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Research Article

Design of System-of-System Acquisition Analysis Using Machine Learning

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A system of system's ability to function is derived from the integration of systems from different sources. An SOS's systems serve two purposes: first, to accomplish their own specific aims, and second, to provide resources to the SOS as a whole. In the last few decades, machine learning and data analytics have been widely used in system design and acquisitions. Every organisation that acquires a sophisticated system employs some type of data analytics to evaluate the system's independent objectives, which is universally accepted. Data analytics and decision-making regarding the independent system is rarely shared across SOS stakeholders, even though the systems contribute to and benefit from the larger SOS. The goal of this research is to determine how the exchange of data sets and the corresponding analytics by SOS stakeholders can improve SOS capacity. Predicting SOS capabilities by exchanging relevant data sets and prescribing information connections between systems, we propose to use machine learning techniques. This article serves as an intermediate analysis of the above research work and aims to estimate the benefit of information sharing among the SOS stakeholders. In this research, we have applied different machine learning models to the IBM HR analytics data set to determine the corresponding analytics by SOS stakeholders that can improve SOS capacity. We propose using machine learning techniques to forecast SOS capabilities through the sharing of relevant data sets, and we prescribe the information linkages across systems to make this possible. This paper provides an update on the progress being made toward the aforementioned research project, and its primary focus is on developing a method to put a dollar amount on the benefits of information sharing among the many parties involved in the SOS.

1. Introduction

A system of systems (SOS) is a collection of many heterogeneous distributed systems that have been acquired independently and continue to operate and be managed independently [1]. The system-of-systems capability relies on the systems' ability to work together effectively, notwithstanding their independence [2]. For acquisition decisions, it is crucial to take into account more than just one system; rather, it is necessary to take into account all of the systems within the SOS [3].

Through the use of collected and previously used data, predictive data analytics may foresee and forecast future consequences [4]. In Babylonian times, data was stored on tablets to anticipate harvest, but a dramatic leap in the ability to reason over enormous volumes of data arose in the 1940s with the advent of computer development [5, 6], storage, and machine learning techniques [7]. In the 1940s and 1950s, data analytics models were utilised to anticipate the consequences of nuclear chain reactions in the Manhattan Project and weather forecasts using the ENIAC computer [8]. Data analytics that is used to produce or prescribe the optimum courses of action in light of available information is known as prescriptive data analytics [9].

1.1. Problem Statement. In the decades following World War II, the requirement to optimise the course of action encouraged the development of the operations research discipline, which eventually led to "Analytics 1.0" for the introduction of data-based decision-making in corporations [10]. Enormous companies such as Google and Amazon have adopted Analytics 2.0 as the new paradigm for processing large amounts of structured and unstructured data (also known as big data) [11–13]. "Analytics 3.0" is a term used to describe the ability of organisations to incorporate this "big data" into their decision-making process, which is shaped by the volume, variety, velocity, and validity of data [4]. To say that most successful firms use Analytics 3.0 for business and product development is not a generalisation.

Analytics 3.0 deployment presents a unique challenge for the acquisition and development of SOS capabilities, as each of the contributing organisations employs a different set of predictive and prescriptive analytics tools for their respective systems (the Literature Review of Machine Learning Techniques and Applications in the DOD provides details on predictive machine learning techniques as applied primarily in the DOD application space) [7]. All SOS stakeholders rarely have access to these analyses and the underlying data sets [14–16].

1.2. Motivation. SOS is a diverse enterprise, and in this article, we pursue research toward an information-centric framework that aids early-stage decisions at the corporate level. Digital engineering (DE) and its related components in other engineering tasks [17], such as model-based systems engineering (MBSE) for the systems engineering domain, provide an important backdrop for our work. Digital models are employed by DE and MBSE throughout the acquisition process. Many people are focused on how to implement DE/MBSE and the desire to have models work together rather than how well the extended enterprise (or "acquisition ecosystem") is aware of and trusts the various data sets that underpin models and development processes that use them, which is a more demanding issue. Data management and analytic deployment techniques that establish synergies between multiple enterprise entities and link stakeholders, resources, policy, and economics between various systems are among our objectives in this area. Data aspects such as survey categories, types of variables, ownership/privacy of data, and the interconnection of data sets are examined in the framework. These data sets exist at the local system level but may not be shared with SOS/enterprise or vice versa for SOS acquisition. Predictive and prescriptive analytics can be used because of data access, and this allows us to explain how sharing and connecting data sets can lead to better results at the SOS level. An example is used to demonstrate how valuable techniques from the field of data science/machine learning can be used. As this is a relatively new field of study, we are focusing on determining which of the most persistent research problems deserve further investigation.

1.3. Contributions. The contributions of this study are as follows:

(a) We have determined how the exchange of data sets and the corresponding analytics by SOS stakeholders can improve SOS capacity

(b) We have predicted SOS capabilities by exchanging relevant data sets, and prescribing information connections between systems, we propose to use machine learning techniques

(c) This article serves as an intermediate analysis of the above research work and aims to estimate the benefit of information sharing among the SOS stakeholders

(d) We have applied different machine learning models to the IBM HR analytics data set to determine the corresponding analytics by SOS stakeholders that can improve SOS capacity

(e) We propose using machine learning techniques to forecast SOS capabilities through the sharing of relevant data sets, and we prescribe the information linkages across systems to make this possible

(f) This paper provides an update on the progress being made toward the aforementioned research project, and its primary focus is on developing a method to put a dollar amount on the benefits of information sharing among the many parties involved in the SOS

2. Literature Review

SOS's ability to function is derived from the integration of systems from different sources. An SOS's systems serve two purposes: first, to accomplish their own specific aims, and second, to provide resources to the SOS as a whole. In the last few decades, machine learning and data analytics have been widely used in system design and acquisitions. Every organisation that acquires a sophisticated system employs some type of data analytics to evaluate the system's independent objectives, which is universally accepted. Data analytics and decision-making regarding the independent system are rarely shared across SOS stakeholders, even though the systems contribute to and benefit from the larger SOS. Certain areas of knowledge acquisition can be greatly aided by the use of machine learning algorithms. We have initiated a systematic examination into how to transfer the functions of knowledge-based systems onto those machine learning systems that supply the requisite information, given the potential of machine learning for knowledge acquisition.

In Dahmann et al. [4] research, there are various parallels and differences between NCE system and SOS, which highlights the implications for system engineering and acquisition. The first half of this study provides an overview of our current understanding of SOS and the implications of this understanding for SE. It then studies the attributes of NCE systems and compares them to those of SOS systems in order to conclude. The study concludes with an examination of the implications of these findings for systems engineering and procurement practices.

There are significant development hurdles in all three dimensions of military capabilities, including technological, operational, and programmatic aspects of the system of systems development. A scarcity of tools exists for determining how to create and evolve SOS in a way that takes into account both performance and risk considerations. In the study by Colombi et al. [18], the application of methodologies from financial engineering and operations research is beneficial in the optimisation of portfolios. The authors make it easier for SOS architectures to evolve by offering a framework that allows for architectural selection at a certain evolutionary decision epoch. Generic nodes on a network are used to model hierarchies of interconnected systems. These generic nodes, subject to connectivity and compatibility constraints, collaborate to achieve broad capability objectives. Portfolio algorithms are capable of dealing with a wide range of problems, including uncertain data, poor performance between nodes, and development risk. This naval warfare scenario demonstrates how to identify "portfolios" of available systems from a list of candidate systems by using a search algorithm. For example, by allowing the optimisation problem to handle the more mathematically intensive elements of the decision-making process (e.g., the feasibility of solutions and optimality), the number of connection rules, the feasibility of solutions, and optimality are all decreased. As a result, while making final decisions, human decision-makers can concentrate their efforts on picking the appropriate risk aversion weights.

