OPTIMISATION OF SYSTEM OF SYSTEMS REENGINEERING: A PERSPECTIVE OF ENTERPRISE RESOURCE PLANNING (ERP) SYSTEMS

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Abstract - Meeting the speed of change in the current dynamic and fully digitalised world is a main concern for any company that wants to grow. Improving profitability and performance mostly rely on scalability through system integration. Systems of systems reengineering is an important transformation tool that enables organisations to compete and remain sustainable. Systems reengineering is a continuous approach that helps companies to stay up-to-date in meeting customer expectations. Reengineering of systems of systems leads to the integration between two or more independent systems. The current study emphasises on optimisation requirements for systems to software systems engineering that manages integration between software systems in the field of enterprise resource planning (ERP). System of ERP systems reengineering through system integration should be include strong system architecture, infrastructure, workflow management as well integration security as critical setup components. Research findings showed that 40% of people strongly agreed that system architecture through integration layer that includes domains and cloud computing as well as integration process are the primary variables to consider while intending to implement systems of ERP systems. Furthermore, 60% of people strongly agreed that system infrastructure determine a solid and successful systems of systems installation as well as workflow management. Additionally, 80% of respondents agreed on the importance of integration security as first priority of system of software systems reengineering. Besides this variables, observations showed that 55% of participant strongly agreed that change implications, people and project team as well as risk management need to be managed concurrently in order to achieve business objectives and goals associated with system of systems reengineering.

Keywords - Systems of systems, reengineering, software, ERP (enterprise resource planning)

I. INTRODUCTION

Meeting the speed of change in the current digitalised world is about developing new strategies to stay aligned with the globalisation and thus survive. Some organisations go for information technology devices and software upgrade while others choose to transform their overall business approaches through business reengineering. In any case, change through information technology remains a better option as it enables other areas of the business. Although business processes as well as people constitutes powerful enablers of business reorientation, the current study focuses on IT systems of systems in the field of ERP. A system can be defined as a collection of separate entities that are put together to meet the same objective through scalability and short time service delivery. A system intends to solve a big problem that one or many standalone systems cannot efficiently achieve. When a system is composed of many other systems, it constitutes the so-called systems of systems. IT systems of systems refer to as integration between systems provided the system subcomponents are independent systems that operate efficientlyas highlighted by Maier (1998). A difference needs to be made here between systems of systems where sub-components are systems and software and not hardware or additional devices. In this case of figure that involves software systems, it is called systems of software systems engineering.

Enterprise resource planning is a management software that companies install to manage their daily business activities whether at national or international level. ERP systems comprises integrated modules that represent specific departments and functional units inside the organisation. This suggests that ERP solutions are systems that allows interface integration and remote connectivity between functional units as well as users (Sage, 2018). System integration can be done between businesses(Business-to-business) or between business and users(Business-to-customers). The current paper focus on integration between two or more independent business systems also named systems of systems.

II. BACKGROUND

Systems can be isolated or connected to other different systems. This leads to the concept of open versus closed systems (Chick, 2004). Systems of systems falls within the concept of open systems as they are opened to interact with any other systems in the outside world. Globalisation implies adoption of IT revolution, connexion of things through internet of things. Systems of systems are found everywhere in different areas such as household appliances, computers, automobiles and so on where devices are interrelated. Enterprise systems also need complementarity into other systems belonging to different organisations and institutions. Some companies have integrated their systems with business partners such as bank for payment, customer facing for customer relationship management and productivity improvement.

In the past few years, speed on innovation and IT revolution have created open systems ready to communicate with other systems as synergies. Traditional IT systems were made out of standalone applications that resulted on manual reconciliation of statements from different departments. This approach was limited and not efficiency enough to promote business growth. Many countries around the world especially South Africa have moved to the integrated ERP software to efficiently manage all areas of the business as a whole. Regarding powerful system functionalities such as flexible system architecture, workflow notifications and web-based solutions offered by ERP systems, evidence showed that system of system reengineering can be seen as an additional functionality. ERP applications depend on internet connection to achieve system of systems deliverables. The government should ensure that nation internet providers release sufficient amount of internet data for companies operations. Enterprise systems can be linked to systems such as bank, customer, stock systems to form one completed system using internet connection. Although systems of systems reengineering is very complex to implement on the infrastructure as well as architectural side. However, interoperation and connection allow company to scale business functions and increase revenues. Observations showed that a proper system of system engineering design process is not well established. Formal methods of system integrations should be official and served as foundation for future researches and software engineering implementation. The current study provides a synthesis model of system of systems in the field of ERP software reengineering.

