Engineering Design of an Environmental Management System: A Transdisciplinary Response to the Rhino Poaching Problem

Henk Roodt
StoneToStars Ltd, Dunedin, New Zealand
Email: info@stonetostars.co.nz

Hildegarde Koen
Council for Scientific and Industrial Research (CSIR), Pretoria, South Africa
Email: hkoen@csir.co.za

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Abstract. The big issues we face today, that require properly engineered solutions, contain society, nature and man-made components. It is difficult to consider these systems within the traditional systems contexts, where we can set well-defined boundaries during the design (analytical decomposition) process. Still, the analysis/synthesis process must be thorough enough to ensure that the functional, physical and allocated architectures that are discovered and defined during the analytical phase, can deliver a reasonable, traceable outcome on synthesis of the solution.

The authors firstly accept that the feedback loop and recursive causal nature inherent to eco-socio-technical systems cast them in the domain of *wicked* problems. Systems engineering relies heavily on being able to understand the questions and the needs of stakeholders to be addressed through the accurate conceptualising of a problem and associated solution space. Thus, in this paper we turn to the concept of complexity for guiding principles to address the wicked problems through appropriate research (analytical) methods that transcends disciplinary focussed solution finding. To highlight the proposed approach the development of an environmental management system as a response to the rhino-poaching problem is briefly discussed. The approach, when refined, should be able to address other resource management efforts.

The Problem with Big Questions and Mega-Systems

As the global human population grows and the natural resources are increasingly under pressure, there is no scarcity of really big questions to answer. But while we marvel at the complicated nature of the large hadron collider and consider what the physicists and cosmologists tell us about the possible early history of the universe, we often shy away from the questions that hide in the murky depths between the disciplines. This is mostly the result of our segmented research capability and knowledge base. The segmentation has its benefits in that it helps us decide what knowledge would be used to address the issue at hand. This is consistent with the approach Descartes and Aristotle proposed: a system of inquiry grounded in a logical objectivity and a process of disjunction and reduction to yield understandable pieces of a bigger problem.

"Disciplinary Decadence"

Arguably one of the most successful methods to understand the world we live in, it has given rise to a multitude of disciplines of study, driven by increasing specialization and segmentation. Montouri quotes Gordon who calls this "disciplinary decadence", a situation that leaves little room for knowledge from other sources (Montuori 2013).

Obviously the disciplines bring huge understanding of specific issues, but none of the sciences (disciplines) offer a wide enough and an effective way to integrate the information generated in these various disciplines. For this reason, Buede (Buede 2009) says that system engineers must be "big picture people". He continues to state that depth of understanding is achieved by *iteration* through the design process (analysis and synthesis) to get to a sufficiently detailed solution specification. This approach is captured in the now well-known systems engineering "Vee" (Forsberg and Mooz 1991), shown in Figure 1.

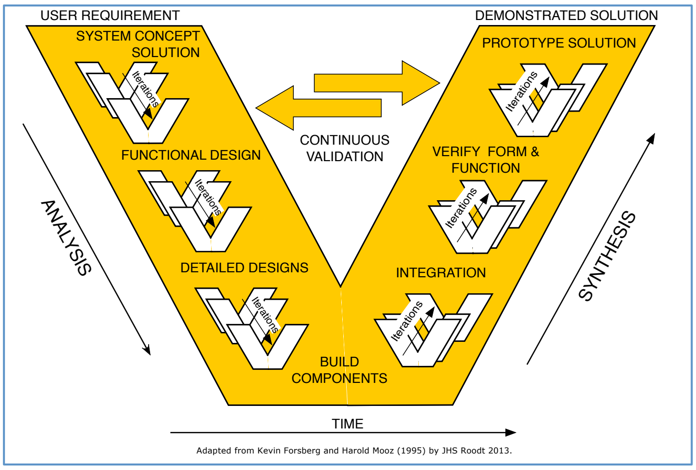

Figure 1. Highlighting the iterative nature of the "Vee".

Tame Problems

The Vee starts with a requirements elicitation process and interpretation of stated needs. From experience we know that this process works well when the problem is well defined, meaning that we can define the boundaries of the problem space that differentiate it from the larger environment in which it is contained. In such systems the requirements can be agreed to and are captured in a logical framework. They remain stable over time and functional and architectural decomposition is possible. When the sub-system functions and architectures are subsequently assembled, the behaviour of the synthesised system will be very close to, or exactly as was expected. For this reason system engineering program managers traditionally spend quite a bit of energy to try to ensure well-defined problem spaces and subsequent solutions. It comes down to isolating those elements that can be controlled within reason from those that cannot be similarly controlled (Stevens 2011).

