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EFFECTS OF OUTSOURCING ON FLEXIBILITY OF SYSTEM OF SYSTEMS

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ABSTRACT

The requirements of various stakeholders associated with System of Systems (SoS) are constantly changing. Consequently, the shareholders priorities of return and risk continuously shift. However, their expectations of gaining value from the enterprise are enhancing.

One way of enhancing value from the enterprise is by having the right amount of flexibility associated with the SoS. Flexibility can be defined as the ability of a system to be able to adapt and cope with the changing environment. Enterprise flexibility means creating options at various levels of the enterprise, developing ways and means of change across the range of options. One possible way of creating enterprise flexibility is by outsourcing certain functions which would help affect the flexibility of an organization. The outsourcing done might also have an effect on each of the building blocks of SoS Flexibility.

In this paper, we will look at how outsourcing would affect each of the building blocks of SoS flexibility as well as the overall flexibility of an organization and whether it is beneficial or not for an organization to outsource functions depending on how it affects their flexibility.

Keywords: *Outsourcing, Flexibility, System of Systems (SoS)*

Introduction

Systems are an integrative part of the global business scenario and organizational flexibility is becoming a requirement in order to remain competitive and keep pace with the changing operating environment and increasing complexity of systems. In recent years, the term System of Systems (SoS) has been increasingly discussed in both industry and academia as an emerging systems solution to complex problems. These complex problems with emergent and adaptive behaviors have also created a demand for flexibility in these systems. It is the dynamic environment that these systems routinely perform in that has begun to create this demand. As a result, there is a reciprocating impact on customer needs that are continuously changing, which results in an exponential increase in complexity. In order to remain competitive, these systems and the organizations that realize them have to have more options, which is a direct influence on flexibility. These options also create a strain on the resources of any system, both intellectual and physical. To address these constraints while maintaining a requirement for flexibility, the

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organizations that design these systems have to maintain a competitive advantage and by so doing rely heavily on the outsourcing of capabilities and resources. Outsourcing can enable an organization to be more competitive and offer the customers more value. However, outsourcing and the flexibility it potentially propagates, introduces a new set of risks. In this paper we will describe these emerging systems called System of Systems (SoS), discuss a set of outsourcing risks that we have identified in our research, and conclude with a discussion of the implications these outsourcing risks have on SoS and in essence their flexibility.

Flexibility of SoS

As the world experienced major structural and operational changes in production and manufacturing around World War II, there was a significant evolutionary paradigm shift in dealing with new complexities by introducing new engineering techniques that focused on a single complex system rather than separate individual components. It became known as the discipline of Systems Engineering (SE). Still, a process of rapid global acceleration, especially in the military sector continued and called for the next level of development in engineering and systems. The objective was to address "…shortcomings in the ability to deal with difficulties generated by increasingly complex and interrelated system of systems" (Keating, Rogers et al. 2003). There was a need for a discipline that focuses on engineering of multiple integrated complex systems (Keating, Rogers et al. 2003).

Today, these systems are defined as System of Systems and the discipline for developing their realization is known as System of System Engineering (SoSE). Some of the examples of System of Systems (SoS) are: The Internet (Maier 1996), The Transportation System (DeLaurentis 2005), The Integrated Deepwater Systems (IDS) program (O'Rourke 2007), The Future Combat System (FCS) (Lane and Valerdi 2005), and The Yellow cab System (Gorod and Sauser 2007).

There have been many attempts to better define SoS. For example, Kotov defined them as, "large scale concurrent and distributed systems that are comprised of complex systems" (Kotov 1997); Manthorpe's military specific definition states, "system of systems is concerned with interoperability and synergism of Command, Control, Computers, Communications, and Information (C4I) and Intelligence, Surveillance, and Reconnaissance (ISR) Systems" (Manthorpe 1996); and Lukasik's education specific definition states, "SoSE involves the integration of systems of systems that ultimately contribute to evolution of the social infrastructure" (Luskasik 1998).

Alternatively, some scientists took a different approach by focusing on distinguishing characteristics rather than providing an abstract definition. According to Boardman and Sauser (Boardman and Sauser 2006) there are five "…distinguishing characteristics (i.e. autonomy, belonging, connectivity, diversity, and emergence), that can help us to recognize or to realize a System of Systems (SoS)" (Boardman and Sauser 2006). Boardman and Sauser also proposed that there are opposing forces or paradoxes within each characteristic "that are influenced by fluxes in realizing or recognizing a system" (Sauser and Boardman 2006). We will later describe the balancing of these fluxes as the inherent flexibility in a SoS.