III. LITERATURE REVIEW

Few researches have been done in the field of systems of systems optimisation. However, observations and evidence from the current IT environment have facilitated comprehension and applicability of systems interconnectivity. The following review of literature covers system of system reengineering, system architecture and ERP systems.

IV. SYSTEM OF SYSTEM REENGINEERING

System integration is one aspect of systems of systems reengineering process that allows to achieve specific business goals. System integration consists of putting subsystems parts together in a logical and cost-effective way besides optimisation purposes. Maier (1998) in his study about systems of systems found that relationship between systems can be virtual, collaborative, acknowledged and directed as depicted in the figure 1 below. He defined relationship based on whether there is a central authority or a team to coordinate interaction between entities of the whole system.

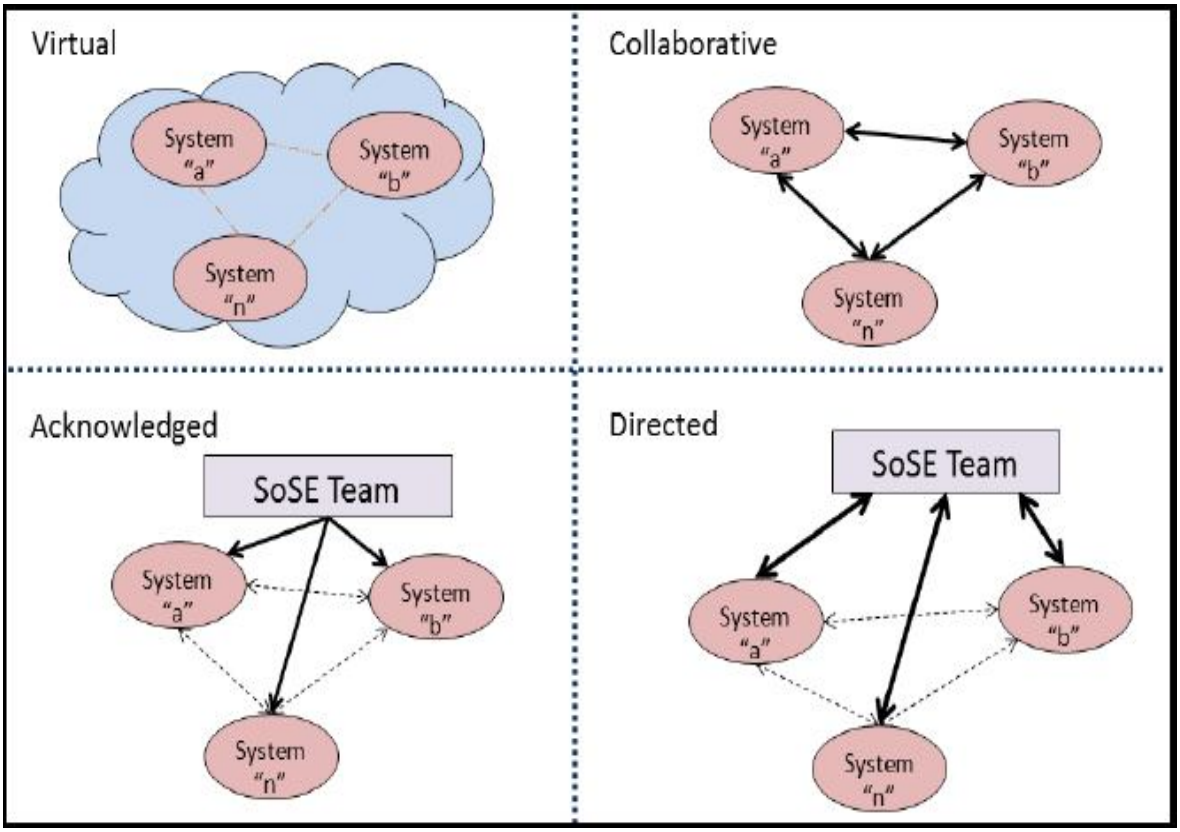


Figure 1: Types of systems of systems
Source: Maier (1998)