In the past, programme managers have utilised technical performance measures (TPMs) to establish whether or not a programme is on pace to reach its performance objectives. It is possible to build a deterministic method of estimating the operational performance of a project by utilising TPMs throughout the project's lifecycle. When it comes to a set of systems that are universally accepted, TPMs, on the other hand, can be difficult to compute (SOS). For a deterministic state similar to TPM usage, an SOS performance measure (SPM) has been developed and proven. It serves the same function as TPMs and may be used in the same way. The reality reveals that several of the SOS components are subject to significant uncertainty during the development process of the system. As a result, in order to more precisely account for an SOS's ability to achieve its desired performance, it is necessary to take this unpredictability into account. In order to account for this uncertainty, [18] develops an extension of the SPM concept known as a stochastic SPM. To demonstrate how this expansion of the SPM technique improves its effectiveness, an antisubmarine warfare (ASW) operation is used in this example.

How typical systems engineering activities have evolved to enable SOS-level systems engineering is discussed in detail in the Department of Defence's Systems Engineering Guide for Systems of Systems, which was just released this month. According to the study conducted for this handbook, modelling and simulation are helpful in the development of SOS systems. While some modelling and simulation are currently being used, more support would be advantageous if models could be generated rapidly and used to assist in decision-making when it is needed. In order to achieve these objectives, the Systems Modelling Language (SysML) is employed in [18] research.

System-of-systems procurements might include the purchase of many systems, or they can be purchased as stand-alone items. A considerably more common occurrence in the United States Department of Defence (DOD) is the acquisition of one or more new systems that are intended to interoperate with existing systems as part of a system of systems (SOS) with additional capabilities. The success of any SOS acquisition is dependent on the effectiveness of the contract structures and acquisition processes used. The difficulties associated with the acquisition of SOS are recognised in this work, and the findings are explored. According to the findings, the SOS acquisition should be accompanied by a significant systems engineering effort, as well as modifications to the existing contractual processes, frameworks, and organisational structures, before being finalised. As a result of [18], modifications to current and future Department of Defence SOS procurement are recommended.

SOS (system-of-systems) management faces a major issue in dealing with the possibility for member systems to evolve in an uncontrolled manner. Organisations become more inefficient, more expensive, and less able to respond rapidly to changing circumstances when they lack control over evolution. In order to achieve common aims, systems of systems (SOS) connect together a variety of systems that were designed independently and to various standards. The objectives and aims of the member systems are preserved, as is a great deal of their autonomy. As a result, there is an increased possibility that decisions on evolution will be made unilaterally within member systems, which could have negative consequences for the SOS's stability, efficiency, and trustworthiness. A modified version of HAZOPS (hazard and operability study) is used in [18] to examine the hazards associated with SOS evolution and presents a technique to assist nonspecialist end users in identifying, organising, and discussing this information. The report uses a case study of a recent RAF (royal aviation force) Nimrod air crash to examine the methodology, and the official inquiry revealed serious flaws in the Nimrod SOS's operation. Conclusions and future prospects for research are discussed in the paper, which concludes that the technique proposed would be a valuable support for SOS evolution processes.

The authors need to look more closely at how the BMDS interacts with other systems, especially those built by other agencies. Interstitials are used in the context of systems interoperability, interoperability, and integration. The authors believe the SOS literature has not given enough attention to this problem. The BMDS is an excellent case study for the SOS because many of its components are existing programmes of record. The pieces work as intended, but their performance metrics may not match the SOS's higher-level requirements. Interoperability is a BMDS challenge to achieving predictable national capacity. Some of the new capabilities requested by national leaders may include changes to kill chains, C2 structures, coordination, and performance. To attain these new capabilities, record programmes must be changed and system components integrated. SOS engineers must objectively evaluate competing solutions and trade-offs. Reference [18] provides a variety of technological methods for integrating a complex adaptive SOS. New mathematical tools such as graph-theoretic modelling and simulation techniques such as agent-based modelling will be introduced. Finally, new design maturity measures will be introduced. This study will use the theatrical BMDS design and interstitials to depict the integration domain. They may assist the BMDS to reach its full potential by focusing on the interstitial area of the overall BMDS SOS build and applying suitable technical rigour and engineering due diligence.

Data management strategies for business analytic capability growth should be informed by continuing research into developing an information-centric framework. Data collecting aspects (e.g., survey categories, types of variables, ownership/privacy of data, and connection of data sets) are examined in the framework to determine the type and effectiveness of predictive and prescriptive analytics that can be used. Using a system-of-systems engineering approach, the authors of [19] take into account all key stakeholders' interests, resources, and operations; policies and economics of data gathering and curation; and the various predictive/prescriptive analytic deployments that can be achieved. Data architectures and analytic components across an organisation are envisioned to be orchestrated in an integrated manner to maximise informational synergy and to extend the analytic capabilities of prescriptive and predictive elements that are deployed in an organisation. When it comes to predictive and prescriptive analytic applications, minor, straightforward modifications in how data is acquired have a significant impact. Using the concept problem, the framework's ideas are seen in action.

The best practices of OSSD projects are merged with new capabilities for virtual system acquisition in [20], which analyses and develops concepts that will lead to that combination of capabilities. With the use of virtual systems, it is possible to drastically cut acquisition prices and cycle times for software-intensive systems while simultaneously improving them. Implementing electronic government applications makes use of modern information technology and processes (IT). Using open-source software development in the creation, deployment, and ongoing expansion of complex software system applications is a relatively recent strategy in the field of software system development. The development of large-scale, user-friendly, and highly reliable software systems necessitates the development of new resources, products, techniques, and production environments, all of which are being rethought as part of the open-source movement. The open acquisition is a brand-new concept that brings together the best of open-source software development with cutting-edge electronic government processes to create a revolutionary new way of doing business. This study describes the development of an open acquisition framework for virtual system acquisition, as well as its demonstration. Furthermore, this study highlights the next steps to be taken in order to deploy open acquisition approaches inside this framework.

Instead of the traditional document-centric approach, the model-centered approach (MBSE) is used instead. The development of SOSs lends itself well to a model-centric approach, particularly when the model can describe the independence of the systems that make up the SOSs in question. Using an agent-based paradigm, the system of systems (SOS) and each individual system can be regarded as distinct entities, each with its own dynamics and interactions. Each system must establish its own agenda and priorities in order to contribute to the growth of the system of systems (SOSs). System-to-system interactions may be required in order to achieve the overall aims and capabilities of the SOS. The research of [3] investigates an acknowledged system of systems (SOSs) and the various systems that are associated with it, which are represented in an agent-based model (ABM). Individual system agents' decisions are recorded in the ABM's decision models for system dynamics, system-to-system, and system-of-system discussions. ABM, which integrates the key elements that drive SOS dynamics, can be used to test and analyse the dynamics of individual systems and the dynamics of the system as a whole.

