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Systems Engineering: Why is it Important ?

Beni Suranto

Department of Informatics, Faculty of Industrial Engineering
Universitas Islam Indonesia
e-mail:beni.suranto@uii.ac.id

Abstract

This paper is concerning about systems engineering which has strong relationship with software engineering field both in the concepts and in the practical aspects. This paper starts with the explanation about some important concepts in systems engineering such as definitions, characteristics, and real practice examples. The next part of this paper will discuss about the need of systems engineering and the professional competencies of systems engineers. The last part of this paper will discuss about the benefits of teaching systems engineering to software engineering students.

Keywords : *competencies, software engineering, systems engineering*

1 SYSTEMS ENGINEERING CONCEPT

INCOSE (2006) stated three representative definitions for systems engineering. The first definition defines systems engineering as a profession, the second definition defines systems engineering as a process, and the last one defines systems engineering as a perspective. From those definitions, there are some important keywords to define what systems engineering is : wholeness, iterative, interdisciplinary, and sociotechnical.

To understand the concept of systems engineering we must first understand systems thinking. Systems thinking is the basis for the systems engineering perspective. It occurs through some enriching processes such as diagnosis, learning, dialog, and discovery that allow engineers to sense, model, and discuss about the real-world so they can have a better understanding to define and work with large or complex systems. Systems thinking can be considered as a unique perspective about the wholeness of systems (INCOSE, 2006). Engineers with a good systems thinking will be more aware of the wholeness aspect of systems and how all elements in the systems interrelate. Engineers with a good system thinking always know exactly how their systems can be integrated in the larger context of daily life. They also completely understand about their systemss behaviors and how to effectively manage them.

Systems engineering is different from traditional engineering disciplines such as mechanical, computing & software, mining, electrical, petroleum, or aerospace. With the "ystem as a whole" perspective, systems engineering emphasis the systems total operation. Systems engineering concerns with not only engineering design but also external factors of the system

and the interactions between the system with the environment (Calvano, 2004). Also, its not only aware about the inside view but also the outside view of the system. Systems engineering can be understood as a concept that bridges all traditional engineering disciplines involved in a big, large, complex project. Furthermore, systems engineering inherent some important aspects of the project management concept that concern with the engineering effort in the project, setting the mission or objectives of the project, guiding the projects executions, and evaluating the projects results (Klatt, 2009). Some examples of complex systems required systems engineering in their development process are shown in Figure 1-4.

(Source: http://tech4technology.com/wp-content/uploads/2012/08/mars-rover-curiosity-sky-crane-landing.jpg)

Figure 1: NASA's Mars rover Curiosity

(Source:http://media.treehugger.com/assets-/images/2011/10/japan-nuclear-reactor-power-meltdown-earthquake-photo-04.jpg)

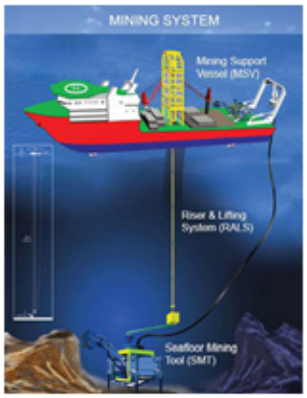
Figure 2: Nuclear Power Plant

2 THE NEED OF SYSTEMS ENGINEERING

The aerospace and defence industries are two major fields where systems engineering is intensively used, but this concept are also used in many other fields. Rouse (2007) mentioned that every organization is complex and can be considered as a system. Systems engineering is a primary need for improving organization and is a powerful weapon to defeat the three

(Source: http://www.thehindubusinessline.com/multimedia/dynamic/00767/BL29ASH1_767297f.jpg)

Figure 3: Car Manufacturing Plant



(Source: http://www.marinelog.com-/IMAGESMMVII/nautilus.jpg)

Figure 4: Offshore Mining System

evils of engineering : complexity (underestimating the complexity of the project), lack of understanding (of the objectives of the project, the relationships within elements of the system, solutions of problems occurred during project life cycle) and communications problems (between engineers in the team, between organizations, within the project).

Systems engineering is becoming increasing prevalent and important, especially in the projects that aim to produce large or complex systems. By applying appropriate systems engineering methodologies, the project team can effectively manage complexity and change during the system life cycle. The need for systems engineering also driven by the fact that in the past 50 years the delivery time of a new product (from prototyping phase to market penetration phase) has dropped dramatically by more than a factor of four. This is shown in Figure 5.