In addition to the above, Schmidt (2006) assumed that data intensive and heterogeneity should be considered as further characteristics of systems to systems. He argued that systems put together will use a much larger volume of data. Moreover, systems of systems components have been conceived and programmed using different types of computer languages and databases besides continuous version updates of each system. This suggests that system of systems scaling is questionable due to system complexities and configuration differences between systems' components. However, heterogeneity can be handled at the integration layer following specific conversion language. Whether form a technical, managerial or governance source, system complexities are related to the level of business processes in place in the organisations and the characteristics of the sub-systems. System integration affects internal structure of subsystems in order to be able to match and easily communicate with external subsystems. This needs to be carefully managed in such a way that the component system can independently deliver his services besides integration services. Hannan and Freeman (1977) argued that systems should follow the homoestasis principle that is about information exchanges between systems while maintaining a state of equilibrium over time. This suggests self-regulation and independent state of each subsystem as highlighted by beer (1975). Beyond automation that comes with system integration, Maturana and Varela (1975) argued that systems should have a self-organising features that stimulate the internal complexity of a subsystem to be aligned to the complexity of the other subsystems or the environment, the so-called autopoiesis. According to TrowBridge, Roxburgh, Hohpe, Manolescu, &Nadhan (2004), integration between systems scan be done at data, functional, presentation, portal and process levels. They argued that data, functional and presentation levels can be done through a middleware system. It is important to note that middleware technologies don't always match due to differences at protocol, data format, computer language and environment level (Schmidt, 2006).

V. SYSTEM ARCHITECTURE

According to rklesolutions(2017), ERP system architecture is made of multiple servers that allow to achieve system roles such as data execution, processing, web, printing, help reading and so on. They also argued that efficient management system should be cloud-based to limit continuous infrastructure installation and maintenance. Integration layer manages integration between infrastructures, architecture as well as business transactions using service interface standards such as Http, IP address and URL. Companies go for service driven architecture as a solution of developing cloud computing using web-based applications (Sage,2018). Besides integration layer, architecture layer holds servers that supports applications, database, routers and switches. Cloud technology approach uses platform as a service (Paas) as well as internet as a service (Iaas) as enablers of architectural deployment. Evidence show that cloud-computing is itself a form of storage security for business data. System architecture is also defined by interconnectivity and how linked are the systems involved. Systems can be directly connected through point-to-point integration or using a middle ware system as a bridge.Systems of systems architecture should follow the following principles as pointed by Maier (1998):

- Design sub-system should deliver value even if they are incomplete.
- Control of all sub-systems and the overall system
- Design appropriate system interface to facilitate interaction and communication
- Define incentives collaboration tips

To successfully manage systems of systems engineering require understanding and management of systems vulnerabilities and risks besides system owners' behaviour (Sillito, 2010). He also defined reductionism as an engineering techniques that defines clear boundaries and issues belonging to each system components. The truth is that reductionism principles cannot be strictly applicable on software engineering because direct coalition between independent systems improves data exchange.
According to Boardman and Brain (2006), differentiation between systems and systems of systems resides on the autonomy, belonging, connectivity, emergence and diversity tool that subsystems can acquire.

VI. ERP SYSTEM

Gericke et al. (2010) found out that information technology platform as well as architecture management are success factor candidates(SFCs) groups that are very important for application and system integration. ERP solutions are web-based applications that uses workflow monitor functionalities to improve communication through email notifications between servers and users (Sage, 2018). System to systems can only be done if sub-systems can allow interface with other systems. ERP systems have multiple levels of interface that can allow interaction with others users, data, process and application as published by Sage (2018). System integration characteristics are not related to system control. Overlaps between subcomponents need to be managed by specific control devices put in place. As the main system, ERP systems can be complexed or not depending on the number of other systems linked to it. System integration face the challenge of selection of the right integration level, mapping differences in interface and technology requirements

between systems (Data type, language, protocol, etc.…).