What is not apparent in the "Vee" diagram is whether a top-down or bottom-up or combination conceptual *design* approach is followed. In a top-down approach the requirements are handled as an intrinsic part of the method and may lead to development of new sub-systems and technologies to realise the solution. In a bottom-up design the exclusive use of existing systems and concepts may yield a solution, but not necessarily one that fulfils all the requirements. For this reason, most design processes are combinations of these approaches, especially where complex systems are involved (Aslaksen 2009).

Mega-Systems and Wicked Problems

A design must be judged relative to how well it meets the requirements of the group of stakeholders that expressed the need or problem. In this lies the rub, so to say. What if it is difficult to identify the inclusive group of stakeholders? Often the requirement is stated very broadly, as a general vision, initially by a small group (the restoration of a wetlands sanctuary for birds) and then it escalates into a large group of potential stakeholders when the farmers, government and other agencies become aware of the issue at hand. Or it is stated as a response to a changing environment, like climate change, where the causalities are all but clear. In many cases it is not possible to deduce from a design if the development of a solution would generate unintended side effects as a result of the interaction of sub-systems. And finally, what if several different designs are offered as an answer to the requirement, all seemingly satisfying it? Renee Stevens (Stevens 2011) states that quite often complex, mega-systems exhibit the characteristics described above.

This brings us back to the dilemma we face with the segmented nature of our knowledge base. Mega-systems and other complex systems exhibit nonlinear behaviour, specifically feedback loop causality and recursive causality. Self-regulating systems typically have mechanisms that use feedback loops to change behaviour, based on internal and external environmental changes. In some instances, especially in social and natural systems, the system may contain a process that is the product of the process that creates it (Morin 2008b). Such systems lack the predictability that we associate with linear causality, making it exceedingly difficult to model or to fall back on past experience to develop understanding.

Rittel and Weber (Rittel and Webber 1973) observed that in the field of public policy (a system that arguably shares many permeable boundaries with other systems) there is a class of problems that cannot be solved using traditional, structured approaches. They called these problems "wicked" in contrast to the "tame" problems, those that can be solved using traditional methods. Wicked problems do not have *optimal* or singular solutions (Pidd 1996). They can only be resolved (a wise option is found) or dissolved (by declaring them incomprehensible or irrelevant).

"Taming" a Wicked Problem. Generally models and descriptions of mega-systems do not help us understand fully how these systems emerge from their components, or what factors play a role in maintaining them. Taming, or simplification, increasingly removes micro-exploratory processes that drive the emergence (Allen and Strathern 2007). This leads to the uncomfortable situation where a model of the system that is less complex than the system itself cannot be used to accurately predict the behaviour of the system in the future (Banks 2002).

As humans, we often reduce complex problems by successive simplification to communicate the essence of the problem. We equate parts of the problem space to patterns we have seen before and collapse the big issue into 'known' units. Schultz (Schultz 2010) calls this the 'veneer of simplicity'. When these simplifications are seen as reflective of the real issue and then addressed at that level (of singular simplifications), a simple answer, that will seemingly do the job, is derived. This answer may "simply" be wrong. Even more concerning, such a wrong solution may manifest as a new issue somewhere else.

"Dealing" with a Wicked Problem. With wicked problems we must consider possibility and diversity rather than probability and uniformity (Roodt 2007) and aim to make wise decisions based on several factors, including societal perspectives, emerging technologies and natural systems that may be impacted by it or impact the system in turn. A new approach is required that transcends disciplinary research (Thompson Klein 2004). It must encourage wide collaboration across disciplines to bring stakeholders with multiple, perhaps conflicting objectives and constraints, to a common understanding of the essence of the problem while allowing a resolution to the problem to emerge iteratively within an acceptable timescale.

Concluding Remarks. Some of the typical issues that must also be addressed are the use of framework models, evaluation of the effectiveness of proposed solutions, validation and verification. Choosing a research and problem solving method that is appropriate for dealing with the concepts discussed above brings new perspectives to the methods that would be applicable to validation and verification, for example. These will not be discussed in any detail in this paper.

Dealing with the Big Questions using Transdisciplinary Approaches

As was stated before, with increasing specialisation, big (broad) questions are often not asked and successfully addressed, because several disciplines may be needed to bring the requisite knowledge to the party. The go-to approach is rather to take a disciplinary perspective and to map the question onto it, or to answer the next logical question (further reduction) once a hypothesis had been evaluated (Figure 2 below). As was mentioned earlier, this *taming* of wicked problems may lead to significant waste as the "wrong" problem may be solved and a wrong answer may not be discovered before it generates a new set of problems (a good example is the development and use of DDT, and subsequent banning of it for general agricultural use).