An innovation always affected by complexity and todays products (i.e. systems required to solve specific problems) have longer life cycle phases because most of them use the incre-

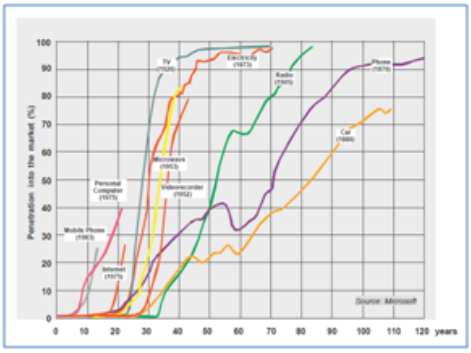


Figure 5: The delivery time of products in the last century (INCOSE, 2006)

mental improvement methods (Klatt, 2009). An appropriate systems engineering principles and processes becomes critical for the industries in order to establish and maintain their competitiveness level. By applying systems engineering principles and processes, the industries can quickly penetrate the market and deliver high quality products to their consumers in an efficient way. Systems engineering offers offers a rigorous process of requirements management that is very helpful for the project team to produce high quality requirements (i.e. well-defined, have adequate levels of traceability, consistent and verifiable). By producing high quality requirements, the project team can ensure that the design of the system accurately reflects the user requirements and the time-consuming changes or modifications to the system requirements in the later phases can be minimized. Furthermore, the project team can reduce the delivery time of the system. Figure 6 explains about how the system life cycle can be improved by applying the systems engineering method.

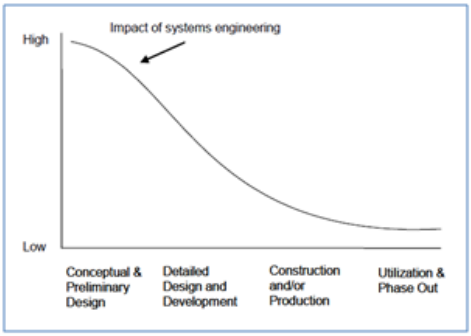


Figure 6: Impact of systems engineering method on the system life cycle (Calvano, 2004)

Beside reducing the delivery time, successful applications of systems engineering also allowing the industries or the project teams to gain significant life-cycle cost (LCC) savings. Well-defined and well-organized systems engineering processes can be very useful for the project team to save their money in some important phases, including the construction, operational use, system support, and the disposal phases of the system life cycle.

Honour (2004) conducted a survey to study about the impact of systems engineering

practices as perceived by INCOSE members and by NASA employees. The survey used more than 40 questions associated with some important aspects of organizations and complex system projects such as cost, schedule, risk, value, demographic, and so on and so forth. The survey investigated two things. The first one is about the overall impact of systems engineering practices on complex systems projects. Second, the survey investigated about the impact of software engineering practices on the cost of the projects. The result is shown in Figure 7 and Figure 8.

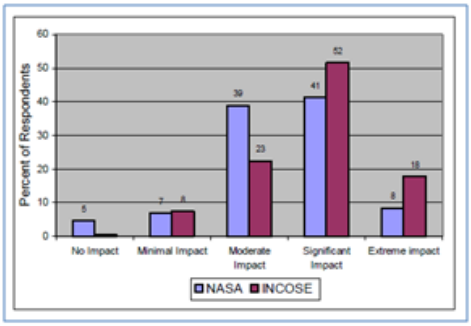


Figure 7: Overall impact of systems engineering on complex systems projects (Honour, 2004)

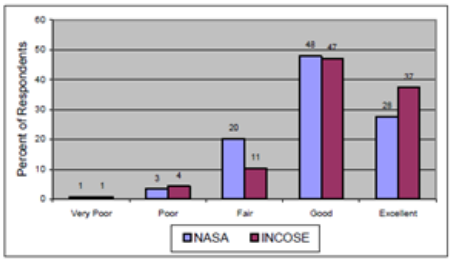


Figure 8: Impact of systems engineering practices on cost of complex systems projects (Honour, 2004)

3 COMPETENCIES AND SKILLS FOR SYSTEMS ENGINEERS

Kasser (2010) stated that a good systems engineer must have competencies in three areas:

1. Knowledge. A good systems engineer must have an adequate knowledge of systems engineering principles and processes and the application domain of the systems they develop.

