# A SYSTEM OF SYSTEMS (SOS) APPROACH TO DISPUTE MANAGEMENT SYSTEMS

Deniz Artan Ilter, PhD / Faculty member, artande@itu.edu.tr
*Istanbul Technical University (ITU), Istanbul, Turkey*

## ABSTRACT

There has been an increasing attention towards more effective dispute avoidance and resolution in the construction industry due to the significance of the costs associated with disputes. Many researchers have attempted to develop systems that aim to manage disputes by providing dispute evaluation, negotiation support, litigation prediction and decision support through the use of various tools. Although these systems have been developed separately, a careful consideration shows that they can be incorporated into a meta-system that pools their resources and capacities to obtain more functionality and performance. This aim fits well with the System of Systems (SoS) approach, which includes incorporating a collection of independent and task-oriented systems into a new, more complex system offering more utility than the sum of the constituent systems. After analysing current dispute management systems in the literature, a framework has been developed for the integration of these systems by SoS approach. The primary objective of developing a SoS framework is modelling the opportunities of cooperation while maintaining independence of the constituent systems, and exploring new systems required in an evolving perspective for a holistic management of disputes in the construction domain. The findings reveal that SoS represents a structured and comprehensive approach to modelling dispute management systems as a networked meta-system. SoS approach provides mechanisms to analysing and classifying existing systems, modelling the opportunities of cooperation between the constituent systems, adding or subtracting systems to and from the system in evolution, and maintaining the same amount of management and resources as before with more precise results from each system. As a result, the effectiveness of the constituent systems is expected to increase due to interoperability and resource sharing in the SoS framework.

**Keywords:** Dispute resolution, Dispute management systems, System of systems (SoS) approach.

## 1. INTRODUCTION

There has been an increasing attention towards more effective dispute avoidance and resolution in the construction industry due to the significance of the costs associated with disputes. Many researchers have attempted to develop systems that aim to reduce the number of claims and disputes, and mediate between the parties, hence avoiding litigation (Pulket and Arditi 2009). Such systems aims to embed the accumulated know how, past experience or past outcomes in the dispute resolution process, so that it is possible to make more informed decisions. There are various types of dispute management systems in the literature serving the various purposes with the use of various tools. Although these systems have been developed separately, a careful consideration shows that they can be incorporated into a meta-system that pools their resources and capacities to obtain more functionality and performance. This aim fits well with the System of Systems (SoS) approach, which includes incorporating a collection of independent and task-oriented systems into a new, more complex system offering synchronization and more utility than simply the sum of the constituent systems (Popper et al. 2004).

The specific scope of this study is dispute management systems, which involve negotiation support, litigation prediction, resolution method selection, resolution performance measurement, dispute potential indexing and dispute impact indexing systems. After analysing current dispute knowledge management systems in the literature, a framework has been developed for the integration of these systems by SoS approach. The primary objective of developing a SoS framework for dispute management systems is modelling the opportunities of cooperation while maintaining independence of

the constituent systems, and exploring new syst ems required in an evolving perspective for a holistic management of disputes in the construction domain. As such, possibility of and benefits to establishing the existing dispute management systems as a networked structure through the SoS approach is investigated.

The methodology adopted includes comprehensive literature review to identify possible components of the SoS framework and analysis of the tools used in the constituent systems to determine possible relationships among the components. The characteristics of the identified systems in relation to SoS approach are discussed and as a result, SoS framework architecture is developed. Determination of the appropriate IT technologies for implementing the SoS framework into a web-based tool and evaluation of the web-based tool through a focus group is planned as a further research.

## 2. THEORETICAL CONCEPTS

A system is defined as an assemblage of interacting, interrelated, or interdependent elements comprising a unified whole that is capable of its own action and the System of Systems (SoS) is the result of a group of individual systems (Held 2008). Several researchers have attempted to define and describe the SoS concept, however there is ambiguity to individual definitions, as well as a few disagreements. In many cases, the definition of SoS changes depending on the specific context the research is trying to create. Kotov (1997) defined SoS as large-scale concurrent and distributed systems, the components of which are complex systems themselves. DeLaurentis (2005) described SoS problems as collection of heterogeneous systems that are likely to exhibit operational and managerial independence, geographical distribution, and emergent and evolutionary behaviours that would not be apparent if the systems and their interactions are modelled separately. Pei (2000) defined Systems of Systems Integration as a method to pursue development, integration, interoperability, and optimization of systems to enhance performance. In a simpler definition, SoS is the arrangement of interdependent systems connected to provide a capability greater than sum of the member systems (Boardman et al. 2006).

