Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

An Approach to choose Systems Engineering using Research Methodology

Ritesh G. Patankar[1], Manoj P Parmar[2], Nilesh D. Patel[3]

[1]*EC Department, Government Polytechnic, Gandhinagar*
[2]*IT Department, Government Polytechnic, Himatnagar*
[3] *EC Department, L.C. Institute of Technology*

Abstract-- One of the challenges of Systems Engineering Research is a series of choices related to what to study & how to study. This article focuses on the specific questions related to research methodology choices in systems engineering. The reasons for methodological choices in systems engineering are discussed. The connections between theory, methodology and domain and provide implications for researchers are discussed. This article presents a simple research model to help researchers to enhance their research work.

Keywords-- System Engineering (SE), System Engineering Process (SEP)

I. INTRODUCTION

A System Is …

Simply stated, a system is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective [2, 8].

Systems Engineering Is…

Systems engineering consists of two significant disciplines: 1. The technical knowledge domain in which the systems engineer operates, and systems engineering management. 2. A logical sequence of activities and decisions that transforms an operational need into a description of system performance parameters and a preferred system configuration. An interdisciplinary approach that encompasses the entire technical effort, and evolves into and verifies an integrated and life cycle balanced set of system people, products, and process solutions that satisfy customer needs [3, 8].

In summary, systems engineering is an interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions that satisfy customer needs.

The Systems Engineering Process…..

The systems engineering process is a top-down comprehensive, iterative and recursive problem solving process, applied sequentially through all stages of development,

That is used to:

- Transform needs and requirements into a set of system product and process descriptions.
- Generate information for decision makers, and
- Provide input for the next level of development.

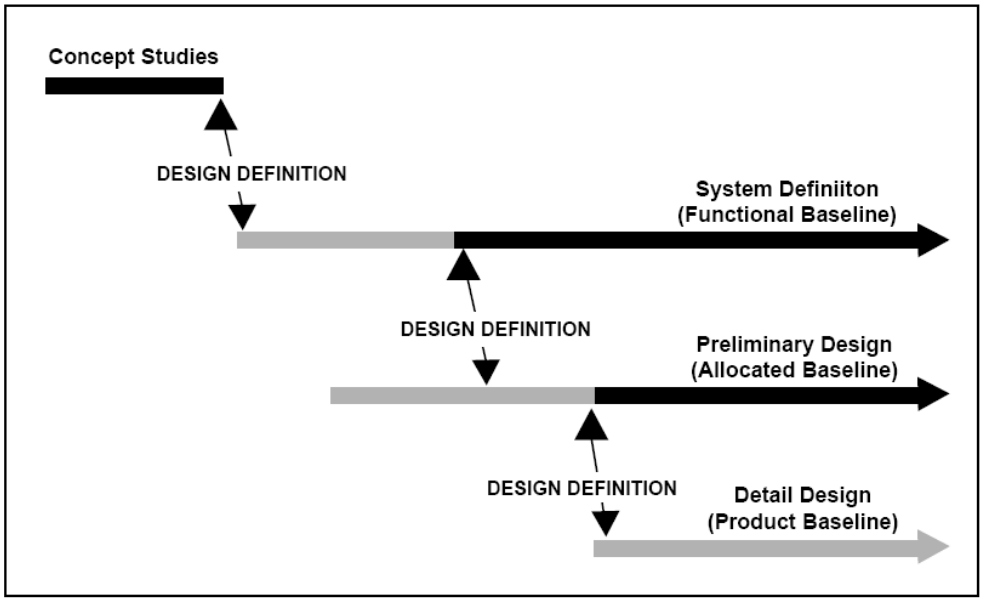

Fig. 1 Development Phasing [5, 6, 7]

II. MOTIVATION

If systems engineering aspires to the status of a serious scholarly discipline "it will have to show that within the subject there is a cycle of interaction between the formulation of theory relevant to serious problems or concerns, and the testing of that theory by the application of methodology appropriate to the subject matter…It will lead to ideas from which we can formulate two kinds of theory, substantive theories about the subject matter … and methodological theories concerning how to go about investigating the subject matter."

The Systems Engineering Process: The fundamental systems engineering activities are Requirements Analysis, Functional Analysis and Allocation, and Design Synthesis—all balanced by techniques and tools collectively called System Analysis and Control. Systems engineering controls are used to track decisions and requirements, maintain technical baselines, manage interfaces, manage risks, track cost and schedule, track technical performance, verify requirements are met, and review/audit the progress [1, 6, 8].