VII. RESEARCH FINDINGS

A successful system of systems reengineering depend on applications, platforms infrastructure, subsystems and materials interconnections. Enterprise system integration brings automation and control of the infrastructure and architecture setup. Enterprise architecture needs to be aligned to system integration principles to develop best practice and thus counter risks. Cloud-based computing optimises business task execution and productivity. ERP systems offer integration with other systems at a data, functional and process level and to the end-users at portal level. System of systems customisation offers the following benefits all related to the environmental change:

- Responsiveness to market conditions
- Optimisation of charges
- Increase on productivity and profitability

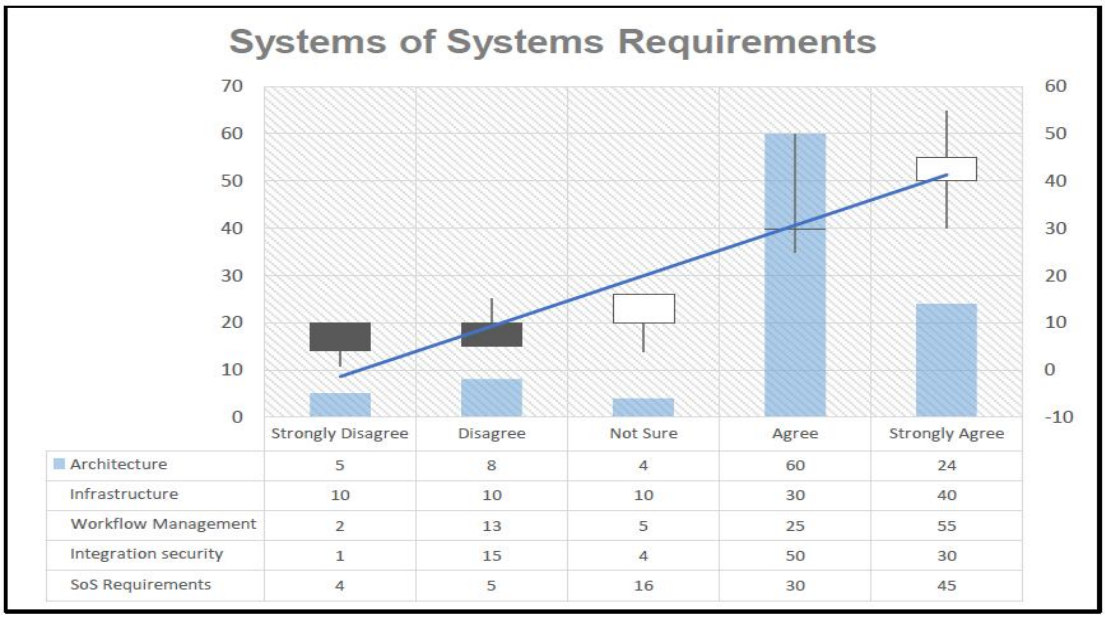
The above benefits can only be achieved if the following core activities are met:

- Relationship between systems. This allows to understand how the systems are inter-correlated for easy maintenance in the future and for license re-initialisation
- Definition of subsystems performance. Assessing subsystems performance allows to measure benefits of system integration
- Installing and developing solid system architecture while addressing new requirements
- Manage change and risks linked to system of system upgrade

System of system engineering in the field of management especially on ERP solution implementation depend on the following elements:

A. Systems of Systems Requirements

Findings depicted on the figure 2 below highlight system of systems requirements applicable both on sub systems and the system as a whole. As a golden rule, systems of software systems reengineering is based on the speed of change and innovation to fulfil customer expectations.