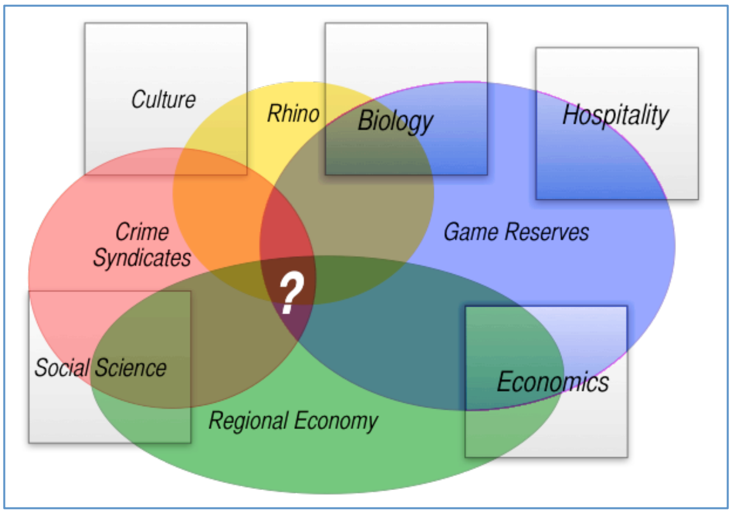

Figure 2. The problem of asking a big question.

Basic research advances the knowledge within a discipline. Research questions are driven by the scientific process and are mostly internally motivated. Multidisciplinary research advances knowledge in several disciplines by considering a problem from within the perspectives of each of the disciplines. The discipline proceeds towards a solution, with little sharing of ideas across boundaries. Each discipline may deliver an answer incongruent with that of another discipline.

Applied research answers questions posed by an external agency about a specific problem, and may use multidisciplinary and interdisciplinary approaches. The goal is to find an answer reflecting several perspectives. If the question in Figure 2 is asked by a regional council in proximity of a game reserve to understand the impact of rhino poaching it requires decisions to be made on economic and social grounds, and several disciplines may be pulled together to answer the specific questions (in each discipline) posed by the council. This set of answers may then be used to make decisions about the rollout of a development strategy.

Transdisciplinary Research

Transdisciplinary Research can be defined in terms of the following requirements (Hirsch Hadorn 2008):

1. To grasp the complexity of the problem and focus on both components of the problem and the interactions between them,
2. To account for the diversity of scientific and societal views of the problem,

3. To link abstract and case specific knowledge,
4. To synthesize knowledge focused on the problem to be solved, and
5. To be perceived to be for the common good.

Importantly, transdisciplinarity is *inquiry driven*, not discipline driven. At the same time it recognises the utility of discipline specific knowledge in the development of knowledge "*pertinent to the inquiry for the purposes of action in the world*" (Montuori 2005). It takes into account context and connection, and it includes knowledge creation by the researcher that is *reflective and self-critical* (acknowledging the *subjective* role of the inquirer). As the requirements are evolved and the structuring continues, a synthesis of possible (re)solutions is developed. Rigorous, transparent documentation of all aspects of the recursive process is crucial to the co-development of a result that is accepted as for the good of all. The process is explained in the following recursive process diagram (Figure 3) redrawn after (Hirsch Hadorn 2008).