The alternative approach of a characterization provides a more comprehensive and precise taxonomy because the definitional approach is limited to industry specific context and lacks general flexibility necessary in successful dynamic trans-disciplinary engineering processes. The review of modern literature indicates that the use of characteristics enables us to better identify dynamic nature of various forces within SoS (Boardman and Sauser 2006). Figure 1 depicts these five distinguishing characteristics and their paradoxes.

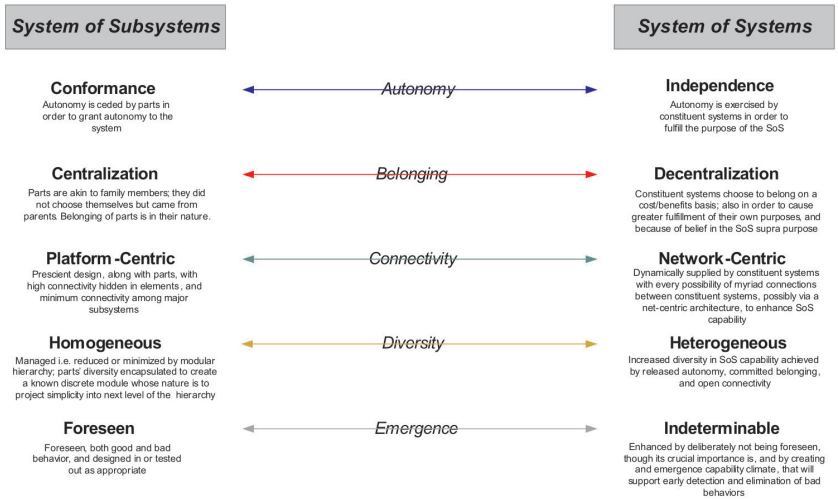

Figure 1. System Characteristics and their Paradoxes, Adopted From (Sauser, Boardman et al. 2008)

Gorod et al., (Gorod, Gandhi et al. 2008) suggested to further extend this theory and combine the ideas of the distinguishing characteristics with the concept of Flexibility (see Figure 2). The authors suggest that a SoS's ability (or agility) to balance between the paradoxes of these characteristics is what defines its Flexibility.

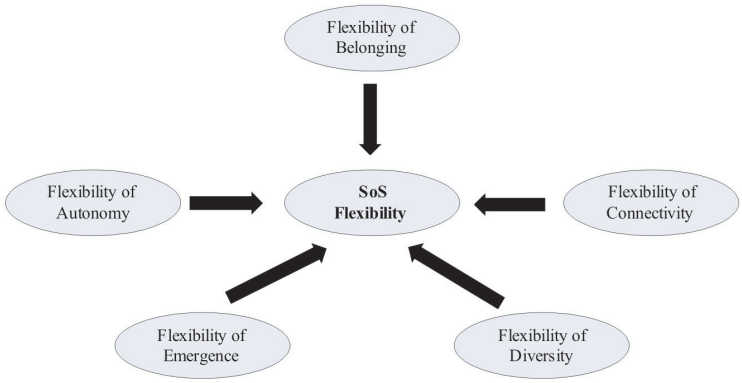

Figure 2. SoS Flexibility, Adopted from (Gorod, Gandhi et al. 2008)

The list below further defines the Flexibility of these characteristics:

Flexibility of Autonomy- The flexibility of autonomy shows how flexible is the ability of a system as part of SoS to make independent choices. This includes managerial and operational independence while accomplishing the purpose of SoS.

Flexibility of Belonging- The flexibility of belonging shows how flexible are the Constituent systems to choose to belong to SoS. This choice is based on their own needs/beliefs and/or fulfillment.

Flexibility of Connectivity- The flexibility of connectivity shows how flexible the constituent systems are with regards to their ability to stay connected to other constituent systems.

Flexibility of Diversity- Flexibility of Diversity shows upto what extent the constituent systems can be diversified.

Flexibility of Emergence- Flexibility of Emergence shows how flexible the constituent systems are in order to result in emergent properties of the SoS as a whole.