	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
Architecture	5	8	4	60	24
Infrastructure	10	10	10	30	40
Workflow Management	2	13	5	25	55
Integration security	1	15	4	50	30
SoS Requirements	4	5	16	30	45

Figure 2: System of systems requirements
Source: Authors' compilation

System infrastructure. 30% and 40 % of participants agreed and strongly agreed that system infrastructure constitutes the basic elements that are installed to host the system architecture. Integration requires hardware that comprise servers, databases, switches and software installation all linked to specific domain. System Architecture. Results showed that 60% of people agreed and 24% of people strongly agreed on the importance of system architecture in building system of systems. Architectural design constitutes the most critical part of the system of systems reengineering. System architecture comprises repository, cloud integration and system domain. Capitalising cloud integration involves cloud investment and resources management.Flexibility and independency of ERP systems promote the evolutionary architecture of the integrated system. Additional components can be removed or replaced or added to each individual system without compromising the authenticity and autonomy of the system as a whole. An evolutionary system of system architecture is characterised by standard interfaces, server layers and continuous verification and validation at the data and process level. Work flow management. Communication between systems especially ERP systems uses workflow management

tool for email notifications and decision making process. Communication channel between system users whether internal or external is managed in the ERP system by the workflow management tool. It is an integrated tool that facilitate business task execution through signatures and email notifications.
Integration security platform. Results showed that80% of people agreed and strongly agreed on the important role of managing integration security while implementing system of systems. Interface as well as sub-system capabilities need to be confirmed by the project team before validation of the integration. As part of the enterprise application integration techniques, the nature of the link between sub-systems determine the architecture structure. In the current case of system to system integration, there is no middleware but only direct or point-to-point access between sub-systems.
Although straight integration becomes heavy and complex to manage over time when many systems are involved, it remains a unique way to improve real time service delivery and business optimisation.

B. Additional Requirements

A successful system of system implementation should consider people, change management and risk management. Figure 3 below displays survey results regarding these three variables.

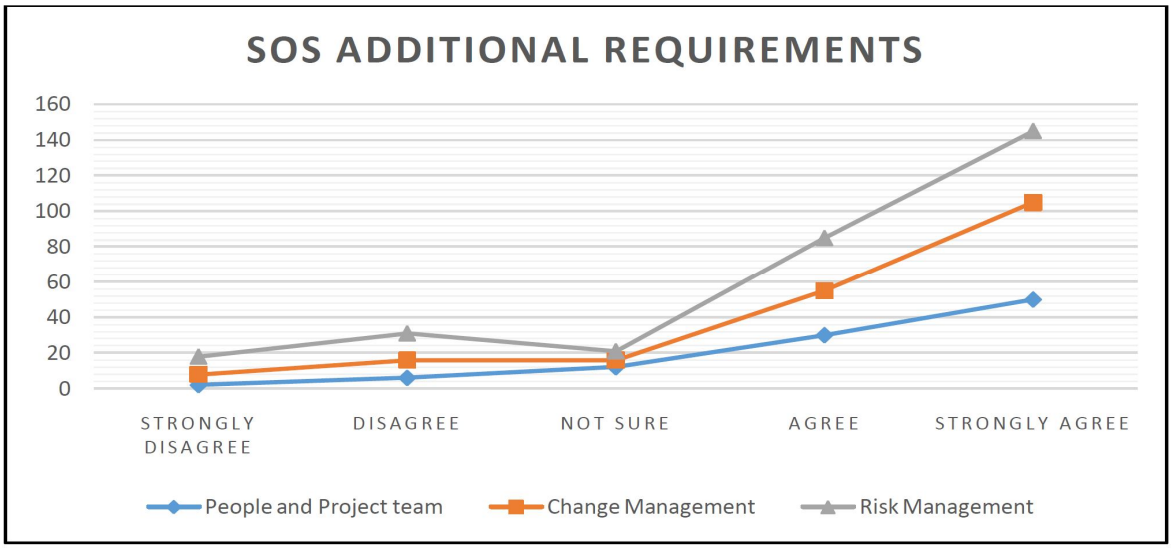


Figure 3: SOS additional requirements
Source: Authors' compilation

People and project team. System of system integration is a project itself and thus requires specific project team to run the integration. 30% and 50% of people consecutively agreed and strongly agreed that people and project team need to be at the centre of system integration project. In fact people are the critical resources that enable business task execution and achievement of the organisational goals. Integration process that mostly includes analysis of requirements, design, testing and validation phases should be written and documented for archives and future upgrades reference. Besides increase on productivity, companies seek for customer satisfaction on system integration done as a continuous operation and not a big-bang task. Change management. Results showed that 55% of people strongly agreed on the importance of managing the change that comes with system reengineering in order to not develop frustrations and resistance.System integration is a form of system reengineering that brings radical change that need to be handled carefully to achieve implementation avoid failure. Lack of control on sub-systems functionalities from owners' side force the central authority to define solid strategies to protect the overall system. Risk management. Risks are associated to change whether from an upgrade of existing systems or installation of a completely new system.40% of people strongly agreed that system integration risks need to be fully managed to successfully meet the objective of system combination for all parties involved.