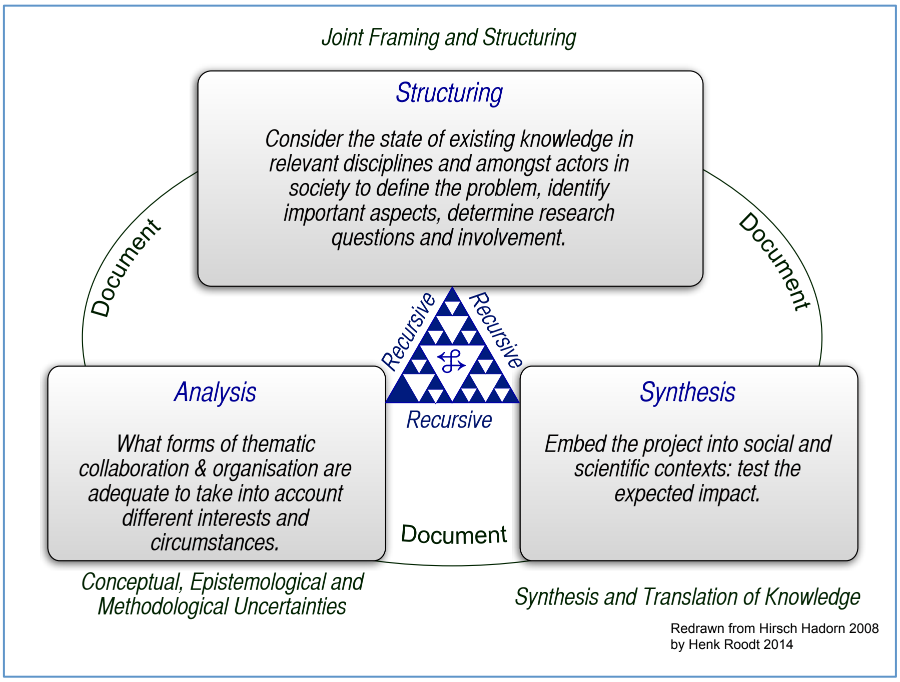

Figure 3. The transdisciplinary directed research method.

This method scales to mega-system projects that include cultural and societal complexity. It deals with wicked problems that have not been explored before, including those in the policy and governance space and it encourages the use of networks of disciplinary experts. Prof Julie Thompson Klein (Thompson Klein 2004), Fellow in the Office For Teaching and Learning at Wayne State University, USA, put it this way: *"One of the transgressive purposes of the new discourse of transdisciplinarity is to renounce the logic of instrumental reason by creating a more democratic discourse involving participation."*

Tools. Pieters and Roodt (Pieters 2010, Roodt 2007) consider several methods to capture the intricate patterns and relationships in a problem space to develop a non-quantitative model or framework description that captures the diversity and possibility of the problem domain. Using *appropriate* problem structuring and pattern discovery methods allow the system design engineers and stakeholders to share and communicate understanding of the problem and to identify aspects that are important to all (Figure 4 below). As was mentioned before, it is critical not to fall into the trap of overly simplifying the patterns; this requires methods that will capture the richness of the problem domain and that will surface new patterns of possibility within the diverse dimensions of the problem.

The outcome of such a process or method can be used to derive research directions and to involve the specialist disciplines required. Each pattern that is uncovered contributes to the solution space as it is analysed. Using modern ranking tools can support the development of longer-term strategic plans to cover the patterns that require initial attention. Over time other tools can be added to consider causalities and to develop likelihood models for different patterns. These methods often contribute to the process of documentation and traceability of decisions.

The understanding of the problem space is increased during this process, but the structuring does not imply that the problem is trivialised. Rather, the recursive method generates new understanding and knowledge that allow the engineers to work with more traditional methods to develop partial solutions, all contributing to the bigger resolution of the problem. In some instances patterns may lead directly to insight that help the stakeholders to make informed decisions.

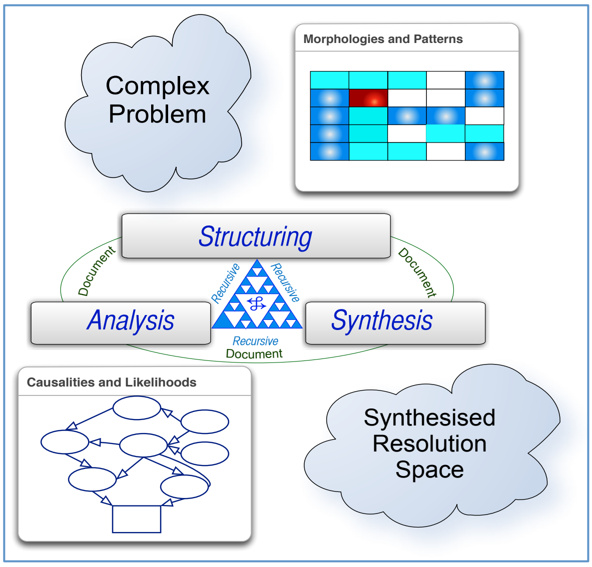

Figure 4. Qualitative and quantitative methods are mixed to structure, analyze and synthesize.

Discussion and Application

How does this approach differ from the standard system engineering approaches we are accustomed to (if it differs at all)? One could argue, as a reviewer rightly did, that the heart of systems engineering is similar or identical to that of the transdisciplinary process. Considering the "Vee" (Figure 1), the purists could claim that the extended framework, which includes several nested "Vee"s, allows for much of the iterative nature of our proposed approach. However, the core of the transdisciplinary approach is recursive. Rather than working towards a consolidated baseline of a requirement, the requirements are diverse and evolving as the understanding of the problem domain improves. The boundaries may move. This does not discount the "Vee" process, it just points out that the initial structuring and analysis may proceed along a different process and that the process of structure-analise-synthesise occurs concurrently, building at each step on one another.