Teams of designers are necessary to possess a diverse variety of design and decision-making abilities when working on large-scale engineering systems. Using formal and computational approaches that have been well-defined for system integration and design optimisation, it is possible to obtain optimal performance for complex systems. Engineers may be ill-suited to handle this type of project, according to design best practices. During their graduate studies, students from four distinct graduate programmes collaborated to build a distributed, sophisticated system. The design histories of the teams reveal three ineffective approaches: global searches rather than local searches, optimising each design parameter independently, and sequential rather than concurrent optimisation processes, according to the results of the analysis. Optimisation of systems was overlooked in favour of optimising the performance of individual subsystems, with no attention given to the impact of changes in individual subsystems on the performance of the system as a whole. Engineers should be taught how to integrate systems as a whole, according to [21].

Cook [2] defines "systems of systems" (SOS) as a subset of large monolithic systems that differ in terms of system characteristics and acquisition methodologies. A distinguishing element of this research is that systems of systems (SOS) are formed from component systems that are acquired through a variety of asynchronous activities. Considering our position as a defence contractor, the authors believe that the current acquisition paradigm does not appropriately address the purchase of component parts for military systems and systems components. The study identifies more particular challenges that must be addressed, as well as alternative mitigating methods that can be implemented. Capacity development and acquisition in broad force areas should be prioritised over project-centric capacity development and acquisition, and top-down, force-structure planning should be given more prominence. The importance of system features such as adaptability, flexibility, and open interfaces should also increase as a result of these developments.

Reference [22] discusses a system engineering process that can be used in the building of advanced military systems and systems of systems. In order to accommodate this, the process has been split down into its constituent elements, with each stage being described in great depth. It is discussed how to utilise legacy equipment while also ensuring that new parts are seamlessly and synergistically integrated. As part of the integration and testing of these systems of systems, it will be necessary to develop new dimensions and measurement systems in order to assess performance. Whenever these systems are used by the military, it becomes necessary to examine whether or not a new doctrine, standards, and procedures are required.

When it comes to "systems of systems," the implementation and control of these systems vary significantly from the implementation and control of individual systems. Because of this, the systems engineering processes required to ensure the proper implementation of systems of systems differ dramatically from those commonly applied to individual systems. Successful implementation of systems of systems necessitates the use of a multi-tiered systems engineering technique that goes beyond the conventional single-system approach, according to the finding of [23].

Although information systems (IS) were supposed to have a significant impact on socioeconomic and human development in developing countries, the benefits have been less than expected. Many elements influence an information system's long-term survival (IS). Africa's technology transfer efforts have relied too largely on foreign finance and technology. Informed by local needs and structures, relevant information systems must be designed locally. Reference [24] recommends that information systems be acquired, developed, and implemented in Zambia (Africa) based on local demands and structures. Five public interest user companies in Zambia were researched in detail, as were literature evaluations on IT acquisition, development, and deployment in South Africa, Kenya, India, and the developing world. Obstacles to sector growth in Zambia include people, technology, and poor execution. Before citizens enjoy locally created and manufactured goods and services, their mindsets must be altered. The sector's growth will be accelerated if authors recognise the value of tiny steps and developing talent while acquiring information systems. A paradigm (the acquisition, development, and implementation framework; ADIF) has been designed to ensure that information system investments are maximised.

Our understanding of the system of systems (SOSs) engineering and management has expanded and evolved along with it. SOS engineering (SoSE) is still looking for a way to provide meaning to this kind of uncertainty, whereas systems engineering has developed frameworks and architectures to do so. SOS literature is reviewed to show that in a dynamic, complex environment, an SoSE management framework is required to meet the needs of constant technological improvement. According to the findings of [1], there are two ways to describe SOS: (1) using distinguishing traits and (2) viewing SOS as a network to which "best practices" for network management can be applied to SoSE. In order to construct an efficient SoSE management framework, the authors rely on these two theories. Use the modified FCAPS network principles for this purpose in order to achieve this goal (SoSE management conceptual areas). There are various SoSE management frameworks that employ these qualities as a starting point. As the last example, the authors use a well-documented and well-known SOS (i.e., integrated deepwater system) to demonstrate how the SoSE domain can be better understood, engineered, and managed.

Increasing evidence suggests that airborne particulate matter is a factor in numerous diseases. The authors of [25] need to know how particulate matter impacts air filters if they are going to design effective filtration devices. We are building an air filter testing setup and automating the data collection process. An air filter's performance can be monitored over time using a data-gathering system. Deterioration can be seen, even if the quality of air filters does not reach dangerous levels. In order to train and test a machine learning model that can evaluate air filter quality, the obtained data is used for this purpose with 99% accuracy; this machine learning is a significant tool in the evaluation of air filters. Finally, a data-gathering system and user interface have been developed that greatly decreases the amount of time needed to test filters. Data collection systems can also alert operators when filters need to be changed or other problems arise with the equipment. An effort to develop a system for automatically determining when the test equipment needs to be repaired and recalibrated failed.

E-procurement software refers to the use of data and communication advancements via the Internet to complete all phases of procurement. With this new arrangement of electronic acquisition software, the majority of firms are succeeding while some fall short. During this investigation, steel companies in Pakistan were surveyed by [26] for their use of electronic acquisition software. Achievement variables for electronic acquisition are influenced by the examination's goal. For this inquiry, a semiorganised discussion from the acquisition administrators of selected associations was held to discuss the differentiating proof of accomplishment components in their organisations. From eight firms, a sample size of 150 respondents participated in a study survey to get quantitative data on the influence of electronic acquisition software's success. The data are broken down using SPSS v22, and a variety of analyses are carried out. Electronic acquisition software has been adopted by every single company, but some practices such as e-sourcing and e-proposal accommodation have not been implemented because of a lack of education in the market, as well as a fear of using new technology at the provider/merchant end, according to the study.

There are a lot of ways to model the acquisition process in [27]. Starting with Winston Royce's waterfall model, authors then go on to more complex and detailed waterfall models, such as the "V" and spiral models. As a result, we will also take a look at other acquisition methods. These many models are all a part of the acquisition process's progression, according to our perspective. Simplification of the procedure is getting more and more feasible and economical as technology progresses. For example, authors have seen an upsurge in concurrent engineering and concurrent design. We will look at models for this cycle and how they connect to the acquisition, research, development, test, and evaluation cycles in the planning and marketing life cycle.

In [8], systems engineering (SE) considerations for integrating independently useful systems into a bigger system that has unique capabilities (a system of systems (SOS)) inside the Department of Defence (DOD) are addressed. The handbook is designed to be a resource for systems engineers who assist SOS work, notably as part of a SE team for an SOS, and it draws on the experiences of existing SOS SE practitioners. SE for SOS may now be better understood and guided because of this first draught of the guide. In some circumstances, the book raises awareness of issues that may need to be addressed by systems engineers undertaking SOS work, but it does not provide practical recommendations. In the future, the guide will develop in scope and content as more people get familiar with SOS.

A number of sources have asserted that the technological and management maturity of the acquirer is a significant element in SISA's success and that best practices should be followed. Because of a lack of understanding of how and why SISA techniques affect software-intensive system development, the Department of Defence (DOD) has been cautious to use SISA practices in its development processes. A hybrid software process simulation modelling approach is employed in [28] to investigate the implications of SISA strategies on both the acquirer and the developer. It is possible to represent the dynamic and discrete properties of SISA programmes using our technique (e.g., the interactions between acquisition and development organisations and the effects of numerous SISA practices). The outcomes of this study will shed light on the various ways in which the activities of the acquirer have an impact on the developer's development cycle.

