THE LEXICAL COMPONENTS OF THE DIMENSIONS OF SYSTEMS THINKING (DST)

The twenty working-level elements that make up the Dimensions of Systems Thinking lexicon are shown alphabetically in the table below. The table presents the definition of the lexical component in the context of a systems thinking; an explanation of why this is an important factor of systems thinking; the difficulties associated with this aspect of systems thinking; an example of this facet of systems thinking being done well (generally from engineering or analysis); and an example of this facet of systems thinking gone wrong. This list was developed to be as complete as possible in the sense that the expression of any systems thinking process could be described using these twenty lexical components – but just as new genus and species are added to the hierarchy of biological classification and new elements are added to the periodic table, new elements will undoubtedly be added to this list as discussion and the development of systems thinking progresses. The list expresses a baseline of a lexicon. In language, there are multiple ways to express an idea and appropriate synonyms exist for every term in the list. This is a non-unique set and other spanning lexicons certainly exist.

	Definition	Why Important	Why Difficult	Positive example	Negative example
Axiological components [1], [2]	Factors not necessarily obvious at first examination of the system, particularly to the decision makers; axiological components frequently involve the underlying values (including feelings and beliefs) or agendas behind the mental model and the willingness of stakeholders to accept change [see: *Outscope*]	The latent axiological components of a scenario may lead to conflicts that hinder the resolution of the problem; identifying and resolving these conflicts may be the only way to truly solve the problem and achieve the normative scenario	The axiological facet can involve deeply set feelings and may include partisan or even religious overtone; trying to discuss them may make the stakeholders feel attacked, possibly making them defensive and less cooperative	A systems analysis of the transportation system in Canada that considers the lifestyle and desires of citizens as well as the political mores of the key decision makers [3]	An aid program that delivers a water purification system to a village to help eradicate childhood diarrhea but ignores practicalities and the local beliefs and sensibilities that must be considered [4]
Descriptive scenario [1], [5]	An illustration of the current state of the system; may include diagram(s) and a taxonomy to describe the system/problem and its environment; considers the functional, physical, allocated and interface architectures of the system; describes the situation as it is and how it got to be that way (See also *Type of System.)*	The systems thinking analyst must have a comprehensive understanding of the system - without being a subject matter expert - in order to properly plan and conduct the systems analysis	The systems analyst is not a subject matter expert and therefore must rely on their own ability to learn the subject quickly while relying on SMEs. The experts that are already engaged with the system are likely too close to it to see the problem clearly	Farmers addressing the causes more than the symptoms of soil erosion in Zambia [6]	The Renewable Fuel Standard 2 (RFS2) (EPA) directed the production of 15 billion gallons of corn ethanol annually to be blended with gasoline for use in internal combustion engines. Data now show that the descriptive scenario was incorrect and the maximum amount of ethanol that could be consumed would be less than 13 billion gallons; ethanol production surpassed consumption and new plants were shut down.[7]
Develop alternatives [1]	Different routes to achieve or perhaps improve upon the normative scenario; Tools to aid the development of alternatives may include: brainstorming, brain writing, dynamic confrontation, Zwicky morphological box, options analysis, Delphi	This is the creative aspect of systems thinking where good outscoping can make the difference in a systems analysis by illuminating new options for system improvement; the systems thinking approach can result in recommendations that lie far from the original concept of the decision makers	All stakeholders will have ideas for how to improve a system, the analyst must filter carefully to avoid excessive analysis and frequently derive original options based on the systems thinking approach	Considering teleworking in a transportation/energy use study [8]	A surgeon who fails to consider alternatives to surgery when treating a patient - in this case performing an unnecessary hysterectomy [9]
Evaluate & rank alternatives [1], [5], [10]	The application of systems engineering tools to score and rank the alternatives for the decision makers; tools may include: modeling (physical, quantitative, qualitative, mental), operations research techniques, utility theory, game theory applications, design of experiments, statistical analysis, simulation, market research, trade study techniques, optimization tools, decision analysis, financial analysis and utility functions	Decision makers want factual, quantitative analysis to support their decisions; they also want valid options, particularly valid ones they had not previously considered;	Sensitivity analysis plays a key role in identifying options and critical metrics. Weightings can then be modified to study optional scenarios [see: *Leverage Points, Iterate Analysis*]	Base re-alignment and closure office - BRAC, evaluated all U.S. military installations and facilities with the objective of reducing the footprint and base costs of DoD [11]	BRAC (Bitburg, Germany air base was closed in 1993 BRAC and all aircraft relocated to Spangdhalem 10 miles away. Two + 1/2 years later, Bitburg was leased back & reactivated at considerable expense so that the runway could be resurfaced at Spangdhalem) [12]

