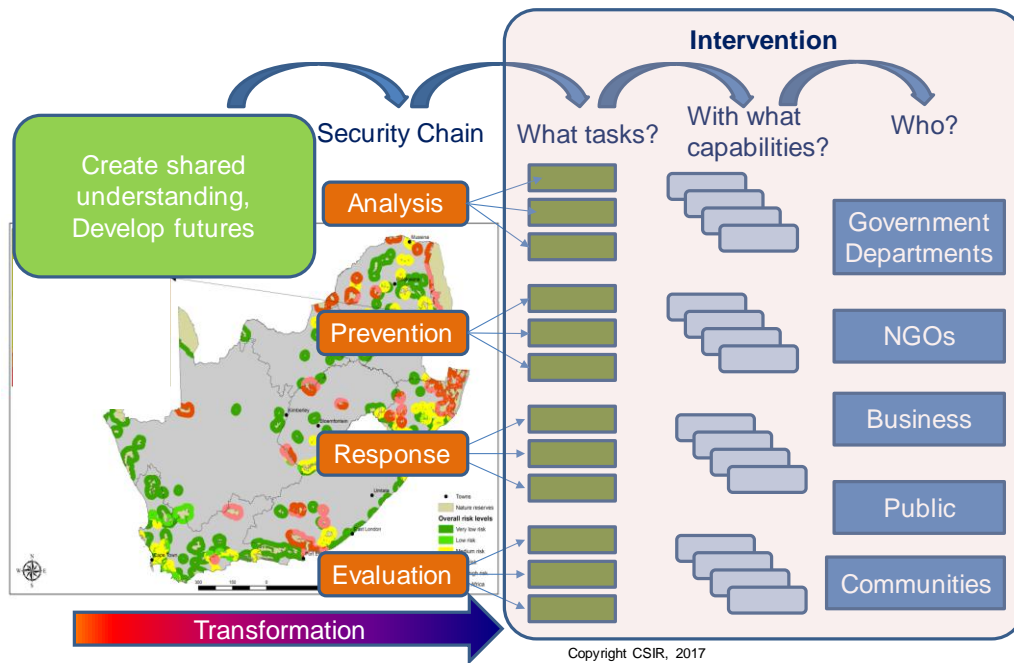
Figure 2.   The whole-of-society approach (Gonçalves, 2017)

From the four generic security chain tasks, namely analysis, prevention, response and evaluation, the tasks required to perform each generic task are identified to mitigate each of the risks while achieving the opportunities identified in the foresight exercise subject to legal and other constraints. From these tasks the required capabilities are identified and allocated to the departments, NGOs, and private sector based on fit in terms of mandate, cost, strategic importance and other considerations. A capability, the "ability to do something", refers to appropriately selected and trained people, processes, information and supporting technical systems, with the right behaviours (which are driven by rewards and recognition, culture, leadership and management) required to perform a task. Capacity is the number of people and equipment quantities required for the capability. Thus the level of capability is about having each of the elements outlined and the required maturity. To proceed practically, an audit of current capabilities in organisations is usually required.

The set of tasks, capabilities and the particular allocation to departments is referred to as an intervention (or in systems engineering language, an "operating concept"). The fundamental principle is that interventions are developed outside organisational mandates. There are always alternative interventions, and at least one alternative should be developed to arrive at a good intervention. The intervention builds on the shared understanding of the situation to co-develop a shared approach to addressing the problem. An intervention may also include defining new capabilities required in an organization. Note that governance is not just about compliance, but must ensure sustainability and relevance of the capabilities in the broader context. To close the gap between required capabilities and current capabilities requires organisation level governance (Hoogervorst, 2009) or dynamic problem solving to close the capability gaps which requires cyclical feedback (Andrews, et al., 2013). In the context of human security, organizations other than just law enforcement are required such as social development, NGOs and the private sector. The key to a whole-of-society approach is that by working across organizations the constraint of individual department mandates is removed in addressing the problem.

The process should not be seen as a linear recipe. Learning is an important part of responding to complexity in a whole-of-society approach and iteration is required to arrive at an intervention.