To build on and extend guidance published by the United States Department of Defence on systems engineering (SE) of systems of systems (SOS), [7] develops and presents an approach to SOS SE that transforms the core elements of SOS SE, their interrelationships, and the artefacts and data used in SOS decision-making from a trapeze model to a more familiar and intuitive time-sequenced wave model representation. A more user-friendly version of the information has been provided, and it is consistent with the progressive development methodologies that are common in the advancement of SOS capabilities. A wave model is developed; its important characteristics are discussed; and examples of SOS efforts reflecting this perspective of SOS SE are provided in the paper. Finally, the study explains how the information necessary for a successful SOS SE is generated, where it belongs in the wave model, how it changes over time, and where it is generally stored.

Machine learning techniques have the potential to significantly improve the efficiency of some knowledge acquisition processes. As a result of the potential that machine learning has for knowledge acquisition, we have begun a systematic investigation into how to convert the functionality of knowledge-based systems to machine learning systems that can offer the necessary information. Reference [29] attempts to give a comprehensive definition of machine learning systems and their associated application domains, which authors believe they will be able to do in the near future.

Reference [30] introduces the concept of system-of-systems difficulties, as well as the key qualities that distinguish them from other types of issues. Following that, the significant ramifications for the aeronautical design community are highlighted. Due to the fact that they concentrate on a network of systems and dynamic behaviour rather than a single system and static behaviour, there are two important characteristics that stand out. The community's existing ability to handle the methodological criteria for examining these characteristics is also restricted. Future transportation concepts are conceptualised as a system of systems in order to better grasp their repercussions. The "proto-method" for dealing with this class of difficulties is introduced and investigated in the transportation sector, as well as prospective approaches to constructing successful models and simulations for transportation. Because the vast bulk of the existing literature on systems of systems is devoted to the study of defence systems, it is vital that civil transportation be included in this research. Currently, civil transportation is not included in this research.

A "system of systems" (SOS) is created by integrating many independent but interdependent systems, each of which can function independently, to produce a larger system with greater capabilities. In the aerospace and defence industries, clients increasingly want broad capabilities and solutions rather than individual equipment. Choosing the correct mix of present and future systems is critical to the SOS design process. Including elements of a future system complicates resource allocation by mandating a dynamic resource. Reference [10] calculates the cost of flying on an unbuilt new plane. Based on this statement, it is an NLP difficulty. MINLP methodologies are employed to address the problem, albeit at a high computational expense. Using a response surface technology improves airline design while reducing computer costs. In a similar way to multi-disciplinary optimisation, the problem can be decomposed into allocation and aircraft design domains, yielding solutions at a cheaper computing cost. The MDO-motivated decomposition strategy appears promising for several SOS design difficulties.

A system of unmanned aerial vehicles (UAVs), including vehicles, networks, and operating plans, must be created at the same time as a part of an integrated system. The challenge in designing areas of unified design space that are not merely a collection of poorly optimised discrete entities is that even at the conceptual level, the resulting complexity can quickly become unmanageable. In order to abstract the integrated system, an object-oriented modelling technique must be employed for the modelling of the integrated system. When [31] strategy is used, it increases the efficiency with which the combined system-of-systems design space may be searched more successfully. The economic viability of an imagined service provider in UAV-based package delivery architecture is analysed in terms of trade-offs between vehicle performance and network topology. When compared to previous approaches, the object-oriented solution offers greater modelling flexibility than those approaches.

An acquisition strategy's identification and handling of possible threats to the company's long-term existence is one of the most critical components of the process. It is necessary to integrate a large number of systems in order to support business processes that span numerous firms or organisations. New risks, such as a large and diverse user base, as well as increasing unpredictability, are incorporated into this operational framework by [32], making the development and implementation of an acquisition plan more difficult to accomplish. The incorporation of these concepts into an acquisition plan can help alleviate some of the problems mentioned above.

Reference [33] describes an IBM-compatible laptop-based data collection and analysis system (PC). Conventional bus slots connect the computer to a D/A converter. The programme supports eight analogue signals, four of which can be plotted on the computer's screen as data is acquired. Data can be stored in ASCII or small binary files to speed up input and output. After a data collection cycle, data can be easily scaled and plotted for review. The extra data reduction features allow for smoothing data and cross plots between any two variables. This technology replaces traditional tape recorders and strip chart recorders by saving data in a format that computers can access in the future. The device is portable and runs on a 12-volt automobile battery. This approach records and displays vehicle motion and driver/rider response characteristics. In between runs, data can be processed and examined fast to impact future test conditions. The strategy works with several typical laptop computers that have easily accessible PC buses. Two current systems that could be used are Datavue Snap 1 + 1 and GRID Case Exp.

Many people use the term "systems of systems," but there is no agreement on what they are, how to differentiate them from "conventional systems," or how their development differs from other systems. To aid in their creation, [34] offers a definition, a limited taxonomy, and a foundational set of architectural principles. Apparently, the taxonomic term "system of systems" is a misnomer. "Collaborative systems" is a better term for grouping. Misclassification is also addressed in this work, and the paper's authors outline how to avoid it in system design. As a result of the classification, the primary structuring heuristics for systems of systems have been identified. Another is the realisation that the architecture of a system of systems is communications. Nonphysical architecture is the set of standards that enable meaningful communication among the components.

The purpose of this literature study is twofold: first, to catalogue the numerous ML approaches that can be used to solve SOS acquisition challenges and to map their input, output, and data needs, and second, to evaluate how these approaches are used to solve a variety of Department of Defence issues. A common theme that has emerged from the assessment of relevant literature is that these techniques are often applied in silos, with results and data sets being kept secret from higher-level decision-makers and the Society of Organizational Learning (SoL). Our research is distinct because we want to examine how various systems perform independent local predictive analytics and how to optimally communicate diverse data sets throughout the SOS hierarchy in order to prescribe the SOS capabilities.

3. Materials and Methods

Due to a lack of communication or judgement in a multi-objective SOS acquisition situation [35], it is usual to see different interpretations of the aims from several officers, developers, and managers. Disparities in requirements defined by different contributors to the SOS have an impact on the ultimate performance and cost, which is the subject of this study. System capabilities and the indices by which they contribute to SOS capability have been defined. They are all desirable. When calculating each SOS capacity, a normalised sum of the capabilities of the separate systems used is used in the relevant area.

3.1. Problem Formulation. Consider, for example, the capabilities of a system of systems, as shown in Figure 1. The system of systems is defined in the definition phase, whereas the abstraction phase defines the links between the various components. According to this arrangement, system β_1 is made up of systems α_1 and α_2, whereas system β_2 includes systems α_3 and α_4. Identifying the correct information pathways and integrating data sets for predictive and prescriptive analytics becomes important when suppliers 1, supplier 2, and system 1 management are all integrated into the same system. Data sets may need to be connected between systems 1 and 2 and between suppliers 1, 2, and 3 in order for the SOS level to function properly, according to this rationale. However, achieving complete connectivity between all SOS components and constituents may not be a practical goal. This raises the challenge of how to determine which data sets should be linked by assessing the influence of their connectedness on the SOS and the figures of merit. Figure 1 shows the conceptual model of the study.