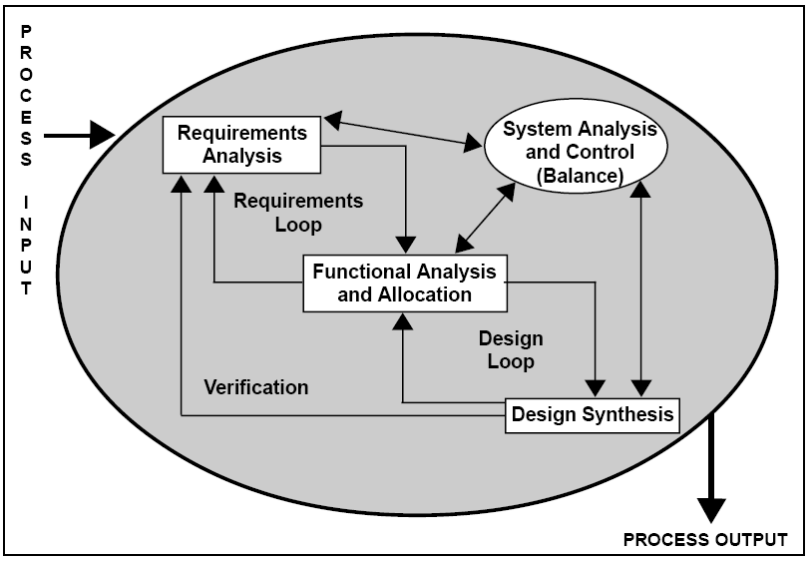

Fig. 2 System Engineering Processes [5, 6, 7]

Choices of Methodology: Methodology is a higher order term that refers to the logical principles that must govern the use of methods in order that the philosophy/theory embraced by the approach is properly respected and appropriately put into practice.

Choice of methodology affects not only the way in which the research is conducted, but also:

- The way in which the data are analyzed.
- The way in which validity is demonstrated.
- The type of knowledge contribution that can legitimately be claimed.
- The applicability of that knowledge to other contexts.

Consequently, methodology must be addressed in the early stages of a research program. It is not adequate for it to be treated as an afterthought or – worse – ignored completely.

Methodology is not detachable from the philosophy/theory of the particular systems approach, or, therefore, from the approach itself. Methods, however, concerned as they are with achieving more specific procedural outcomes, are detachable and can be used in the service of other systems approaches with varying degrees of success and failure".

III. METHODOLOGICAL CHOICES

The selection of an appropriate research methodology is complicated by a myriad of considerations. Systems engineering as a discipline stretches from physical science at one extreme to social science at the other.

Methodological Choices as a set of dilemmas

Examples of research methodologies that are applicable to systems engineering[1] are discussed from the viewpoint of the social sciences. There are at least eight readily distinguishable research strategies:

1. Laboratory experiments
2. Experimental simulations
3. Field experiments
4. Field studies
5. Computer simulations
6. Format theory
7. Sample surveys
8. Judgment tasks

Systems engineering researchers tend to favour strategies that are "field" oriented rather than "lab" oriented because of the people-centric nature of our discipline. Furthermore, there is a preference towards "simulation" over "experimental" since there are not many ample opportunities to study systems engineering phenomena *in situ.* Lastly, there are strong preferences towards "empirical" over "theoretical" which is a reflection of the results-oriented approach of engineers [1].

There is a clear bias in methodological choices in our discipline that is driven by three traditions:

1. **Positivist tradition**. Engineers and physical scientists often (though not always) prefer to define the theory first and then find cases that help validate the theory. The opposite approach, known as interpretive, would be to have no theory defined and allow the observations or data to surface a theory that can subsequently be tested. One of these being the rigidity in which hypothesis testing is done [13].

2. **Method based tradition**. This is simply known as the "copycat" approach that stems from replicating someone else's method. The danger in re-using methods outside the original context comes from transferability of methodology from one context to another. It also assumes that the other person selected the correct methodology for their study which may be unintentionally flawed [13].

3. **Directed tradition.** This can also be referred to as the "my supervisor told me" approach. This is clearly a more difficult discussion to have since research supervisors give advice based on a series of factors such as their personal specialty, the context in which the research sponsor is supporting the work, the availability and form of the data, and the intellectual traditions of the academic department, university or country [13].

Connecting theory, methodology and domain:

Given these approaches, it is logical to consider the question: how *should* our research methodology be selected?

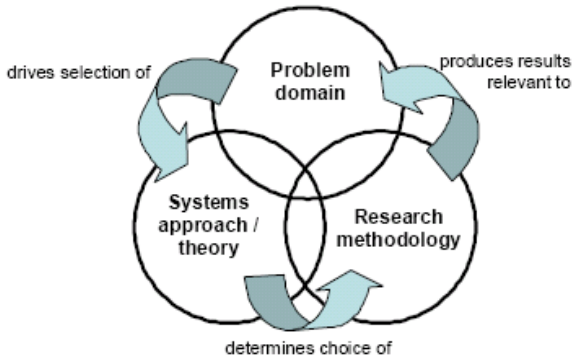

Fig. 3. Connecting theory, methodology and domain [13].