As Parsons points out "…improving policy-making is…about learning, rather than command and control." (Parsons, 2002). Jumping to a solution too early will usually lead to a failed intervention. It is usually necessary to separate the interventions practically, but alignment needs to be maintained. This means that for each intervention, there may be partially overlapping (in the sense that the same actor may be involved in more than one intervention, for example) versions of the whole-of-society model in Figure 2. Similarly, because there are three levels of governance in South Africa, the model could be used at various levels. Without dealing with worldviews, the same kind of thinking and hence policy recommendations emerge again and again. Culture eats strategy[3] for breakfast and without change to organisational ways of doing, there will also be no change in behaviour. Actors with power may want to keep the status quo. Moving from the current situation to a new future through an intervention requires transformation of thinking and culture, shown as an arrow in Figure 2. In particular, the framing of a particular issue and the metaphors used may lead to different interventions or even prevent consensus on an intervention (Schon & Rein, 1994; Thibodeau, 2011). These aspects are dealt with through participative, facilitated approaches.

The next shows how the whole-of-society approach introduced here fits into a vertically integrated approach for dealing with complexity.

Integration required to deal with complexity

There are several dividing lines for the integrating disciplines required at various systems levels, or what Nicolescu (2010) refers to as levels of reality: i) purely technical systems; ii) individual human systems; iii) organisations; and iv) cross-organisation. It is important to note that within each of these levels there may be several systems levels. In a whole-of-society approach, the central element is the actor, with an organization an example of an actor. Firstly, the term actor is used because the legitimacy of each actor may be in question. Secondly, actors may not jointly have shared values, interests or purpose. At a whole-of-society level there is no system, because of a plurality of interest or purposes.

In order to deal with the complexity of wildlife crime a vertically and horizontally integrated approach is proposed in Figure 3. The wildlife specific content is illustrated starting with the problem context and interventions, indicated on the left-hand side, and the integrating discipline on the right-hand side. A methodology appropriate to a particular problem and level is constructed by drawing from the particular integrating discipline. There are a number of levels that are of concern, in this preliminary model:

The **first level** is the **context level** and includes the end-users of wildlife products in South-east Asia, the illicit product distribution network, the syndicates involved in transnational organised crime, poaching networks in southern Africa, wildlife parks, and communities around parks. One of the temptations is to ignore the context and jump in to a solution quickly. The context level is important in terms of understanding the problem and spans the international, regional and national levels.

The **second level** includes the government departments and other organisations involved in **interventions**. The naming of interventions in Figure 3 is similar but not exactly the same as those used by some stakeholders (Department: Environmental Affairs, 2014). Including stakeholders in the development of interventions increases the chance that these interventions are successful. The broader focus of a whole-of-society approach is important because with the complexity, different aspects of the problem are interconnected, but stakeholders are tempted to

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[3] A phrase originated by Peter Drucker.

address the problem in parts, thus creating new problems. Community intervention that addresses stakeholder needs contributes to the constitutional imperative of "peace and harmony" while dealing with specific root causes. The interventions will involve different combinations of stakeholders. Horizontal integration at this level is concerned with understanding and integrating across different interventions, and between organisations involved in the interventions.

The **third level** is a particular capability within an organisation such as physically securing the Intensive Protection Zone in the Kruger National Park. This level provides capabilities for the intervention.

The **fourth level** includes the technologies for a particular capability, such as command, control and communications, surveillance technologies and responder technologies.

One level should not be assumed to be more important than another and activities occur on all levels simultaneously. Each of these levels requires horizontal integration, such as harmonising interventions at the whole-of-society level. There is a temptation to dismiss methodology in the face of complexity and to be "practical" – this simply results in "muddling through" (Lindblom, 1979). To avoid this in the face of complexity, not only have integrating disciplines have become more important, but also the relationship between these integrating disciplines.

The four *integrating methodologies or disciplines* (right-hand side of Figure 3) span the various levels of the systems hierarchy. The **whole-of-society** is concerned with developing interventions that span departmental mandates, individual organisations and communities based on foresight and drawing on different disciplines. It is first useful to understand the evolution of enterprise engineering to understand how the whole-of-society might evolve.

The **enterprise engineering** level (single departments and interoperability between these) is about capability evaluation and assessment against strategic requirements for the purpose of implementing capabilities. This is not just about ICT but includes organisational design: leadership, rewards and recognition, and culture. A brief history of enterprise engineering is provided, so that the whole-of-society development can be appreciated.