The transdisciplinary approach expands the solution space by *facilitating* knowledge sharing and solution development by a wider stakeholder set, rather than focusing on the requirements and know-how of the initial owner of the problem. It effectively moves beyond the zero-sum game of poachers and consumers trying to increase the number of poached horns, while the game owners and police try to reduce the numbers.

The rhino owners are the original owners of the problem in this case. However, as the problem escalates, it attracts the interest of environmentalists, tourists, etc. They may have different requirements to the original problem owner. The ultimate solution becomes a moving target and the requirements evolve with every sub-system solution developed, as the feedback in the temporal system "outsmarts" the reactive nature of the solutions.

Structuring: The problem is structured by bringing in multiple stakeholder viewpoints (during analysis of the domain) to develop a framework with an enlarged space of possible synthesised solutions. For instance, by bringing in experts on wildlife management to represent those stakeholders seeking to reduce poaching, while also including anthropologists and other social scientists to represent the consumers of rhino horn, a framework can be developed that could handle more than the standard zero-sum strategy. The framework would allow for strategies such as limited rhino horn consumption, the development of alternatives to the rhino horn and others that may arise from multi-disciplinary discussions.

Analysis: The relationships and uncertainties within the framework can continuously be analysed in a collaborative manner to account for multi-stakeholder interests (and the synthesis of resolutions in each event) and environmental circumstances. For instance, Bayesian networks can be developed to predict the proportion of rhino horn consumers who would accept alternatives. Agent-based simulations or role-playing exercises can be used to uncover complex, adaptive behaviour that may result from the promotion of alternatives to the rhino horn. System dynamics models can be used to explore the feedback mechanisms between stakeholders and the financial systems involved.

Synthesis: Diverse candidate solution strategies can be synthesized and embedded into the social and scientific contexts. The expected impact of these strategies can be simulated by the systems tools under developed in the analysis phase and aid new structuring of the domain. For instance, agent-based models can be used to determine whether influences from tribal leadership will tip community behaviour towards total rejection or acceptance. System dynamics models can simulate the reactive behaviour of the poachers, which can include increased effort to promote the rhino horn as well as reduced recruitment due to decreasing demand. Bayesian networks would be helpful in assessing the likelihood of these various systems-wide outcomes. When the strategies are actually implemented, data collected after implementation can be used to update the Bayesian networks, which would result in changes in the likelihoods of various outcomes. If there are significant changes in the likelihoods, then the solution strategy can be adapted accordingly. For instance, if it is found that an alternative to the rhino horn would be accepted with very low likelihood, then either new alternatives can be investigated or an entirely different strategy can be deployed. Another iteration of structuring, analysis and synthesis can be used to engage the stakeholders in developing new strategies.

Recursion and documentation: The discussion focussed on the three processes in the transdicsiplinary approach. However, the core element tying them together is the recursion that occurs, rather than iteration. This means that the process calls on itself during execution. The three elements are tied together and each calls on a full set of three as was discussed above. This "call back" or "run back" nature of the process is unique. It allows for more rapid decision-making and successive action. Documenting the twists and turns obviously becomes critical to ensure that new understanding is shared and that the process can be terminated once the growth in understanding tapers off and the problem domain can be classed as resolved, or remains unresolved. In essence the process aims to be diverse at one level and integrative at another.

Stopping criteria: A recursive process needs a stopping flag! As the problem domain is understood better and a variety of decisions lead to implementation of (re)solutions, the problem may shift into a new paradigm. This may be seen as a stopping criterion for the process. Setting up and documenting flags to ensure that a return of the problem can be signalled may be seen as the last actions of such a project package.

In the next section core elements of the process will be demonstrated briefly by discussing the initial phases of developing a systems response to the rhino poaching problem in South Africa.

Developing a Systems Response to Rhino Poaching

Rhino poaching is a serious problem, especially in South Africa. Rhinos are poached at an alarming rate and the demand increases dramatically each year (Modise 2014). Figure 5 illustrates this drastic increase in poaching attacks since 2008. The poaching incidences went from one rhino being poached every 4.4 days in 2008, to one rhino being poached every nine hours in 2014 (Modise 2014, Unknown 2014).