An analytical solution is impossible due to the problem's complexity and magnitude in real-world implementations. By first constructing an SOS capability measure by collecting different systems from inside the DOD application domain, we demonstrate how SOS capability evolves due to sharing preferences between sub-hierarchical systems while keeping the autonomous system goals. To that end, we will study the use of machine learning techniques to forecast and prescribe the connection of data sets across various hierarchical levels. SOS acquisition issue formulation is the primary emphasis of this paper's interim update; however, a future update will explore methods for selecting machine learning techniques.

3.2. Framework. A synthetic problem was created to run simulations using Python and interface with other existing system-of-systems (SOS) analytical tools. The synthetic problem is an IBM HR-based analytics for employee attrition, which was chosen since it is a multi-domain problem involving education, employee satisfaction, job satisfaction, job performance, performance rating, relationship, and work-life balance. The systems in IBM interact to provide logistical support and system-level capabilities to achieve

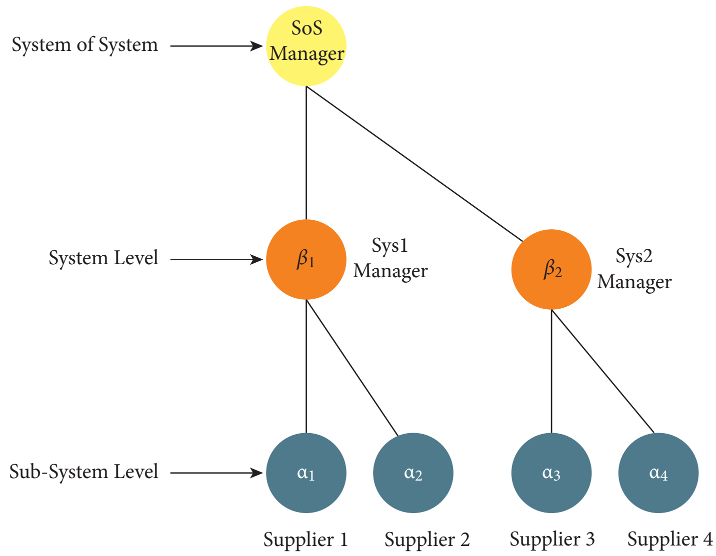

Figure 1: Conceptual model.

certain SOS-level capabilities. Figure 2 shows the framework of the current study:

System capabilities and the indices by which they contribute to SOS capability have been specified. They are all desired. Each SOS capacity is derived from the total of the individual system capabilities in the relevant domain. Portfolios including information about various architectures and their associated SOS performance index and cost are generated for each case. Some systems provide the required capabilities, while others give the necessary support, making up a portfolio.

3.3. Data Set Description. Employee attrition is caused by a variety of circumstances, such as a lack of job satisfaction, a lack of work-life balance, or a lack of opportunities for advancement (https://www.kaggle.com/datasets/pavansubhasht/ibm-hr-analytics-attrition-dataset). To keep things interesting, IBM data scientists generated this fictitious data set. Table 1 shows the data set description and features distribution.

Figure 3 shows the attrition level in data set and frequency distribution of label 0 or 1.

Figure 4 shows the attrition distribution on the basis of travel readiness.

Figure 5 shows the distribution of attrition on the basis of the department of employees.

Figure 6 shows the attrition on the basis of education level and the distribution of frequencies on the basis of qualification level.

3.4. Data Preprocessing. Processing raw data into a comprehensible format is known as preprocessing. Because we cannot do anything with raw data, it is a critical phase in the data mining process. Before using machine learning or data mining methods, make sure the data is of high quality. It is just a set of procedures that convert or alter data. It is a prealgorithm process of data transformation. In the context of data processing, the term refers to the use of a computer to

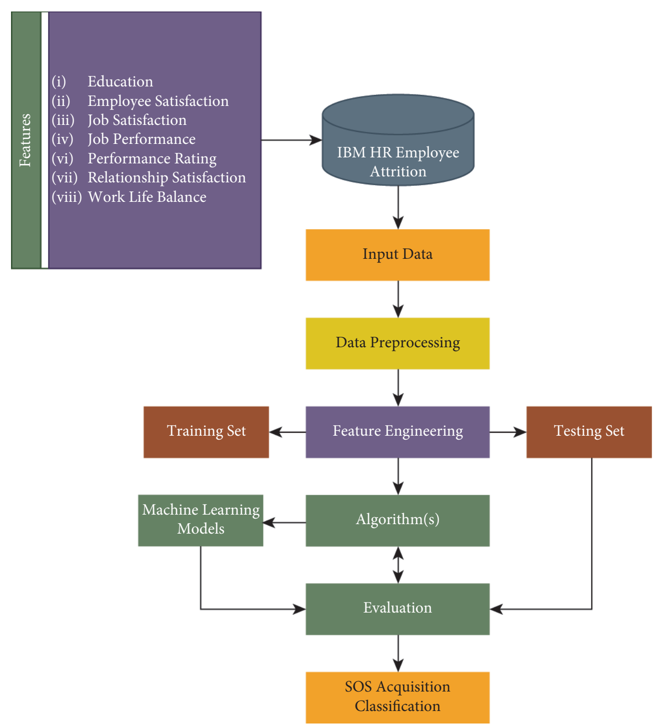

Figure 2: Framework.

extract, convert, or otherwise alter data. Before data can be used, it must be preprocessed. Processing raw data into a clean data set is known as preprocessing. Before running the algorithm, the data set is preprocessed to look for anomalies such as missing values, noisy data, and other irregularities. Figure 7 shows feature correlation matrix.

3.5. Feature Engineering. In machine learning and statistical modelling, feature engineering refers to the process of selecting and transforming the most relevant variables from

Table 1: Features' description.

Feature	Description	Features labels and values	Type of variable
Education	Education level of applicants and candidates	(1) "Below college" (2) "College" (3) "Bachelor" (4) "Master" (5) "Doctor"	Input
Employee satisfaction	Level of satisfaction from an employee as described by the company	(1) "Low" (2) "Medium" (3) "High" (4) "Very high"	Input
Job satisfaction	Job satisfaction level of an employee while searching and joining a job	(1) "Low" (2) "Medium" (3) "High" (4) "Very high"	Input
Job performance	Performance of employee during job in a company	(1) "Low" (2) "Medium" (3) "High" (4) "Very high"	Input
Performance rating	Performance rating shown by company as per the performance of employee	(1) "Low" (2) "Good" (3) "Excellent" (4) "Outstanding"	Input
Relationship satisfaction	Behaviour and relationship of satisfaction level with other employees	(1) "Low" (2) "Medium" (3) "High" (4) "Very high"	Input
Work-life balance	Balance between job and life	(1) "Bad" (2) "Good" (3) "Better" (4) "Best"	Input
Attrition	Strength and acquisition	0 or 1 No or yes	Output