An enterprise is an intentionally created entity of human endeavour with a certain purpose. There are a number of developments leading to improved technologies for achieving integration of enterprises (Hoogervorst, 2009). The 1970's saw a shift from a data-centric view of the world to an information-centric one (Figure 4). This resulted in enterprises being shaped and held together by information technology (IT). But the emerging paradigm was *intention* based and held together by *collaboration and cooperation*. Built on information systems, and drawing on organisational sciences, a new area of enterprise engineering is emerging. This is important since the behaviour that the enterprise exhibits depends not only on the technical systems, but also on management and leadership practices and organizational culture (Hoogervorst, 2009).
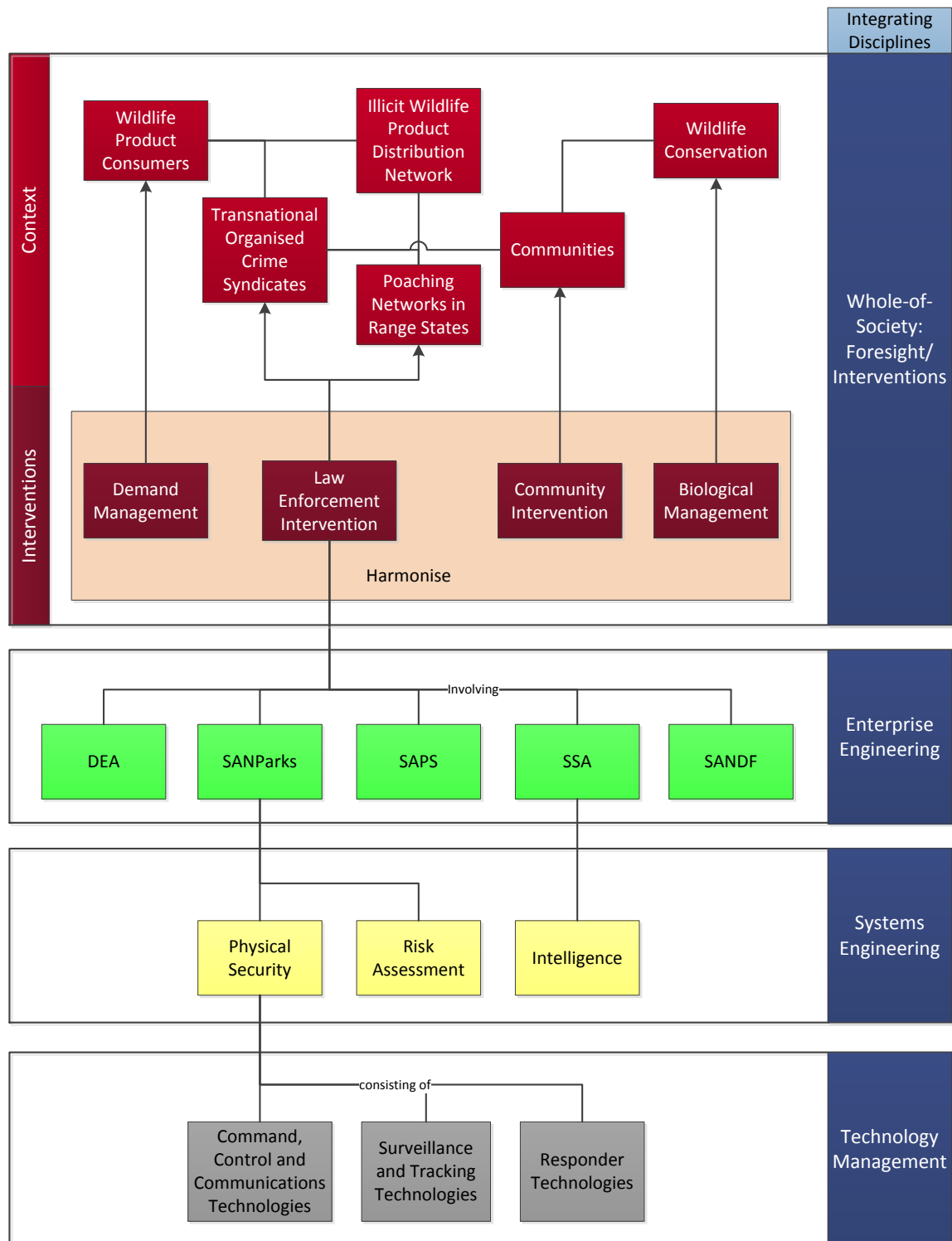
Figure 3. Vertically and horizontally integrated approach to addressing wildlife crime (illustrative model – not complete)