Analysing various definitions and cases of SoS, Bulbul et al. (2009) also deduced that SoS concept has an ambiguous boundary and a nature that varies according to the context. Bulbul et al. (2009) also pointed out that the earlier descriptions of SoS focus on systematic decomposition of complex systems and their characteristics such as interoperability, emergent behaviour, operational/managerial independence and component based structure. More recent works, on the other hand, emphasize that SoS is a complex relationship structure that evolves (Abbott 2006, Fusswinkel 2007, Meilich 2007, and Lewis et al. 2008).

Several combinations of traits have been proposed by researchers as inherent to SoS problems however not all them are exhibited by every such problem. Analysing fourteen publications by several researchers, Bulbul et al. (2009) assembled the common characteristics of the SoS approach as: interoperability, emergent behaviour, operational independence, managerial independence and evolving development. However, Held (2008) argued that collaboration, emergent behaviour and complexity are not necessarily the requirements of SoS and suggested that a SoS has the following characteristics: (1) The system can be subdivided into independently operating systems. The independent systems must themselves be systems (~ operational independence), (2) The system does not depend on all elements for survival (~ managerial independence), (3) Systems in a SoS have some form of communication (~ interoperability), and (4) Elements have a common mission.

According to Bulbul et al. (2009), SoS can be used either when studying existing systems or when developing a new system. In studying existing systems, the SoS approach is utilized for putting existing systems into a perspective, identifying the relationships between entities, interpreting the modelling results and relating them to a wider context. Here, the aim is to comprehend existing sub-systems, how they can be grouped or related within a hierarchy, and how they can be improved. On the other hand when used for developing a new system, the developers are able to identify the complexity of the problem beforehand so that the SoS approach is used as a conceptual framework to guide the exploration of complex systems. In all these cases, multiple “sub-systems” are defined as parts of the SoS for achieving a higher goal. In order to provide synergy and interoperability between these sub-systems, a SoS formalism is selected.

The approach adopted in this study covers using SoS for both studying existing systems and developing a new system as defined by Bulbul et al. (2009). First existing dispute management systems are studied in terms of possible interrelations and then, these are established as the constituent systems of a meta-system through the SoS approach.

## 3. DISPUTE MANAGEMENT SYSTEMS

Dispute management systems are systems developed with the aim of avoiding, reducing and effectively resolving disputes between the parties through various tools. Most of these systems have been developed with the use of artificial intelligence (AI) tools such as, fuzzy logic (FL), case-based reasoning (CBR), analytical neural networks (ANN), genetic algorithms (GA) or the use of AI with other approaches such as the game theory (GT). While they may have different purposes within the dispute management domain, the commonality of these systems is that they all use past dispute knowledge or records created in databases. Some examples to the eminent dispute management systems in the literature have been listed in Table 1 presenting their contents and input data types.

Table 1: Contents and input data types of dispute management systems.

| Author(s) | Content of the System | Input Data Type |
|---|---|---|
| • Cheung et al. (2001) | • Dispute evaluation system based on FL | • Dispute experience, opinions and linguistic variables |
| • Ross et al. (2002) | • CBR based dispute evaluation system (GMCRCBR) | • Certain attributes of the past dispute cases |
| • Cheung et al. (2000) | • ANN based dispute evaluation system | • Dispute cases in a standardized format |
| • Belucci and Zeleznikow (1998) | • GA based negotiation support system | • Dispute case |
| • Montano and Malaga (2002) | • GA based support system for multiparty multi-objective negotiations | • Dispute case |
| • Belucci and Zeleznikow (2001) | • GT and AI based mediation support system | • Dispute case |
| • Lodder (1999) | • Argumentation tool for conflict | • Dispute case |
| • Belucci et al. (2004) | • Online dispute resolution (ODR) system supporting negotiation and dialogue | • Dispute case |
| • Kolodner and Simpson (1989) | • CBR based settlement system (MEDIATOR) | • Certain attributes of the past dispute cases |
| • Sycara (1990) | • CBR based settlement system (PERSUADER) | • Certain attributes of the past dispute cases |
| • Han and Feng (2005) | • CBR based negotiation support system | • Dispute cases in a standardized format |
| • Arditi and Tokdemir (1999) | • ANN based construction litigation prediction system | • Litigation records |
| • Arditi and Tokdemir (1999) | • CBR based construction litigation prediction system | • Litigation records |
| • Arditi and Pulket (2010) • | • AI based prediction model for construction litigation | • Litigation records |
| • Chau (2007) | • a particle swarm optimization (PSO)-based neural network approach for prediction of the outcome of construction litigation | • Court decisions in the last 10 years |
| • Ilter (2010) | • Multi-criteria decision making (MCDM) based resolution method selection system | • Expert judgement |
| • Cheung et al. (2004) | • CBR based resolution method selection system | • Certain attributes of the past dispute cases |

As presented above, there are various systems designed to manage disputes. These systems can be broadly grouped as (1) Dispute evaluation systems, which generally deal with identifying the causes of construction dispute, the likelihood of occurrence or the impact of the dispute, (2) Settlement systems, which generally deal with negotiation support and litigation prediction and (3) Decision support systems, which generally deal with selection of the appropriate dispute resolution method.