Indices of performance [1]	Criteria for ranking alternative solutions to the problem; must be: meaningful, understandable, related to individual objectives and determined from defined metrics (see: *metrics*) using system modeling, statistical analysis, datamining, trade studies, house of quality, hierarchical decision tools, financial analyses, etc.	A quantitative, logical ranking of alternatives is the basic result of a systems analysis; this ranking is supported by the IPs and generally includes the option to make no change - the baseline scenario.	The analyst must avoid performing unnecessary analysis, using inappropriate analysis tools, over-complicating or over-simplifying the analysis	Decision trees with probabilities derived from statistical analysis that are used by doctors when performing differential diagnosis [13]	More accurate forms of statistical regression not used because they may be harder to understand or compute (e.g.: support vector machines used in place of artificial neural networks because ANN was determined to be more difficult to use.) [14]
Interactions [1], [2], [15]	A systemic analysis of the interrelations between goals, activities, constraints, resources, stakeholders and other system interactions	Illustrating systemically the interrelations of a system can reveal key cause/effect relationships including nonlinearities and feedback loops that may not be otherwise be evident but should factor in the analysis	System complexity can make charting interrelations daunting, automation can alleviate much of the task; unexpectedly high levels of causality can lead to a re-definition of system boundaries	Correctly modeling the integration and correlation of energy and agricultural markets resulting from US corn-based ethanol policy [16]	Failure to correlate prior to the decision to invade Iraq what the consequences in term of global terrorism might be [17]
Iterate analysis [1]	Repetition of the systems analysis in order to consider modifications to the scenario	Systems analysis tools allow the consideration and evaluation of many options as the analyst modifies the scenario(s) to accommodate new ideas including changes derived from the original analysis such as changes to leverage points identified in the sensitivity analysis of a simulation	Frequently the scope of the analysis will limit the number of options and iterations	Total-system performance assessment for Yucca Mountain - second iteration considers effects of climate change and other new factors [18]	Poor business decisions that can result when management fails to iterate through all the possibilities - Bob Rice **THREE MOVES AHEAD: WHAT CHESS CAN TEACH YOU ABOUT BUSINESS [19]**
Leverage Points [20]–[23]	Focus points in the system where a small change to the system could lead to a large reaction	Identifying leverage points allows the systems analyst to study optimal mechanisms for systems change as well as potential systems vulnerabilities	Leverage points, particularly in complex systems, tend to be counterintuitive. Engaging the leverage point incorrectly will degrade the state of the system quickly so careful analyses must be brought to bear.	Royal Dutch Shell analysts identifying in the early 1970s the risk and potential effect of an Arab oil embargo and planning accordingly. **The art of the long view** - Peter Schwartz [24]	Forrester's study of urban dynamics (1969) showing that subsidized urban housing is a leverage point - the less of it there is, the better off a city is, including low-income residents [as cited in **Thinking in Systems: A Primer**, D. Meadows, 2008] [22]
Life cycle of system [11, [5]	Temporal description of the life of a system (may include temporal system boundaries); the lifecycle considers what comes before the system and what comes after in a cyclical concept to retirement (aka: cradle to grave or cradle to cradle) context	Considering the cyclical nature of a system vs. the linear approach is a hallmark of systems thinking. All systems can trace a beginning and no system will continue forever.	Analysts like to focus on linear segments of the life cycle - because it's easier and sometimes that's enough, but doing the extra work to outscope and consider the entire system life cycle can reveal important aspects of the system and lead to better solutions	Life cycle comparison of paper vs. plastic disposable grocery bags that shows plastic has less environmental impact [25]	Modern industrialized agriculture that took the traditionally cyclical system of agrarian society and replaced it with a linear industrial system without consideration of the system lifecycle [26]
Metrics	The data used to determine system performance; must be: measurable, objective, nonrelativistic; may be from existing data, survey data, data collected from a correctly designed experiment	Metrics form the core of the systems analysis. If they are incorrect, the analysis is invalid	Fitting the analysis to the data instead of obtaining correct data must be avoided; the data delivered by the key decision makers may not be useful, but omitting them may cause offense; the existing data may not be valid or missing critical variables thus overlooking key information;	OECD metrics for main economic indicators [27]	The use of data from extreme weather events such as high snowfall or increased tornados to negate or support climate change analysis [28]