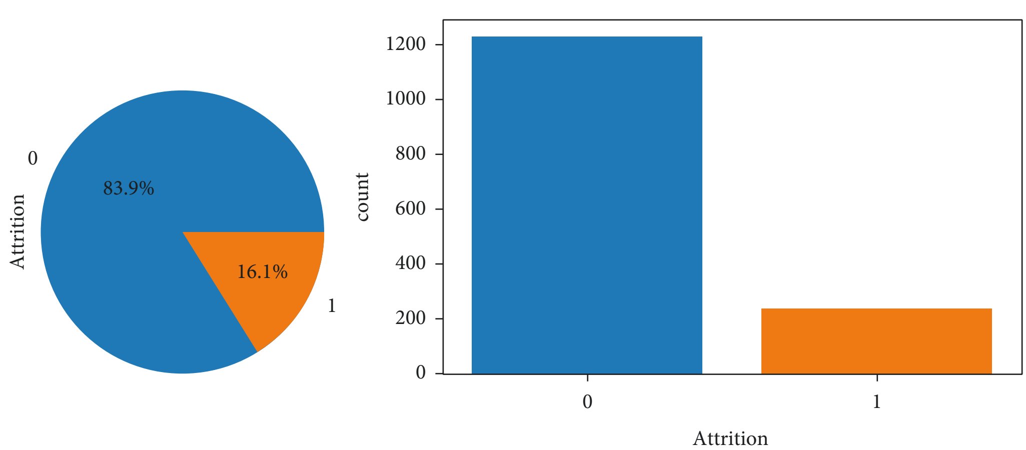

Figure 3: Attrition level.

raw data in order to build a predictive model. Engineers use domain expertise to extract features from raw data via feature engineering or feature extraction. The goal is to enhance the quality of machine learning outcomes by providing these additional attributes in addition to the raw data that would otherwise be provided. Figure 7 shows the feature correlation matrix showing the correlation of most related features.

3.6. Classification Models. This study's objective is to determine how SOS stakeholders may improve SOS capacity

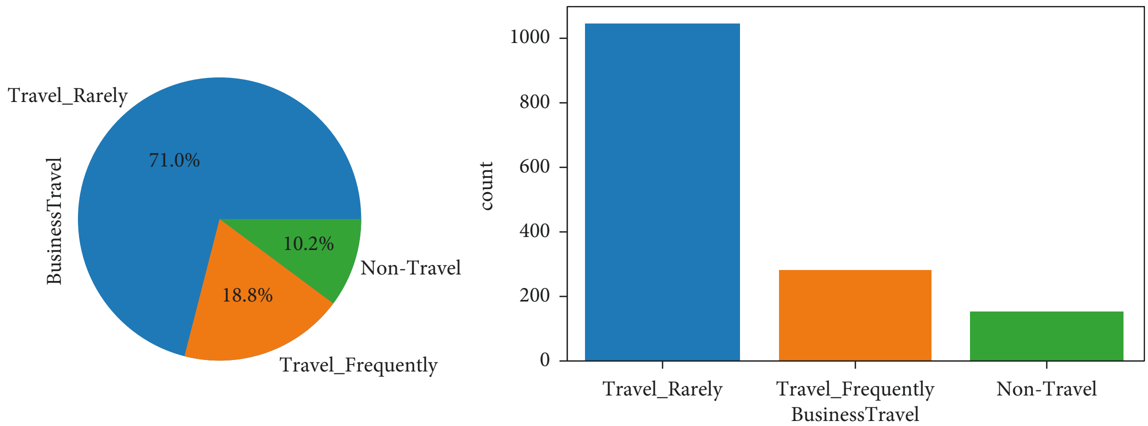

Figure 4: Distribution on the basis of travel readiness.

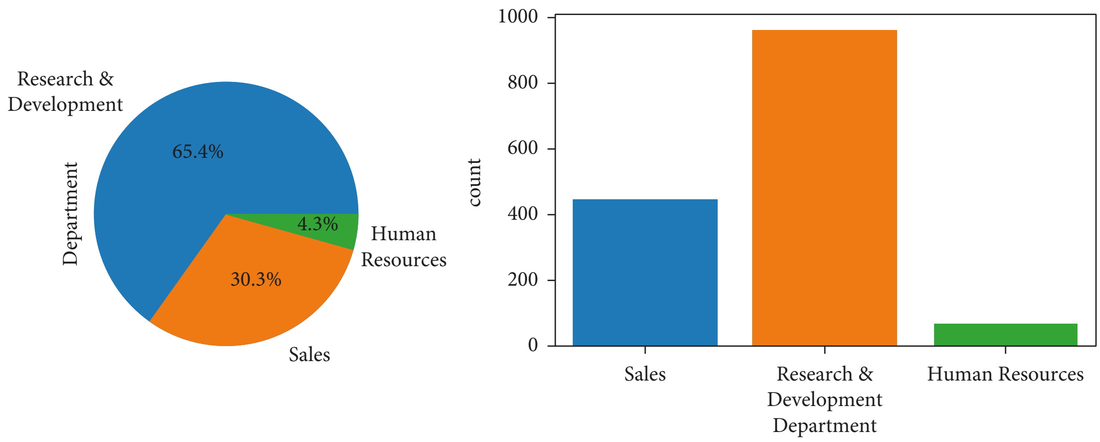

Figure 5: Attrition on the basis of the department of employees.

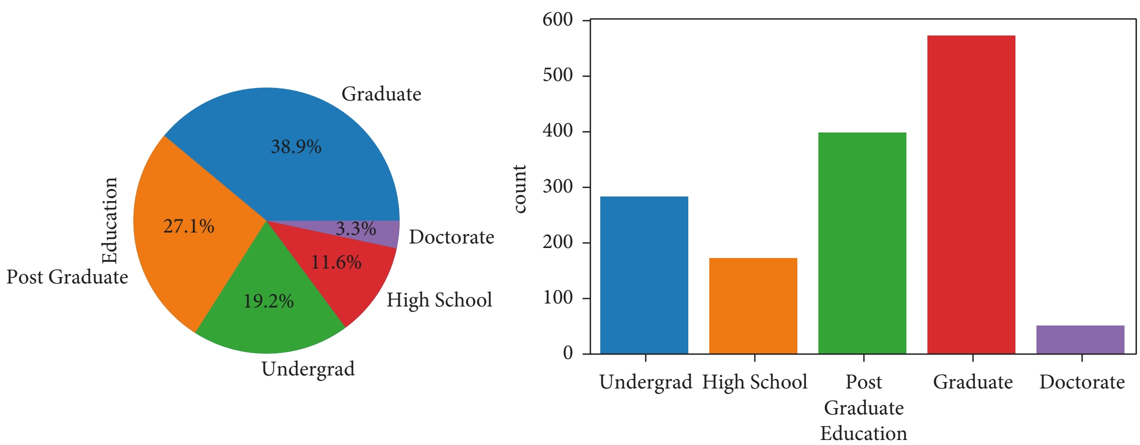

Figure 6: Attrition on the basis of education level.

by exchanging statistics and the corresponding analytics. We suggest using machine learning approaches to predict SOS capabilities through the exchange of relevant data sets and the prescription of information linkages between systems. Using data from previous research, this article estimates the value of exchanging information among SOS stakeholders. Using a variety of machine learning algorithms, we were able to identify the SOS stakeholders who are most likely to benefit from using the corresponding insights. For this purpose, we are using the following models:

(a) Support vector machine

(b) Logistic regression

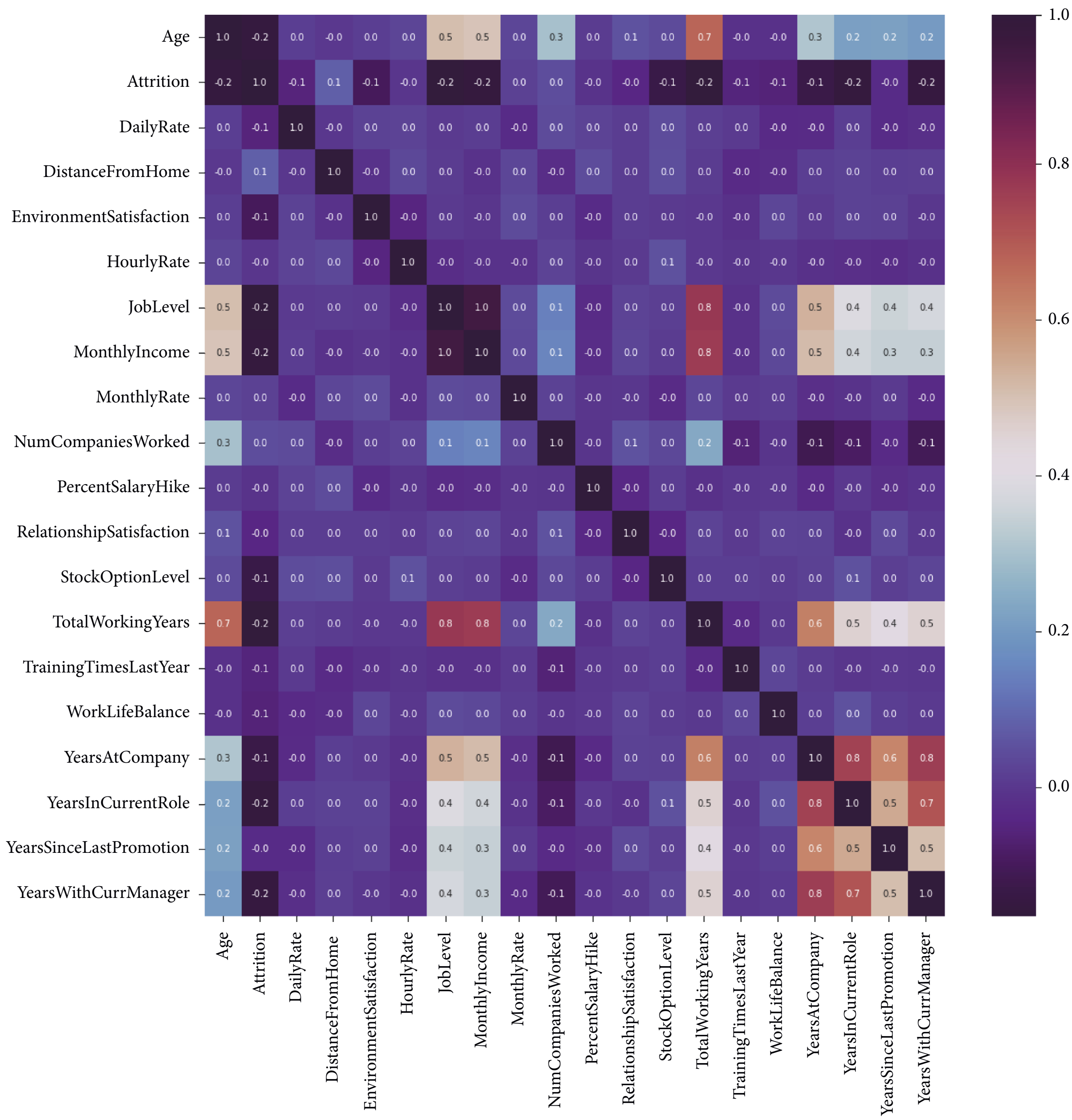

Figure 7: Feature correlation matrix.

(c) Decision trees

4. Results and Discussion

Predicting SOS capabilities through the interchange of relevant data sets and the prescription of information linkages between systems is something we propose doing using machine learning methodologies. The value of information exchange among SOS stakeholders is estimated in this article based on past research. We were able to identify the SOS stakeholders most in need of the corresponding insights by utilising a range of machine learning algorithms.

4.1. Support Vector Machine. For the attrition of employees, SVM has shown promising results. We have used different kernels of SVM for the prediction of attrition in employees through IBM data sets. The confusion matrix in Figure 8 shows that SVM has shown good performance with 2,400 true positive and 12 true negative values.

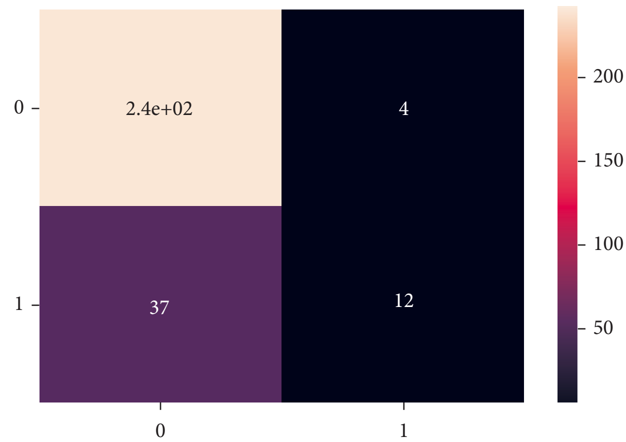

Figure 8: Confusion matrix of collective SVM kernel response.

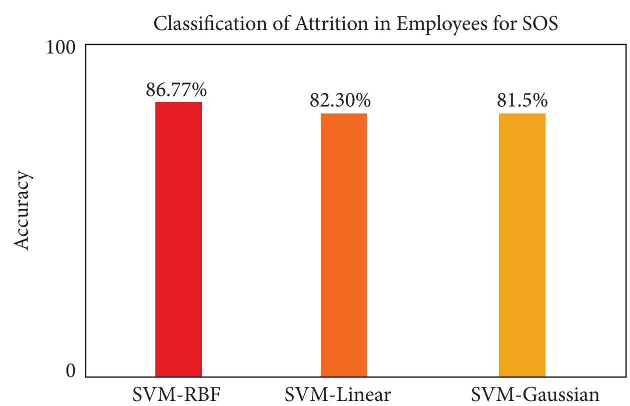

Figure 9: Performance of SVM.

Figure 9 shows the performance of SVM models for the prediction of attrition in employees for SOS acquisition. SVM-RBF kernel has shown the highest accuracy of 86.77%.

4.2. Logistic Regression. For the attrition of employees, LR has shown promising results. We have used LR for the prediction of attrition in employees through IBM data sets. The confusion matrix in Figure 10 shows that LR has shown good performance with 2,400 true positive and 9 true negative values.

Figure 11 shows the performance of LR models for the prediction of attrition in employees for SOS acquisition. LR has shown the highest accuracy of 84.6%.

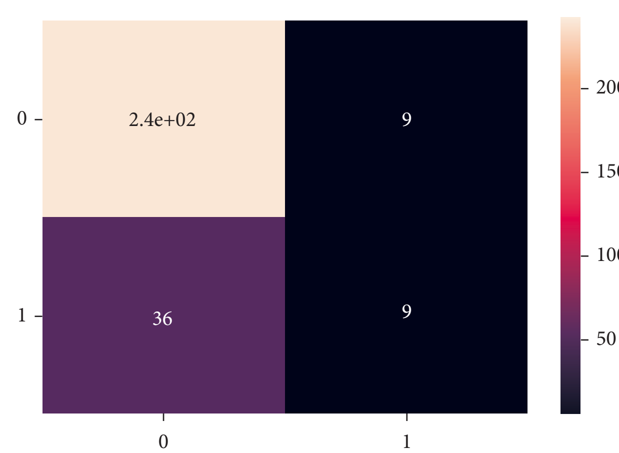

Figure 10: Confusion matrix of LR response.