As shown in Table 1, some of the dispute management systems have the same purpose but are developed through different approaches or tools. For example, while Pulket and Tokdemir (1999) developed a construction litigation prediction model using CBR to enable the disputants save money and time by providing litigation outcomes, Chau (2007) used particle swarm optimization (PSO)-based neural network approach for prediction of the outcome of construction litigation. Similarly, Cheung et al. (2001) used the fuzzy sets theory to develop a construction dispute evaluation model, on the other hand Ross et al. (2002) used CBR approach in his system called GMCRCBR serving the same purpose.

Another prominence regarding the dispute management systems is that while being developed by different researchers discretely, some of the systems embrace opportunities for cooperation. In other words, while these are independent systems under evolutionary development, they have a common mission of supporting the management of disputes, some of them have potential interoperable connections and the most important thing is they have common resources, which can be pooled and shared, thus benefit from a Systems of Systems approach.

## 4. SOS APPLICATION TO DISPUTE MANAGEMENT SYSTEMS

Bar-Yam (2004) expressed the trend towards networking as follows; “as we continue to march towards an ever-increasing complex world, and as information flow opens avenues of possibilities, we will need to develop networked structures”. Indeed, there are significant benefits to connecting systems that cooperate and complement each other instead of operating them as separate entities. These systems should be brought together enabling interoperability and data sharing. In this section, possibility of and benefits to establishing the existing dispute management systems as a networked structure through the SoS approach is investigated.

In his paper analysing the SoS approach in the aerospace industry, Crossley (2004) pointed out that a significant challenge in system of systems design is determining the appropriate mix of independent systems. Designing a SoS has to rely on some principles. The literature regarding these design principles is fragmented due to different domains the studies were executed in. Below is a list of principles (characteristics) for the design of a SoS, compiled from the research by Crossley (2004), Held (2008) and Bulbul et al. (2009), and a brief discussion of dispute management systems in relation to the suggested principles.

*Common Objective*: The constituent systems should have a common objective to be organised as a SoS. While being developed for different purposes such as settlement or decision support, all the dispute management systems have a common objective of maximising dispute management capabilities by definition. Thus, the primary objective of the SoS can be phrased as “supporting decision making in dispute avoidance and resolution processes in construction projects through generating, analysing and making predictions regarding different options”.

*Interoperability*: Interoperability requires diverse groups or systems to work together. Crossley (2004) defines interoperability as the ability of systems to provide data, information, materiel, and services to, and accept the same from other systems and to use the data, information, material and services to enable them to operate effectively together. In fact, establishing an environment allowing interoperability between the component dispute management systems is crucial for a holistic and successful dispute management process. As in the definition, component systems can produce data that would be used as input to another. For example, results obtained from a litigation prediction system can be used as input in a decision support system used for resolution method selection. On the other hand, some of the component systems can complement each other. For example, a dispute potential determination system and a dispute impact determination system can be used together for serving a broader goal of dispute risk analysis.

*Operational Independence*: Operational independence is defined as the possibility of usefully operating the component sub-systems independently when a SoS is disassembled into its components

(Bulbul et al. 2009). It is natural for all the constituent dispute management systems operate independently since they have been developed independently. There is no constituent system that is dependent on another to operate in the SoS.

*Managerial Independence*: In order to have managerial independence, component systems should be separately acquired and integrated to a SoS while still keeping their operational independence (Bulbul et al. 2009). All dispute management systems can be integrated to the SoS separately. Replacement or removal of a systems have no effect on the operation of other systems, but may only affect the overall efficiency of the SoS through breaking potential collaboration channels. Moreover, the differences in the purposes and technologies of the systems naturally require both operational and managerial independence.

*Evolving Development*: Evolution in a SoS simply means that at any level, the SoS does not appear fully formed (Bulbul et al. 2009). The design of a SoS should allow yet-to-be-designed systems to be considered as potential options in the future. Due to evolution of the user needs, the components can differentiate into different systems in order to fulfil the requirements regarding the management of disputes and relevant decision-making processes in the SoS. Independently operating constituent components allow a SoS to continually evolve. Thus, the SoS is a dynamic entity, new systems are added, and current systems are replaced or removed in time. As new systems are developed in dispute management area, they can be integrated into the SoS easily. Also, dispute management systems can expose and deliver emergent properties while working in cooperation as parts of the SoS.