Normative scenario [11, [2]	The description of the system in the optimal, desired state as agreed upon by the key decision makers and as the ultimate outcome of specific proposed alternatives. Should be a clear, measurably quantitative change from the descriptive scenario	The normative scenario must thoughtfully consider the needs of and impacts to all stakeholders and their respective mental models. Outscoping plays a key role in understanding the real normative scenario - the problem the client may not see.	The key decision makers may not understand what the actual goals of their system may be and therefore may be focused on a solution that may not be optimal.	Defining a comprehensive energy system scenario in Copenhagen, Denmark that reduces consumption, produces minimal pollution and waste while approaching sustainability [29]	U.S. Army effort (2003-2009) to develop an integrated Future Combat System based on a flawed perception of future threats and future technologies [30]

Objectives [1], [2]	Clarification of the normative system in a hierarchical manner that sets the stage for the systems analysis; the objectives include the sub-goals required to solve the problem, i.e.: to get from the descriptive to the normative scenario; the objectives tree starts with the principal objectives and branches out to the sub-objectives required to progress toward the superior objectives	A well-described, hierarchical objectives tree becomes a clear definition of the problem and a framework for a systems solution to the problem. Practical aspects of working toward the solution such as indices of performance, metrics and requirements definitions are derived from the objectives tree.	The objectives tree requires the input of subject matter experts who may not fully understand the problem but are capable of in-scoping the problem analytically to make the sub-objectives practical; the level of granularity of the sub-objectives can omit key characteristics if too broad or bog-down the analysis if too fine; (see Scope)	Fitch's 8 goals for an urbanizing America [31]	Failure to develop a clear objectives tree for the Future Combat System - the objectives were vague and centered around technology risk reduction [32], [33]
Observer Effects	The analysis affects the system so the analysis and the analyst must be considered as parts of the system being analyzed. The analyst must correctly position his/her self within the system as an observer and source of recommendations, not a decision maker.	Unless a system is 100% automated, the act of systems analysis will have some impact on the system. A correct systems analysis must take this effect into consideration and account for it in the sensitivity analysis and the recommendations. A systems analysis that introduces bias from the analyst will not reflect the correct system objectives and requirements.	The primary decision makers are immersed in the system and frequently do not understand the systems aspect of the problem. The analyst must always be cognizant of the primary decision makers and not confuse roles. Recommendations must suit the normative system – the system that does not contain the analyst.	A retail firm engaged a systems analysis firm to provide a staffing simulation model. The analyst correctly brought to bear an outside-the-system perspective and determined that the problem was not staffing but store layout – resulting in a valid systems analysis. [1]	An analyst at an FFRDC working on a simulation project said, “I don’t have a client, only a sponsor.” He had confused roles making himself the primary decision maker and without input from the actual primary decision maker. The analysis failed. [1]
Outscope [1]	An expanded generalization of the problem and the system in which it exists beyond the original problem description to add insight (limited by practical concerns, see *scope of the analysis*)	Outscoping is a key factor of systems thinking - the ability to step back from the system and see it with systems eyes allows better problem definition and leads to better solutions; outscoping can produce both blue-sky alternatives as well as revised value for the option to do nothing.	Outscoping can be one of the hardest things for experienced engineers and professionals to consider; they know their subject matter much better than the analyst, but this focus prevents them from viewing the problem through systems eyes. To outscope all judgment and criticism must be suspended.	The Department of Defense directing that managers must open teleworking to as many employees as possible (30 percent by 2020) to improve quality of life, reduce traffic congestion & pollution [34] iPod ecosystem & a thermostat "Steve had a way of scoping the problem bigger. He could just look at a problem and find the solution by thinking larger." [35]	Citizens (Atlanta, Ga) voting against a one-cent sales tax hike to improve transit when they spend, on average, 127 minutes of every day stuck in traffic [36]