4.3. Decision Trees. For the attrition of employees, decision trees has shown promising results. We have used decision trees for the prediction of attrition in employees through IBM data sets. The confusion matrix in Figure 12 shows that decision trees has shown good performance with 2,400 true positive and 9 true negative values.

Figure 13 shows the performance of decision trees models for the prediction of attrition in employees for SOS acquisition. Decision trees have shown the highest accuracy of 83.5%.

Further models have been compared with these three models but do not perform well. We have compared SVM, LR, and DT with naïve Bayes, KNN, and random forests. Table 2 shows the comparative analysis of ML models.

Comparatively, ML models have shown good accuracy for the classification of attrition in employees in IBM data

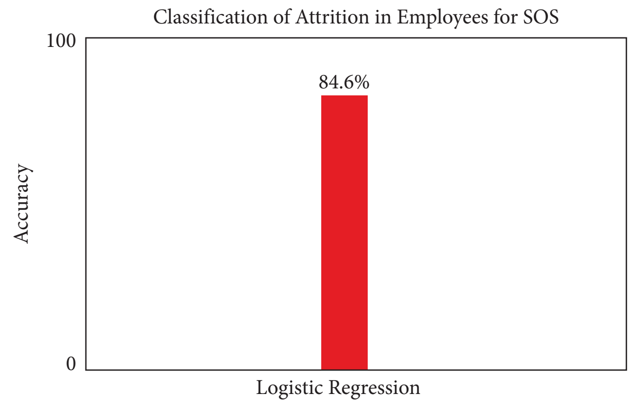

Figure 11: Performance of LR.

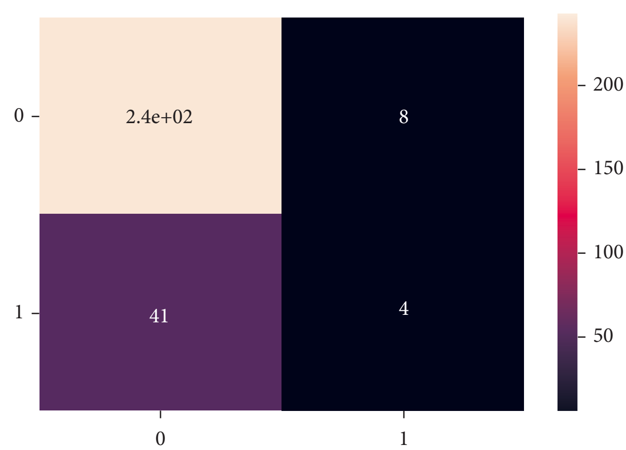

Figure 12: Confusion matrix of decision trees response.

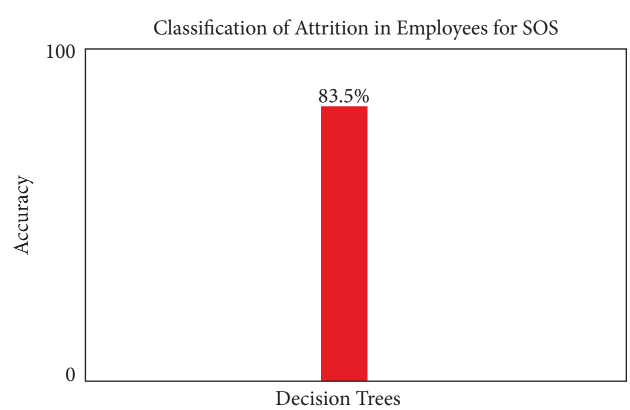

Figure 13: Performance of LR.

Table 2: Comparative analysis of ML models.

Model	Training testing ratio	Accuracy (%)
SVM	70:30	86.5
LR	70:30	85
DT	70:30	83
RF	70:30	72
NB	70:30	71.5
KNN	70:30	60.7

sets. Table 3 shows the comparative analysis of the current study with the previous state-of-the-art methods:

We recommend applying methodologies from machine learning in order to create predictions about the capabilities of SOS by exchanging critical data sets and prescribing information linkages between various systems. This can be done by trading off-key data sets. The purpose of this essay is to act as a sort of intermediary analysis of the research

Table 3: Comparative analysis.

Reference	Techniques	Data sets	Outcome	Accuracy (%)
Crossley et al. [10]	Multi-disciplinary analysis	Pertinent data sets	SOS acquisition	78.00
Gorod et al. [1]	NN	Pertinent data sets	SOS acquisition	75.55
Cook [2]	SVM	Pertinent data sets	SOS acquisition	83.00
Dahmann et al. [4]	NN	Pertinent data sets	SOS acquisition	80.00
Our proposed method	SVM, LR, DT	Pertinent data sets	SOS acquisition	86.50, 85.00, 83.00

endeavour that was discussed earlier. In addition to this, the purpose of the paper is to conduct an analysis of the benefits of information sharing among the stakeholders in SOS. Within the scope of this investigation, we used a number of distinct machine learning models in the IBM HR analytics data set in order to determine which types of analytics, when carried out by SOS stakeholders, had the potential to result in an expansion of SOS capacity. With a rate of 86.77%, SVM RBF has demonstrated the highest level of accuracy in the classification of acquisition as attrition of personnel.

5. Conclusions

The ability of a system to work is obtained from the integration of systems coming from a variety of diverse sources. The systems that make up an SOS have two main functions: first, to achieve the goals that are unique to them, and second, to supply the SOS as a whole with the resources that it needs. In the most recent few decades, one of the most common applications of machine learning and data analytics has been in the process of designing systems and acquiring new ones. It is a commonly understood practice that each company that invests in a complex system will use some form of data analytics in order to evaluate the system's individual goals. Even if the systems contribute to and benefit from the wider SOS, data analytics and decision-making on the separate system are rarely shared among SOS stakeholders. The purpose of this study is to investigate the ways in which the stakeholders in SOS can increase their capacity by exchanging data sets and the analytics that correlate to those data sets. We suggest using machine learning approaches in order to make predictions about the capabilities of SOS by trading off-key data sets and prescribing information links between different systems. This article is intended to serve as an intermediate analysis of the study effort described above. Additionally, the article's goal is to evaluate the benefit of information sharing across the SOS stakeholders. In this study, we deployed several different machine learning models to the IBM HR analytics data set in order to evaluate which analytics, when performed by SOS stakeholders, can lead to an increase in SOS capacity. SVM RBF has shown the best accuracy in the classification of acquisition as attrition of employees with 86.77%. Since a fully connected data enterprise is probably not feasible in practice, one of the main challenges we hope to overcome as this project progresses is determining which data sets need to be connected throughout the SOS. Current efforts are directed toward elucidating the role that machine learning can play in predicting the SOS capability, giving access to system-level decision-making loops, and prescribing the next steps for establishing information flows between systems in the SOS. A fully connected data enterprise is probably not realistic in practice; hence, one of the primary issues in future we want to overcome as this project continues is selecting which data sets need to be connected throughout the SOS. Current work focuses on clarifying the role machine learning can play in predicting SOS capabilities given system-level decision-making loops and prescribing future actions for building information flows between SOS systems.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Ethical Approval

The paper does not deal with any ethical problems.

Conflicts of Interest

The author declares that there are no conflicts of interest in this work.

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