Figure 3. Shows the connections between research or problem domain, systems approach or theory and the research methodology is to be used. The main principles are that:

- The theory being used should be consistent with the problem domain and context.
- The research methodology used should be consistent with the theory upon which it is based.
- The research output – the answer to the research question - should be relevant in the problem domain.

Using the problem domain to determine the systems approach /theory

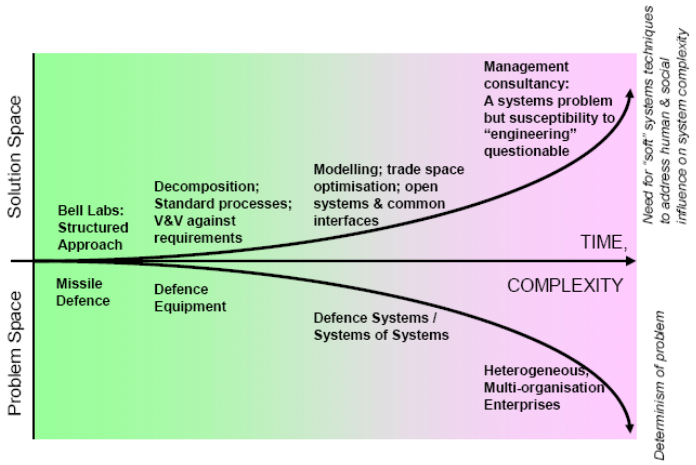

Fig. 4 Types of System Engineering [13].

Figure 4 identifies the different types of systems engineering which have evolved in a defense environment in the 1950s, although the principles are equally applicable in other domains. It illustrates that as problems become more complex, the most useful systems principles and approaches change, reflecting an increasing need for softer approaches. With time, and increasing complexity, we are moving towards the right hand side of the graph in Figure 4. Not in everything – some problems still sit in the green area – but increasingly, we need different systems techniques, approaches, theories (solutions) to solve our systems problems [1, 7, 8].

Selecting methodology based on systems approach

At the left hand side of Figure 4, experimental methodologies are appropriate for the conduct of SE research, but as we move to the right it becomes more difficult, more susceptible to issues of validity and ethicality. At the left hand side, 'human issues' in the system relate to, for example, ergonomics and cognitive capabilities. At the right hand side there is a need to deal with social issues such as trust.

IV. CONCLUSION

Research in systems engineering starts with a clear articulation of the current situation and its perceived problems. Researchers can transform the problem into objectives. They can look for new ideas, or methods or techniques from the existing body of knowledge to improve the current situation.

REFERENCES

[1] Rhodes, D. and Valerdi, R., "Enabling Research Synergies Through a Doctoral Research Network in Systems Engineering," Systems Engineering, 10(4), 348-360, 2007.
[2] Valerdi, R., Davidz, H., "Empirical Research in Systems Engineering: Challenges and Opportunities of a New Frontier," Systems Engineering, 12(2), 169-181, 2009.
[3] Alexander Kossiakoff, William N. Sweet, "Systems Engineering Principles and Practice Second Edition.
[4] Eric Honour, "Understanding the value of System Engineering" Pensacola, FL32533.
[5] Chris Salter, NASA, Sami Saydjari, DARPA, "Toward a Secure System Engineering Methodology"
[6] SEBOK, Guide of System Engineering, May 13, 2014.
[7] System Engineering Fundamentals, Dept of Defense, Virginia, January 2001.
[8] Checkland, P. (1981), Systems Thinking, Systems Practice, and Chichester, UK: Wiley.

[9] Ferris, T.L.J., "On the Methods of Research for Systems Engineering," 7th Annual Conference on Systems Engineering Research, Loughborough University, 2009.
[10] Ferris, T.L.J., Cook, S.C., Honour, E.C., "Towards a Structure for Systems Engineering Research," 15th INCOSE Symposium, Rochester, NY, July 2005.
[11] Jackson, M.C. (2003), Systems Thinking: Creative Holism for Managers, Chichester, UK: Wiley.
[12] Lee, N. & Lings, I. (2008), Doing Business Research: A Guide to Theory and Practice, London, K: Sage.
[13] Brown, Samantha, Valerdi, Ricardo "Towards a Framework of Research Methodology Choices in Systems Engineering", 8th Annual Conference on Systems Engineering Research (CSER), 2010.