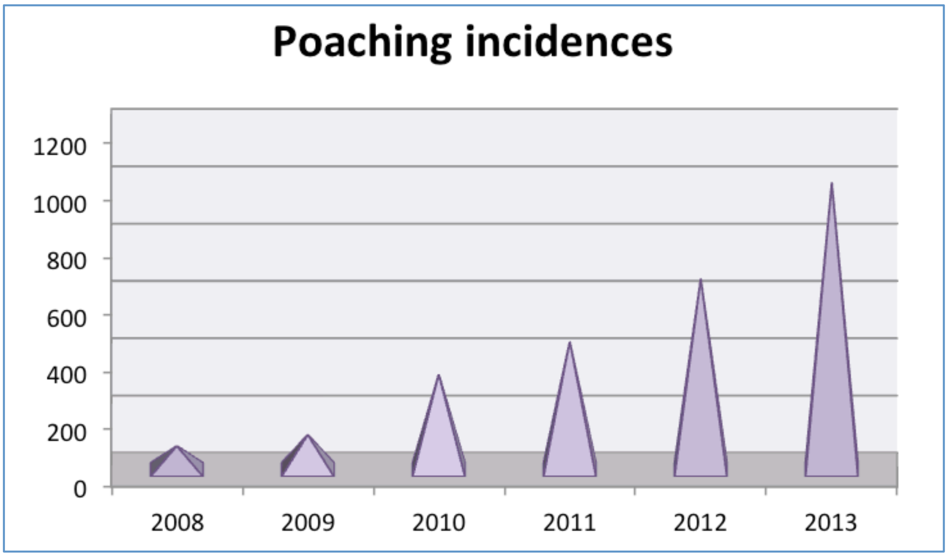

Figure 5. Poaching incidences 2008 – 2013.

In the first few months of 2014, there have been a total of 376 incidences in South Africa. Every day nearly three rhinos are lost. Figure 6 shows a breakdown of the poaching figures for 2014 from 1 January 2014 until 15 May 2014. The Kruger National Park (KNP) is targeted the most with 65% of the total poaching incidents. If the current poaching rate continues, the rhino population could be extinct by 2026.

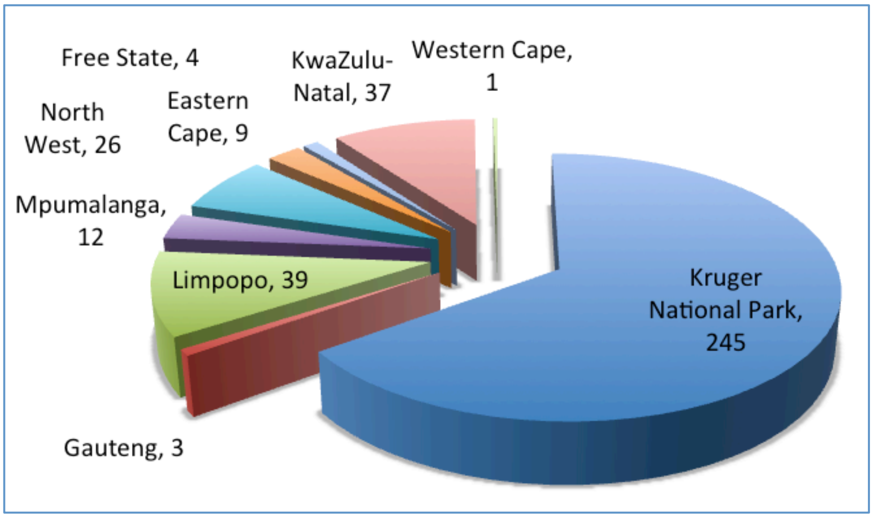

Figure 6. Rhino poaching numbers for South Africa 1 January 2014 – 15 May 2014

Rhinos are poached for their horns that consist mainly of keratin (Unknown 2006). Many cultures believe that rhino horn is extremely valuable and that it can cure ailments (Unknown 1983, Ellis 2005). At the same time, rhinos have high commercial value as a tourist attraction in game reserves, adding to the commercial viability of wild life parks as one of the so-called Big Five animals to be spotted. As a result game reserves and national parks are going to extreme measures to mitigate the problem posed by poaching. These interventions are however focussed on the 'component' level in many ways and include poisoning of the horns to cause violent sickness in humans that take the preparations made from the horn (Smith 2013, Gosling 2012), to deploying the military in the Kruger National Park (Mouton 2012), to erecting more fences. There is also a flood of technical solutions under development (Kings 2014).