System of systems come with associated risks that need to managed and thus mitigated and limited. It entails identification, assessment and control of malicious issues related to whether the internet through cyber-attacks or the application itself.Overtime system incompatibility improve and become a challenge that can be managed through change strategies and differentiation.

C. Synthesis Model

The above-mentionedfindings helps to build the following model that summarises the whole system of systems architecture including subsystems, integration platform and integration process all interconnected through cloud computing. The model also includes additional requirements such as people, change and risks that influence system of software reengineering.

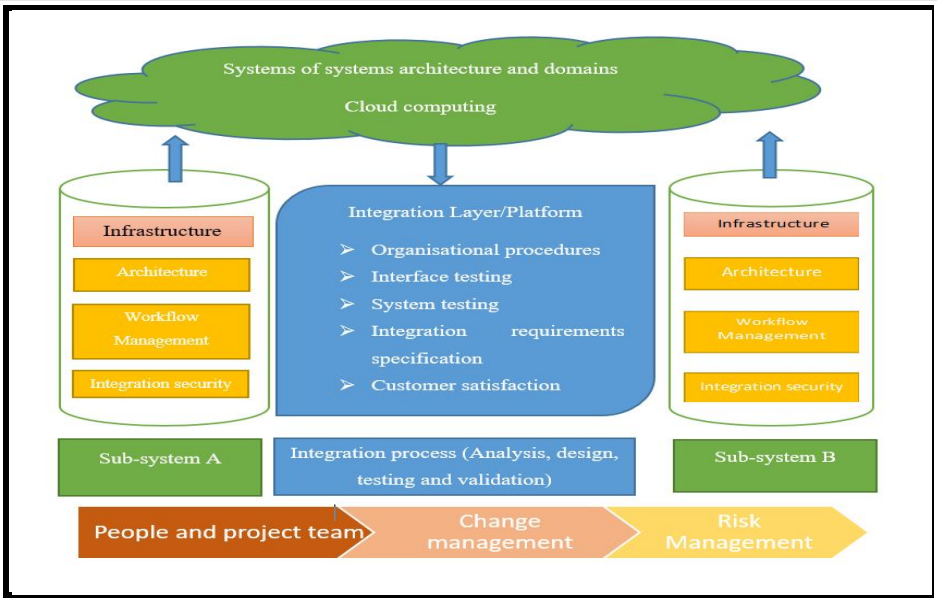


Figure 4: System of systems architecture mode
Source: Authors' compilation

RECOMMENDATIONS AND CONCLUSION

Recommendations

A better understanding systems of systems reengineering needs to be done at a functional or business level through business modelsbut also at programming or computing level. The current study only talks about systems of software reengineering at a management level and not using computer language to demonstrate how data field interact together in the communication channel. This paper didn't emphasise on challenges linked to the complexities of system integration as faced by ERP systems. Further studies should consider the above suggestions for better efficiencies purposes.

Conclusion

Systems of systems by means of systems integration is an important tool for new digitalised world where automation and optimisation is the premier objective. As the principal enabler of digitalisation, governments should provide and ensure business compliance with internet of things through cyber defence against data breaches and attacks. The above-mentioned research findings proved that 60% of people agreed on system architecture as the main component of systems of systems implementation requirements. 40% of people working on ERP systems strongly agreed that system infrastructure and workflow management facilitates connection between systems compared to 80% of people regarding integration security. In addition to these elements, findings showed that people resource, change implications and risk management need to be considered at functional as well as technical level while going for systems interconnectivity. Above all, ERP systems as web-based solutions ensure optimisation of system reengineering through dependability, flexibility and safety in integration with other management software systems. The proposed synthesis model summarises combination of system of systems requirements that will serve as foundation of system of system reengineering model for future upgrades.

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