We contend that this Flexibility of SoS is an important phenomenon in today's ever changing complex dynamic environment. It allows us to engineer complex systems, which can be simultaneously, emergent enough in order to keep up and cope with the changing operating environment and yet be effectively governable.

Outsourcing

The term outsourcing is used if services and business functions are provided by an external organization. The organization that receives the services is called the client or buyer and the external organization is called the outsourcer, vendor or service provider (Rost 2006). Outsourcing could include one of the following two options: (1) handing off processes to third party vendors or (2) keeping the processes in-house, but sending them to internal lower cost locations within the organization (Robinson, Kalakota et al. 2005). Outsourcing encompasses manufacturing, IT and back-office services. Alternatively, international outsourcing can also be defined as international fragmentation of the value added chain (Egger and Egger 2006).

The global workforce has long sought to economize the production of goods and services through outsourcing. The day and age has now come on us, where no product can remain to be designed, developed and manufactured in a vacuum. Henry Ford's vision of the "specialization and division of labor" is no longer economically feasible under one roof. Parts and people must be outsourced in order to provide an economically, as well as, technically competitive product. In contrast, to in house (where variables such as parts, material and labor are fused together at one location), outsourcing requires explicit coordination and cooperation. However, to some degree this relinquishes control of the product during the development and production phases.

Outsourcing is a strategically important activity that has both positive and negative aspects. The advantages could be short and long term. An important but less well researched issue concerns outsourcing in relation to the long term performance of an enterprise (Wu, Li et al. 2005) . In order for outsourcing of SoS to work effectively, supply chain management must work in a timely, as well as effective manner to provide products/services to the consumer. This does not come without risk which has to be identified and the effects of this risk on the SoS has to be analyzed.

While there are advantages, there are several disadvantages that are thought of as consequences of the risks associated with outsourcing. These risks have been identified and listed below and they are likely to affect System of Systems (SoS) when its constituent systems are outsourced.

1. *Schedule Risk:* Schedule risk is defined as the uncertainty in the ability of a project to deliver the end product within a specified period of time (Browning 1998). When constituent systems are outsourced, control of the decision making process does not necessarily rest with the outsourcer (Gandhi and Eschbacher 2007) due to which the risk is considerably higher.
2. *Technical Risk:* Technical Risk is defined as the uncertainty in the capability of the technology to provide the expected performance benefits (Browning 1998). Two sub-categories of technical risks applicable to outsourcing of SoS are interoperatibility, supportability and testing & verification risks (Gandhi and Eschbacher 2007).
   a. *Interoperability Risk:* When two or more constituent systems are integrated and need to interact with each other to perform a certain task, the capability to operate as desired is

called interoperability of SoS, which is considered an essential aspect of correctness of integrated systems (Hao, Lee et al. 2004). However, constituent systems of SoS from different vendors have a much higher probability of not interoperating properly which is called interoperatibility risk.

b. *Supportability & Testing Risk:* Supportability risk can be defined as the risk associated with fielding and maintaining systems which are currently being developed and deployed (FAA 2005). If the constituent systems that are being used are provided by outside vendors, the supportability risk increases as the support staff of the organization would not know as much about the constituent system which would be acting as a black box. This would also be the reason for an increase in the testing risk associated with the complex system.

3. *Cost Risk:* It is defined as the uncertainty of not being able to complete the project within a given budget and the consequences thereof (Browning 1998). Most outsourced constituent systems of SoS only result in about fifty percent of the expected cost savings in the first few months and only become fully effective after a year (Kelly 2007)

4. *Intellectual Property (I.P.) Risk:* It is defined as the risk of the organization's internal intellectual property being used by the supplier to develop a competing product (Sullivan 2004). The likelihood of this risk occurring will increase considerably when constituent systems of SoS are outsourced, particularly to countries where I.P. laws aren't implemented as strictly as they are in the U.S.

5. *Quality Assurance Risk:* Even the best development teams create code that have "bugs," which is why quality assurance, especially when done offshore, is extremely important. A major risk when outsourcing is whether adequate quality assurance processes will be in place (Gandhi and Eschbacher 2007).

6. *Scope Creep Risk:* Normally what happens in projects is that there is a gradual introduction of requirements that weren't part of the project's initial planning. Due to the communication barriers mentioned above, this leads to what is called "scope creep," which results in costly delays to the outsourced project (Lorber 2007).