According to Hoogevorst (2009) Enterprise Governance is required to achieve unity and integration. There are at least two important developments in the area of governance. Firstly, corporate governance is moving away from just financial compliance and internal control to include effectiveness and sustainability, which involves strategy implementation. Secondly, there is a trend to consolidate and integrate corporate governance, IT governance and initiatives that transform the enterprise into an integrated whole. IT systems designed primarily to support

enterprise purpose and objectives are relevant from a compliance point of view as well. Technical systems (not only IT) that are designed to integrate with the organisation have a better chance of being accepted (Schneider, et al., 1996). In order to ensure compliance, tasks need to be understood, along with the required authority and responsibility. Thus, compliance is tightly linked to the design of the enterprise. Enterprise governance is an integrative organisational competence for continuously exercising guiding authority over enterprise strategy and architecture development, and the subsequent design, implementation, and operation of the enterprise (Figure 5). There are a number of reasons for integrating the three competencies shown in Figure 5. Firstly, internal control cannot be separated from the processes and their execution since the tasks that make up these processes require responsibility and authorisation, which impacts the design of the enterprise. To avoid failure of strategic initiatives requires focusing on the enterprise as whole to ensure adequate unity and integration as the enterprise acquires new capabilities incrementally and enterprise strategy changes. While there has been some discussion on integration this does not mean that differentiation is not important. In fact, a balance between integration and differentiation is required, as was pointed out earlier and by others (Lawrence & Lorsch, 1967).
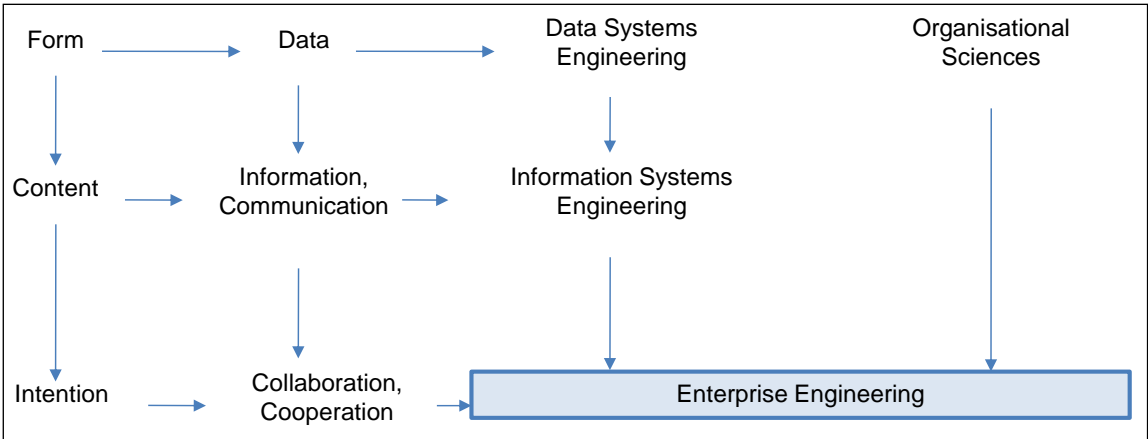

Figure 4.   Enterprise Engineering Family Tree (Hoogervorst 2009)
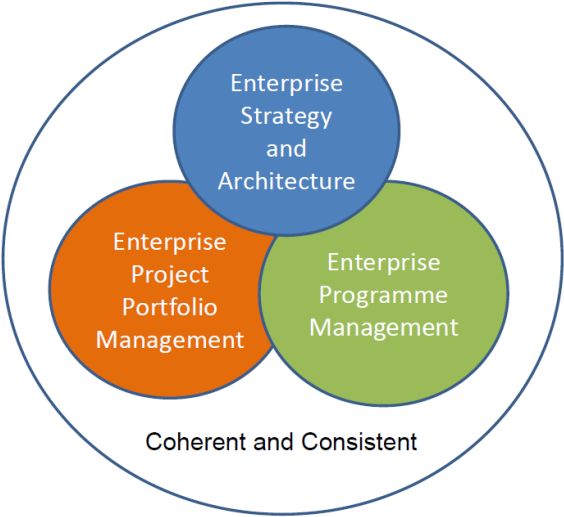

Figure 5.   Enterprise Governance Core Competencies (Hoogervorst, 2009)

Programme management is the management of a cluster of projects whose execution must be coordinated to achieve an overarching goal. Project portfolio management is the totality of

activities for ensuring that the project portfolio is accurate and up to date, such that project management and pertinent evaluation and decision making is facilitated. Portfolio management is about getting the big picture, for example about resources needed, project execution priorities and risks, and project progress.