*Competition of the systems*: Because the constituent systems are capable of independent operation, the systems could not only cooperate but also compete for subtasks in a SoS (Crossley, 2004). As shown in the previous section, researchers have developed systems serving the same purpose with the use of various tools. The possibility of using diverse technologies is expressed clearly in the definition of SoS by Keating et al. (2003) as "SoS are meta-systems that are themselves comprised of multiple autonomous embedded complex systems that can be diverse in technology, context, operation, geography and conceptual frame". Thus SoS is developed as an integrated, performance-based framework that hosts constituent systems serving the same purpose with the use of different tools and technologies, thereby allowing the users to benchmark similar systems where needed.

In order to establish competition between systems serving the same purpose using different approaches or technologies, it was decided to group the constituent systems under meaningful and appropriate sub-tasks i.e. sub-systems. After an analysis of the aims and methodologies used, existing dispute management systems were classified into three groups as below:

(1) Dispute evaluation systems, which generally deal with identifying the causes of construction dispute, the likelihood of occurrence or the impact of the dispute

(2) Settlement systems, which generally deal with negotiation support and litigation prediction

(3) Decision support systems, which generally deal with selection of the appropriate dispute resolution method

Establishing competition between the component systems in each sub-system does not hinder opportunities for cooperation of the systems in different sub-systems. For example, decision support systems may take data from evaluation systems because selection of an appropriate dispute resolution method is only possible after a dispute is thoroughly evaluated.

Following the establishment of the sub-systems, it was seen that the SoS can benefit from a fourth sub-system (and task) of performance measurement, which could host systems dealing with the measurement of the performance of specific dispute resolution processes or methods. Besides being stand alone useful systems, performance measurement systems can also contribute to overall efficiency of the SoS by providing feedback to constituent decision support and settlement systems. Although such a system does not currently exist, performance measurement is included in the design of the SoS as a yet-to-be-designed system based on the evolving development principle of SoS approach.

The last step in the design of the SoS is establishing the core platform of interoperability. This requires the development of a *dispute knowledge management system* through building adequate claim and dispute libraries (databases) in the construction domain. Such a system can be integrated to the SoS developed in this paper as the central data providing system since nearly all constituent systems work on past dispute cases as presented in Table 1. Sharing and pooling the resources of all the component systems in this manner will bring a greater efficiency to each system as well as the SoS

itself. There are of course problems to be solved regarding this central dispute knowledge management system, such as how the data should be stored. As construction disputes are characterized by multiple factors and dimensions, the problem of data storage fits nicely with the multi-criteria approach. Due to the different needs of the component systems, dispute data should be stored and managed using a diverse and complete set of criteria. However, identification of the criteria and development of the Dispute Knowledge Management System will be tackled in the next stage of this research.

Figure 1 presents the SoS framework developed for dispute management systems. The input to SoS is the dispute data, which is managed by the dispute knowledge management system and stored in the dispute database. From this central system, each constituent system can obtain data. As each system will be sharing data, more accurate results will be possible for all systems. The SoS is divided into sub-systems that host systems serving the same purpose developed with different tool. For example, there may be more than one litigation prediction system in the SoS to allow users to benchmark if needed. Collaboration channels may be established between each sub-system as explained above. This framework can be implemented as a web-based tool, which connects each constituent system to each other and the central dispute knowledge management system.