Recommendations	Provide results in a language that the key decision makers can understand. May also include system requirements and/or a system design; recommendations are clear, concise, brief and support all statements with results from the system analysis in an executive summary. Follow-up with more depth in a conclusions section at the end of the analysis.	The best analysis ever done will be of little worth if the analyst cannot properly communicate the results; Brevity and clarity are critical; high level decision makers presented with a myriad of complex recommendations have precious little time to probe them deeper	Engineers tend to be proud of their hard work and eager to show it off - but executives want clear, concise answers not volumes of results; great care should be taken in presenting outside-the-box recommendations that they not be dismissed for their seemingly extreme perspective.	Present recommendations in the form of a clear, easy to understand list as in "Why Invest with Children's Paradise" slide 11 [37]	Pentagon PowerPoint slide of the integrated defense acquisition life cycle [38]
Scope of the analysis	Limits to systems analysis driven by data availability, cost, available time, politics and other limitations imposed upon the analysis; after outscoping, the scope imposes practical limits that rein-in the analysis; [boundaries define system, scope defines analysis]	Just like system boundaries, limitations to the scope can result in the omission of important system impacts. Assumptions that are made in modeling alternatives are included in defining the scope of the analysis and need to be verified as part of the evaluation.	All systems analyses are limited by their scope but the systems analyst must also use systems thinking to maximize the impact of the analysis given the limitations to the scope	A Limited-Scope Reliability-Centered Maintenance Analysis of Wind Turbines that focuses on the most critical subsystems with respect to failure frequency and consequences. [39]	The model of everything will take forever to build and be of very little practical use [40]

State of system [5]	A categorization of the system in terms of its life cycle and environment, the state can include the technology readiness (TRL), stage of development, position of the system within its life-cycle, cost of system;	Understanding the state of the system can help determine if the system is ahead of its time, obsolete, an over-extension of current technical capability, overly ambitious, or a breakthrough whose time has come	The technical assessment of the state of the system may initially come from key decision makers/subject matter experts whose perception may be incorrect; the state of the system may include factors not considered before the systems analysis	Introduction of the iPod system at the point where the technology and the customer base were ready for a new medium to store music that interfaced easily with a personal computer [41]	Thirty years of development and expenditure toward missile defense including high-speed missiles, airborne lasers and space-based interceptors. [42]
System boundaries [43]	The definition of the system in terms of what it encompasses: the temporal, spatial, and physical limitations of the system; system displacement;	A description of the boundaries of a system considers what will be improved, affected or replaced by the system and, conversely, what affects the system under study, as the system changes and is changed by its environment - observing what constitutes that environment helps the systems thinker to define the system boundaries. Incorrect system boundaries can result in the omission of important system impacts	System boundaries may seem well defined at the initial stage of the analysis but become subject to change as the analysis progresses. Analysts may focus on limited dimensions of the system boundaries, omitting other dimensions and thus omitting important aspects of the system	Defining the boundaries of the nitrogen ecology to include the impact of automobile emissions on watersheds [44]	An auto company that develops an SUV while ignoring the temporal system boundaries of the life cycle in which the cost of fuel may climb to a point where the vehicle becomes unaffordable to the target market [45]
System stakeholders [1]	The human elements and organizations that have an effect on the system and/or are affected by it	Virtually all systems are judged by their impact on the stakeholders; for example, this could be the return on investment for some stakeholders, the political benefit for some stakeholders or the health impact on some stakeholders	When outscoping the system, stakeholders on the margin may be inordinately affected by the system or have an inordinate impact on the system; analysts tend to focus on the key decision makers and neglect other stakeholders; the term "stakeholder" is undergoing a period as an overused buzzword in some analyses	Including considerations of tribal stakeholders regarding a burial ground in a systems analysis of a new building construction [46]	Corn-ethanol biofuel systems analysis that erroneously omits the millions of stakeholders worldwide who depend on inexpensive American corn for sustenance [47]
Type of system [51, [48]	The type of system will have several descriptors and may include: natural or man-made; closed or open; static or dynamic, simple or complex, reactive or non-reactive	Categorizing the type of system under consideration is a prerequisite to properly establishing the system boundaries; deciding how to represent or model the system; and considering what nature the solution to the problem will likely take	It can be more convenient to model one type of system versus another and this can influence the analyst to incorrectly use the tools they have instead of the correct approach	Categorizing energy systems as dynamic systems, not the static, closed-cycle systems described in a life-cycle assessment [49], [50]	In a pollution analysis, incorrectly classifying a production system as a steady-state system instead of a dynamic one [51]

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