2. Cognitive characteristics. A good systems engineers must be able to identifies, thinks and solves the problems during the system life cycle both in the conceptual and real-world domains.

3. Individual traits. A good systems engineers must be able to works wirk, communicates with, influences and leads other engineers in the project team.

Figure 9 shows more detail about three competencies areas aboved.

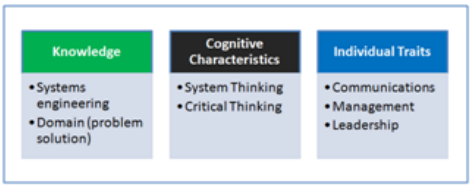


Figure 9: Three competencies areas of systems engineers (Kasser, 2010)

Ryschkewitsch and Schaible (2009) mentioned 11 personal characteristics of a good systems engineer:

1. Intellectual curiosity. A good systems engineer must be able and desire to learn new things. He/she must have strong perpetual learning spirit and always be motivated to encounter new ideas, problems, challenges, and technologies.

2. Ability to see the big picture. A good systems engineer must be capable to maintain a big-picture perspective during the project. He/she must have a complete understanding about his/her role in the project and the project itself.

3. Ability to make system-wide connections. A good systems engineer must understand the connections among all components of a system in his/her project.

4. Exceptional two-way communicator. A good system engineer must have very good communication skills (listen, talk, and write) in order to bridge the communications gaps on his/her team.

5. Strong team member and leader. A good systems engineer must be skilled both in leadership and management.

6. Comfortable with change. A good systems engineer always realize that during the project life cycle change is inevitable so he/she anticipate change and find the solution about how the project deal with the effects of the change in a proper way.

7. Comfortable with uncertainty. Systems engineers will always find uncertainties during the project. h. Proper paranoia. It means that a good systems engineer always expecting the best, but thinking about and planning for the worst.

8. Diverse technical skills. A good systems engineer must be has an adequate understanding of many technical disciplines.

9. Self confidence and decisiveness. A good systems engineers has a good self-confidence and undertands his/her strength and weaknesses.

10. Appreciate the value of process. A good systems engineer appreciates the value of process.

4 THE BENEFITS OF TEACHING SYSTEMS ENGINEERING TO SOFTWARE ENGINEERING STUDENTS

In general, software engineering courses (e.g. programming methods, object-oriented development, requirement engineering, software testing, etc) mainly focus on techniques to develop software systems and less discuss about the softwares operational context. This situation has at least two negative consequences (Sommerville, 1998):

1. Some students have no understanding of the relationships between software and other components of large, complex systems. Many students do not appreciate other disciplined approaches required in the software development process because they are self-taught software developers.

2. Many graduates from software engineering courses have not enough understanding about the problems faced by engineers from other disciplines. They often difficult to communicate and make limited participations in the large and complex systems development process.

By learning about the systems engineering concept, students will get a better understanding of complex systems and real-world problems. For software engineering students, there are at least two positive benefits of integrating systems engineering in their courses (Sommerville, 1998):

1. By understanding the systems engineering concept, students can realize the potential of software engineering as an effective way to provide solutions of problems occurred in a complex systems. This will make they feel proud to be software engineers.

2. Systems engineering will make non-technical factors (human, social, economics, politics, etc) to be more real to students. It will show students that a programming solution is not always appropriate to solve a problem. With systems engineering, students will understand that the real systems strongly influenced by non-technical factors.

From the industry perspective, teaching systems engineering concept to software engineering students is very important since todays most industries in information technology area are unifying software engineering and systems engineering methods in their processes [13]. The industries unify software engineering and systems engineering methods to give them a great ability to tame the rapid changes of information technology. Also, experience indicates that the industries that combined software engineering and systems engineering methods found themselves far more suited to developing large and complex systems (Boehm, 2000).

One of the most popular products of software engineering development is the information system. The most challenging problem in information system analysis process is how the engineers effectively derive the requirements, especially in a complex, performance-critical, safety-critical, and expensive information systems. Systems engineering method is very useful for the engineers to help them to perform the analize problems in complex systems. With systems engineering method, engineers working on a complex systems project will be able to effectively identify the fundamental parameters, develop credible alternate solutions, perform trade-off analyses, and select the best solutions (Osmundson, 2000). Clearly, software engineering students need systems engineering skills to be able to deal with complex systems development process.

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