Broad Requirements. A wide stakeholder group now identifies with the problem of rhino poaching. Initially the game parks and game farms were hit by isolated instances of poaching and needed to protect their investment in expensive fauna. Over time local communities came to rely on the trade that is generated by tourists keen on experiencing the excitement of seeing wild rhino in an authentic setting. Environmentalists are now worried about the continued existence of the species in the wild given the increases in number of rhino killings, while police are tasked to curb the criminal activities surrounding poaching (including weapon smuggling and drug trade). Finally, the defence force must be seen to protect the integrity of the national border as many of the current raids occur as cross-border events.

At another level one should not discount the requirements of the criminals who are fulfilling the cultural needs of those that believe that the rhino horn should be exploited for their own health. Within the communities there are individuals taking part in the dangerous activity of killing the animals and removing the prized horns for a small payment to feed their families and to achieve social standing by being able to acquire symbols of affluence and success. Finally, rhino have a specific role as a species in the ecosystem and one would be safe to assume that the effects of removing them cannot be accurately gauged.

Complex. As was noted earlier, several attempts are being made to put an end to the slaughter, but most of these are focussed on addressing only a subset of the requirements directly and in the hope of having a system wide effect (a zero-sum approach). As with any mega-system, simplification will not necessarily yield a wise solution. Often the interventions are *reactive* and do not take full account of the latency caused by the temporal differences in different parts of the system. For example, one could argue that poisoning the horns (to directly affect the consumer, and thus demand) will only have an effect after the animal is slaughtered, and only on those at the end of the consumer chain. They may not be aware of the reason for their violent illness after taking the preparation containing the poison and may conceivable imagine that paying more for a better source may be a solution. This would drive demand and process up, putting the rhinos at greater risk. Similarly tourists would not be at all keen to see rhinos with brightly coloured horns, or no horns at all. And the criminal traders may even hand out retribution to the foot soldiers that sourced the poisoned horns.

To put this in proper perspective we are reminded by Sandhu and Wratten (Sandhu and Wratten 2013) that four types of *functional* ecosystem services (ES) sustain humans:

1. Supporting (cycling of water and nutrients),
2. Provisioning (production of food and fuel wood),
3. Regulating (control of erosion and water purification) and
4. Cultural (social and spiritual values and aesthetics).

This means that we should consider the rhinos within an ecosystem that supplies these services and their role within it. Manmade functional services include economic systems and agriculture to name a few, and these are to be considered equally.

The key insight from this discussion so far is that the rhino-poaching problem is embedded in a system that contains several nonlinear and recursive causalities – the system is rich in self-organising elements, making it hard to fully model accurately. This is a wicked problem and the real question that must be answered is this: How can we develop a deep enough shared understanding amongst the stakeholders to shift the system from where it is at present (heading to extinction of the rhino) to one where the rhino is preserved and where aspects of the system that could pull it back into the 'negative' outcome are managed to the point where they have only a slim likelihood of being re-activated? This is also the stopping criterion for the project. We accept that some of the stakeholders can only be reached indirectly, but we maintain that they need to be considered as part of the system we seek to manage.

Engaging parts of the system to develop a shared initial understanding. Following the recursive process depicted in Figure 3 and Figure 4 the project was kicked off with discussions with stakeholders from the game reserves at the Council for Scientific and Industrial Research (CSIR), mainly in Defence Peace Safety and Security (DPSS). After an initial meeting, strong communications links were built with the then-CEO of Sabi Sand game reserve. He was already interested in a "predictive modelling tool" to mitigate rhino poaching.

Functionally, the stated requirement for the initial tool is that it must help limit the number of rhinos poached while enabling the police to apprehend more poachers. Although the authors are aware that this is also the zero-sum problem, it is important to get a handle on the domain where there is a focus of resources. As the tool is developed, the assumption that catching poachers will help limit the likelihood of poaching, must be tested by understanding the motivation of the poacher "foot soldier" stakeholder group. As the understanding increases and the patterns of behaviour of the system are extracted, the tool must be updated or superseded to fit with the changing requirements and focus to include the broader stakeholder set.

To prepare for a workshop to be held in upcoming months to elicit expert knowledge from a wider stakeholder group, an initial framework model was developed (focus and problem structuring). The initial model is used as a centrepiece to elicit discussion and to develop common understanding (analysis). Changes to the project at that time will form part of the analysis. The outcome of the workshop will serve as a cornerstone of the modelling task to extract patterns of possible causal interaction and to assign likelihoods to events in the co-developed new model (synthesis and results in the real world).

The rest of the section will focus briefly on the process of the initial problem structuring and concurrent analysis and real world artefact development (the model) that will be used for the next recursive round. In this way the "method emerges from the research" (Morin 2008a).