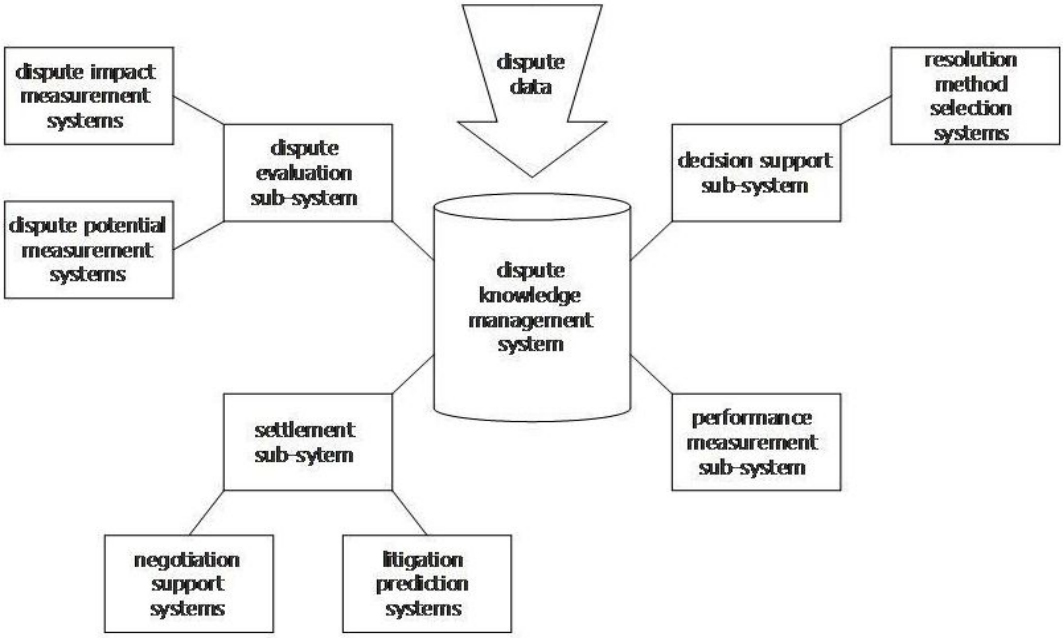


Figure 1: Conceptual SoS framework for dispute management systems.

Benefits of the SoS approach can be summarized as follows:

- Various dispute management systems have been analysed and classified modelling the complexities of this area in order to explore specific aspects and issues.
- In SoS, a network of existing and yet-to-be-designed dispute management systems is established, which can be conceptualized with various sub-systems.
- The opportunities of cooperation between the constituent systems are modelled.
- The development of the SoS is evolutionary, allowing new systems joining or some systems shutting down.
- An unintended consequence, which should be a goal, is that the hierarchy does not increase.
- The SoS approach provides a certain degree of abstraction in modelling that reduces complexity.
- While maintaining the same amount of management and resources as before, more precise results can be obtained from each system in the decision-making processes of the users.
- The effectiveness of the constituent systems is expected to increase when put together with certain characteristics as a SoS due to collaboration and resource sharing.
- A new tool is developed for overall dispute management while maintaining managerial independence for each system.

## 5. CONCLUSIONS

There are various systems designed to manage disputes and while being developed by different researchers discretely, some of these systems embrace opportunities for cooperation and have common resources that can be pooled and shared, thus benefit from a Systems of Systems approach.

In this paper, possibility of and benefits to establishing the existing dispute management systems as a networked structure through the SoS approach is investigated. First, the features of SoS based modelling has been outlined, through compiling the limited literature on SoS, as design principles for the study. These principles have been determined as (1) common objective, (2) interoperability, (3) operational independence, (4) managerial independence, (5) evolving development and (6) competition of the systems. As a result of the analysis of dispute management systems in relation to the suggested principles, it was observed that:

(1) while being developed for different purposes by different researchers, all the dispute management systems have a common objective of maximising dispute management capabilities,

(2) the constituent systems embrace interoperability through resource sharing and cooperation for certain tasks,

(3&4) the differences in the purposes and technologies of the systems naturally require both operational and managerial independence,

(5) independently operating constituent components allow a SoS to continually evolve following the evolution of the user needs and emergence of yet-to-be-designed systems

(6) there are dispute management systems serving the same purpose with the use of different tools and technologies, thereby allowing a competition of the systems.

Modelling of a framework including various systems requires abstractions at different levels and creation of sub-systems as well as interactions. In this study, SoS framework was modelled using four sub-systems namely dispute evaluation, settlement, decision support and performance measurement. While currently no systems exist dealing with performance measurement in the dispute management domain, it was included in the design of the SoS as a yet-to-be-designed system based on the evolving development principle of SoS approach because of its potential contribution to overall efficiency of the framework by providing feedback to constituent decision support and settlement systems. These sub-systems were established around another yet-to-be-designed system called dispute knowledge management system, which is integrated to the SoS as the central data providing system. Sharing and pooling the resources of all the component systems in this manner is expected to bring a greater efficiency to each system as well as the SoS framework itself.

The findings reveal that SoS represents a structured and comprehensive approach to modelling dispute management systems as a networked meta-system. SoS approach provides mechanisms to analysing and classifying existing systems, modelling the opportunities of cooperation between the constituent systems, adding or subtracting systems to and from the system in evolution, and maintaining the same amount of management and resources as before with more precise results from each system. As a result, the effectiveness of the constituent systems is expected to increase due to interoperability and resource sharing in the SoS framework.

The design of the central dispute knowledge management system and implementation of the SoS as a web-based tool, which connects each constituent system to each other and to the central dispute knowledge management system, will be the focus of the following stages of this research.

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