7. *Communication Barriers:* Almost every significant study of outsourcing risks in the past decade has brought up the issue of communication. Communication barriers arise when outsourcing because even though English is a common language, differences in expressions and dialects causes huge communication barriers.

8. *Flexibility Risk:* Nilichiani and Hastings (2007) defined flexibility in the systems engineering field as the ability of a system to respond to potential internal or external changes, affecting its value delivery, in a timely and cost-effective manner. The existence of flexibility can help the system adapt itself to the new conditions that arise because of changes in the environment. When outsourcing the constituents of SoS occurs, the risk of flexibility of the overall system being affected increases significantly. With the occurrence of outsourcing, the amount of flexibility associated with the system of systems could either increase or decrease, depending on the situation under consideration. Gorod, Gandhi et al. (2008), suggested that there are opposing forces in the flexibility spectrum where one side points us towards a rigid form of SoS whereas the other extreme is where the SoS is chaotic. If the SoS under consideration is either extremely rigid or chaotic, the flexibility risk would increase significantly; thus not making outsourcing beneficial. Conversely, if the SoS being considered is in the "optimization area," that is neither too rigid or chaotic, then the flexibility risk is likely to reduce. This would thus make outsourcing beneficial to SoSE being considered in this scenario.

Effects of Outsourcing on Flexibility of SoS

As described in section 2, the building blocks of Flexibility of SoS include Autonomy, Belonging, Connectivity, Diversity and Emergence. Outsourcing has an effect on each of these blocks, which is discussed below in reference to the five characteristics of SoS which are shown in Figure 1.

1. ***Autonomy:*** When a SoS is outsourced, the tendency would be to shift towards conformance as there would be a significant reduction in independence. This is because of the reliance on vendors who could make up the critical path due to which the overall risk of the project increases significantly.
2. ***Belonging:*** Outsourcing would also have an effect on the belonging of a SoS. Outsourcing to a very high degree could lead towards decentralization. Conversely, insufficient outsourcing could lead to centralization.
3. ***Connectivity:*** When considering connectivity, outsourcing could result in a network-centric SoS. This helps to enhance the SoS capability, which can be seen as a benefit by outsourcing SoS.
4. ***Diversity:*** When the diversity aspect is taken into consideration, outsourcing could result in heterogeneous SoS. This could be possible because outsourcing could increase the diversity of the SoS due to different vendors supplying parts from different parts of the country or even world.
5. ***Emergence:*** When a SoS is outsourced, more than likely it could result in a highly emergent behavior pattern, which would result in a high level of indeterminability. The spike in the level of indeterminability is because of the lack of control that occurs as a result of outsourcing and also because of the heightened risks that are associated with outsourcing of SoS, which have been discussed in the earlier section of this paper. Figure 3 shows the matrix for Outsourcing of System of Systems

	Effects of Outsourcing
Autonomy	Shift towards conformance; reduction in independence
Belonging	Outsourcing to a very high degree could lead towards decentralization. Conversely, insufficient outsourcing could result in centralization.
Connectivity	Results in a move towards net-centricity
Diversity	Could create a heterogeneous environment
Emergence	Helps to achieve highly emergent behavior. Results in increased amount of indeterminability

Figure 3: Matrix of Outsourcing for System of Systems

The key to outsource without having heightened risks is to effectively ensure that all the characteristics remain within the “optimization space.”

Conclusion

While engineering a SoS, we have important choices to make regarding outsourcing constituent systems of the SoS or have them engineered in house. If we were to outsource certain constituent systems of the SoS, we need to keep in mind that there could be dual effects on the flexibility of the SoS, that is, it could be beneficial for the flexibility of the SoS or could

lead to a reduction in the flexibility.

In this paper we propose a new methodology to evaluate effects of outsourcing on the five distinguishing characteristics of SoS. This gives the organizations associated with SoS an opportunity to better manage their realization. By this we mean that outsourcing adequately can create more choices for the organization, which would result in increased flexibility of the SoS. Conversely, either excessive or a significant lack of outsourcing could lead to excessive choices and thus lack of governance of the SoS or alternatively it could result too few choices which would translate into increased risk which would affect flexibility negatively. Thus it is important that a thorough assessment be done to see how agility of each of the characteristics are affected by outsourcing and only then a decision should be taken about whether to undertake it or not.

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