Model design criteria. Different approaches were considered according to complexity, computational efficiency, and reliability. A predictive tool is presented to mathematically predict where a next poaching location is going to occur. Different sources of information are fused to obtain a reliable situation picture. The model is updated to reflect new and current information and trends. The idea is not to track the whereabouts of poachers or rhinos, but to send resources to specific hot spots in time to apprehend poachers and safeguard the rhinos.

An initial problem faced was how to fuse the different sources of data. Data might not be in the same units or in the same time frame (as was mentioned earlier, this is an important aspect of this system). Some data sources might also be less reliable than others. Another type of complication arises from the expert elicitation process: how do you obtain expertise and reasonable event likelihoods from experts? Lastly, environmental data is rarely plentiful and accurately measured. This has implications for the accuracy of the model. These realities drive the choice of the underlying logic model.

Bayesian logic was chosen for the initial discussion model, because strong tools exist to develop large reasoning networks using Bayesian logic. Bayesian networks are causal graphical models depicted by nodes and edges. The nodes represent the variables and the edges their causal links. By representing a problem with a Bayesian network, conditional probability (or likelihood) tables can be drawn up and questions can be answered about the system. Bayesian networks allow researchers to intuitively and easily construct visual systems that capture the underlying understanding of the problem space (Bishop 2007). It is possible to automate the updating of information and evidence in Baysian networks as well (Neapolitan 2004). A "what if" analysis can be done whereby certain variables are fixed so as to ascertain how certain management decisions will influence the outcome of the system. It is also possible to do sensitivity analysis to validate the model.

Concluding Remarks

It is generally accepted that problem structuring and system boundary setting are key aspects of systems engineering. As we face more complex systems, the so-called eco-socio-technical systems of the day, a shift in our approach to problem structuring and boundary management is required. It is also clear now that for these systems we need other methods of structuring, analysis and synthesis of the problem domain and possible solutions. In the paper we have gone so far as to state that we must rather aim to develop systems that resolve problems within a certain context than to look for the ultimate solution, and that these new artefacts (models and knowledge of the information age) must be used to make wise decisions, just like the classic artefacts (bridges, flight systems) allowed us to manage and live our daily lives.

Engineering design of systemic answers to complex mega-system problems are now even more important, because the increased segmentation of our knowledge base has made it difficult to ask the hard questions and to address the wicked problems. We proposed that adding a transdisciplinary approach may be one way to handle the complexity of these systems and we clarified how the recursive nature of the process and its inclusive manner can support co-development of new knowledge and understanding as well as artefacts like models to support decision making.

Our example focussed on the initial work of the past couple of years to find a novel approach to the poaching of rare species and the trade in rhino horns, for example. We showed briefly how we believe the transdisciplinary approach will yield an understanding that will lead to wise decisions that will impact all stakeholders and will over time remove the likelihood of the rhino going extinct as a result of poaching. Initial interactions with a few stakeholder groups have been positive and the work is enthusiastically supported.

Word of Thanks

We drew on many personal discussions and interactions in social media and consolidated the ideas here as best we could. Perhaps our biggest "thank you" must go to the reviewers of this paper who gave extensive constructive feedback and even allowed us to add their thoughtful ideas to the **Discussion** section of our paper. We do not know whom these selfless people are – but the cause is served.

From Twitter @cazzwebbo (Dr Carol Webb): Polarities and binary oppositions obfuscate the "truth" about diversity, complexity and the many outliers that don't fit a linear model.

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Biography

Henk Roodt is based in Dunedin, New Zealand. His company delivers technology program establishment and management services, research and business modeling support. This is built on his experience of system design engineering and analysis of complex problem spaces. As a scientist and systems design engineer he also has extensive experience in dealing with international clients and developing big business proposals. He has managed large research teams and is a recognized modeling and simulation expert. He is currently employed by the Waikato Institute of Technology in Hamilton to establish an industry focused transdisciplinary research facility in agriculture in the Waikato region of New Zealand. Henk holds a PhD in Engineering Science and a Masters degree in Physics. He is a member of Simulation Australia, the Institute of IT Professionals of New Zealand, the New Zealand Institute of Healthcare Engineering, the IEEE and the International Council on Systems Engineering.

Hildegarde Koen started her academic career in 2004 at the University of Stellenbosch in mathematical sciences, whereafter she obtained her Masters degree in Applied Mathematics in 2010. She started working at CSIR DPSS for the Command Control and Information warfare competency area in 2010 and is registered at the University of Pretoria's Electronic Engineering department for a PhD. In her spare time she loves baking cupcakes and working on her blog.