Enterprise Architecture is not a new concept, having been widely used in the IT context. But Hoogervorst's central concern is designing an organismic system, i.e. an adaptive enterprise in a *complex* environment, where behaviour is shaped by principles that keep it stable as opposed to rules and regulations which are brittle under uncertainty and complexity.

The **systems engineering** is concerned with the development of operating concepts, requirements analysis, architecting, and verification and validation of technical systems and capabilities. These are the types of practices described in the INCOSE Handbook (INCOSE, 2010).

The **technology management** is about developing, acquiring and maturing new technologies which form part of a system. If there are no existing technologies, then there is potential risk and this requires research. As an example, the CSIR typically performs research and development until the technology has matured to a technology readiness level of seven at which point it hands over to other organisations for further development.

The boundaries between integrating disciplines are fluid. For example, technology management could span into enterprise engineering. Similarly, systems engineering can stretch into enterprise engineering. Further expansion of the systems hierarchy is truncated as soon as "know how" is achieved, which can be through an existing capability, system or technology. The important issue is that the approach be problem focused as opposed to discipline focused or organisation centric and vertically integrated with enterprise engineering, and technical systems. Research can be applied at any of the four levels.

Conclusions

Dealing with complexity requires multiple simultaneous interventions at multiple levels in the systems hierarchy. This paper has outlined how this integration could be approached vertically through technology management, systems engineering, enterprise engineering and whole-of-society levels, each level with increasing decision stakes, conflicting purpose and uncertainty (Funtowicz & Ravetz, 1993). Tasks required to create a particular future, address a problem or create an opportunity are identified outside of an individual organisation and form the link from the intervention at the whole-of-society level to capabilities at the enterprise level. Whole-of-society approaches are not just the application of systems thinking at a higher level in the systems hierarchy. Inayatullah reminds us that (2002):

"Complexity, however, is not a return to systems thinking since the systems approach tends to be apolitical. It generally assumes that subsystems are interest-free or that analysis of the future can be done in a neutral fashion. While the systems approach has been of benefit […] in the past few decades, its inattention to how systems approaches themselves embody a particular type of politics, and a particular language, leaves it handicapped."

This paper has argued that complexity requires governance at multiple levels for addressing complexity in conjunction with longer term vision based on future studies approaches that surface underlying assumptions for deep transformation. Just as enterprise engineering emerged from enterprise architecture to deal with complexity, so whole-of society is emerging from inter-sectoral approaches for complexity (Lopez Herrero, 2013). The need for a whole-of-society approach is inferred from the technology management, systems engineering, and enterprise engineering sequence of integrating disciplines observed in practice. It is not that a whole-of-society "discipline" is desirable, but the integrating effects of a whole-of-society

approach are needed and so for the moment, to build competence, a new discipline is proposed. Such a discipline spans the areas of governance (public administration and business administration) and philosophy (complexity, transdisciplinarity, future studies and ethics) as core with satellite disciplines including any number of social and natural sciences as required for the inquiry at hand.

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Biography

Duarte Gonçalves is currently employed by the CSIR as a Principal Engineer where he currently leads the on-going development and application of a whole-of-society approach to security in the areas of disaster management, infrastructure security and wildlife crime. He has contributed to national strategies in wildlife crime and the development of whole-of-government and whole-of-society approaches nationally; led national study on law enforcement in the area of wildlife crime. In this capacity, he works with a variety of government departments, social scientists, engineers and other experts and has developed experience using transdisciplinary research methods in security for "dealing" with complexity. He has facilitated stakeholder workshops for developing futures and interventions.

Duarte Gonçalves is a registered professional engineer with a PhD in Engineering Development and Management.